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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	02/23/2016	9267877	NXGN-32196	3583

25883 7590 02/03/2016

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

SOLYMAN ASHRAFI, PLANO, TX;
ROGER LINQUIST, DALLAS, TX;
NIMA ASHRAFI, PLANO, TX;

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

U.S.PATENTS						Remove
Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/G.S./	1	8503546	B1	2013-08-06	ASHRAFI, Solyman	
/G.S./	2	8432884	B1	2013-04-30	ASHRAFI, Solyman	
/G.S./	3	8811366	B1	2014-08-19	ASHRAFI, Solyman	
/G.S./	4	9077577	B1	2015-07-07	ASHRAFI, Solyman	
/G.S./	5	3459466	A	1969-08-05	GIORDMAINE, Joseph A.	
/G.S./	6	3614722	A	1971-10-19	JONES, Charles H.	
/G.S./	7	4379409	A	1983-~~08~~ 04-12	PRIMBSCH et al.	
/G.S./	8	4503336	A	1985-03-05	HUTCHIN et al.	

Change(s) applied to document, /T.W./ 1/26/2016

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

25883 7590 10/23/2015
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

TITLE OF INVENTION: SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	01/25/2016

EXAMINER	ART UNIT	CLASS-SUBCLASS
STOCK JR, GORDON J	2886	356-432000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
   1 Howison & Arnott, LLP
   2 ____
   3 ____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

   PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

   (A) NAME OF ASSIGNEE: NxGen Partners IP, LLC

   (B) RESIDENCE: (CITY and STATE OR COUNTRY): Dallas, Texas

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☒ Issue Fee
- ☒ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies ____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☒ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number 200780 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
  NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ☐ Applicant asserting small entity status. See 37 CFR 1.27
  NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ☐ Applicant changing to regular undiscounted fee status.
  NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Brian D. Walker, Reg. #37751/ Date January 11, 2016

Typed or printed name Brian D. Walker Registration No. 37,751

Electronic Patent Application Fee Transmittal

Application Number:	14339836
Filing Date:	24-Jul-2014
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Filer:	Brian D. Walker/Anna Stefanescu
Attorney Docket Number:	NXGN-32196

Filed as Small Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Utility Appl Issue Fee	2501	1	480	480
Publ. Fee- Early, Voluntary, or Normal	1504	1	0	0
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**480**

Electronic Acknowledgement Receipt

EFS ID:	24590239
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	12-JAN-2016
Filing Date:	24-JUL-2014
Time Stamp:	11:13:16
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$480
RAM confirmation Number	9369
Deposit Account	200780
Authorized User	WALKER, BRIAN D.

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 CFR 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 CFR 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 CFR 1.19 (Document supply fees)

Charge any Additional Fees required under 37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	NXG32196IssueFeeTransmittal2.pdf	969628 2b352425774e52c953584e51a9aa4aef3fd86b12	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	32662 a5f70cb9401bdd104f49c493b356b871f105e1af	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	1002290	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

25883 7590 10/23/2015

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	
ART UNIT	PAPER NUMBER
2886	

DATE MAILED: 10/23/2015

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

TITLE OF INVENTION: SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	01/25/2016

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 02/11)

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

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CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

25883 7590 10/23/2015
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

TITLE OF INVENTION: SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	01/25/2016

EXAMINER	ART UNIT	CLASS-SUBCLASS
STOCK JR, GORDON J	2886	356-432000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
   1 ____________________
   2 ____________________
   3 ____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies ____________________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
  NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ☐ Applicant asserting small entity status. See 37 CFR 1.27
  NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ☐ Applicant changing to regular undiscounted fee status.
  NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature ______________________________ Date ______________________________

Typed or printed name ______________________________ Registration No. ______________________________

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 10/23/2015

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	
ART UNIT	**PAPER NUMBER**
2886	

DATE MAILED: 10/23/2015

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

# Notice of Allowability	**Application No.** 14/339,836	**Applicant(s)** ASHRAFI ET AL.	
	Examiner GORDON J. STOCK JR	**Art Unit** 2886	**AIA (First Inventor to File) Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *RCE filed on 10/1/15*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on______.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-30*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 20150630;20151001;20151006
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

DETAILED ACTION

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Continued Examination Under 37 CFR 1.114

2. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after allowance or after an Office action under *Ex Parte Quayle*, 25 USPQ 74, 453 O.G. 213 (Comm'r Pat. 1935). Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, prosecution in this application has been reopened pursuant to 37 CFR 1.114. Applicant's submission filed on October 1, 2015 has been entered.

REASONS FOR ALLOWANCE

3. **Claims 1-30** are allowed.

The following is an examiner's statement of reasons for allowance:

As to **claim 1**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample 'a detector that receives the first signal after the first signal passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample,' in combination with the rest of the limitations of **claim 1. Claims 2-14** are allowed by virtue of their dependency from **claim 1.**

As to **claim 15**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample 'a detector that receives the first light beam after the first light beam passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the first light beam having the predetermined value of the orbital angular momentum associated therewith,' in combination with the rest of the limitations of **claim 15.** **Claims 16-24** are allowed by virtue of their dependency from **claim 15.**

As to **claim 25**, the prior art of record, taken alone or in combination, fails to disclose or render obvious a method for measuring a concentration of a material within a sample 'determining the concentration of the material within the sample based on the detected value of orbital angular momentum with the first signal received from the sample,' in combination with the rest of the limitations of **claim 25.** **Claims 26-30** are allowed by virtue of their dependency from **claim 25.**

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Fax/Telephone Numbers

If the applicant wishes to send a fax dealing with either a proposed amendment or a discussion with a phone interview, then the fax should:

1) Contain either a statement "DRAFT" or "PROPOSED AMENDMENT" on the fax cover sheet; and

2) Should be unsigned by the attorney or agent.

This will ensure that it will not be entered into the case and will be forwarded to the examiner as quickly as possible.

Papers related to the application may be submitted to Group 2800 by fax transmission. The fax phone number for Patent Technology Center 2800 is 571-273-8300.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Gordon J. Stock, Jr. whose telephone number is (571) 272-2431.
The examiner can normally be reached on Monday-Friday, 8:00 a.m. - 6:30 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Tarifur R. Chowdhury, can be reached at 571-272-2287.

Information regarding the status of an application may be obtained from the Patent Application lnformation Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private Pair system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

/GORDON J STOCK JR/

Primary Examiner, Art Unit 2886

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BIB DATA SHEET

CONFIRMATION NO. 3583

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
14/339,836	07/24/2014 **RULE**	356	2886	NXGN-32196

APPLICANTS

INVENTORS
SOLYMAN ASHRAFI, PLANO, TX;
ROGER LINQUIST, DALLAS, TX;
NIMA ASHRAFI, PLANO, TX;

** **CONTINUING DATA** *************************
This appln claims benefit of 61/951,834 03/12/2014 ok /GS/ 10/16/15

** **FOREIGN APPLICATIONS** ************************* none /GS/ 10/16/15

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **

		STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /GORDON J STOCK JR/ Examiner's Signature	☐ Met after Allowance Initials	TX	21	30 ~~31~~	3

ADDRESS /GS/ 10/16/15

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715
UNITED STATES

TITLE

SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

FILING FEE RECEIVED		
1170	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

/GS/

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S74	2092	(orbital near6 (spin quant$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 15:56
S75	812	(orbital near angular) near moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 15:56
S76	477	(S74 S75) and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 15:56
S77	1417	(g01n21/17).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:00
S78	3554	(g01n21/59).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:00
S79	320	(g01n2021/1765).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:00
S80	150	(g01n2021/178).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:00
S81	1270	(S77 S78 S79 S80) and ((determin$5	US-PGPUB;	OR	ON	2015/10/08

		measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			16:00
S82	1	S81 and (S74 S75)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/10/08 16:00
S83	31002	((optic$4 light beam) near5 (helix helical torsion$4 vortex vortice))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:01
S84	39	S83 same ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:01
S85	178	S83 same ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 amount)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:03
S86	730	S83 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:09
S87	9848	(356/432-444).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/10/08 16:10
S88	4	S87 and (S74 S75)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/10/08 16:10
S89	10955	(helix helical torsion$4 vortex vortice spiral) near4 phase	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2015/10/08 16:11

			IBM_TDB			
S90	315	laguerr$3 near4 mode	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:11
S91	245	hermit$ near5 mode	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:11
S92	3248	S83 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:12
S93	61	S83 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 16:12
S94	1	(particle near wave) near4 hologram	FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 17:15
S95	1	(particle near wave) near4 hologram	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 17:15
S96	5	(particle near4 wave) near4 hologram	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 17:15
S97	87	(S90 S91) and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 17:19
S104	3	(("20130327866") or ("20020164806") or ("20080037004")).PN.	US-PGPUB	OR	OFF	2015/10/08 18:53
S105	3	(("20100327866") or ("20020164806") or ("20080037004")).PN.	US-PGPUB	OR	OFF	2015/10/08 18:57
S106	0	("2013002774").PN.	US-PGPUB	OR	OFF	2015/10/08 19:30
S107	1	("20130027774").PN.	US-PGPUB	OR	OFF	2015/10/08 19:30

S108	8	US-7792431-$.DID. OR US-8559823-$.DID. OR US-7577165-$.DID. OR US-20050254826-$.DID. OR US-20100013696-$.DID. OR US-20140355624-$.DID. OR US-20150098697-$.DID. OR US-20120207470-$.DID.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/10/08 19:33
S109	1	("20050259914").PN.	US-PGPUB	OR	OFF	2015/10/08 19:34
S110	10	US-4736463-$.DID. OR US-4862115-$.DID. OR US-5051754-$.DID. OR US-5220163-$.DID. OR US-5222071-$.DID. OR US-5272484-$.DID. OR US-5543805-$.DID. OR US-5555530-$.DID. OR US-6337659-$.DID. OR US-6992829-$.DID.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/10/08 19:35
S111	2	("7729572").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/10/08 19:36
S112	8	US-8503546-$.DID. OR US-8432884-$.DID. OR US-8811366-$.DID. OR US-9077577-$.DID. OR US-3459466-$.DID. OR US-3614722-$.DID. OR US-4379409-$.DID.	US-PGPUB; USPAT; USOCR	OR	OFF	2015/10/08 19:36
S113	4	("4503336").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/10/08 19:37
S114	3248	S83 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:38
S115	15	S114 and (S77 S78 S79 S80 S87)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:39
S116	730	S83 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:40
S117	1769	S89 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2015/10/08 19:40

			DERWENT; IBM_TDB			
S118	13	S89 and (S77 S78 S79 S80 S87)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:41
S119	851	S89 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:54
S120	1540	S116 S119	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:54
S121	18	S120 and (S77 S78 S79 S80 S87)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:54
S122	1531	S120 not S76	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/08 19:55
S133	1161	(orbital near2 moment$2)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 14:58
S134	2092	(orbital near6 (spin quant$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 14:59
S135	812	(orbital near angular) near moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 14:59
S136	191	S133 not (S134 S135)	US-PGPUB; USPAT; USOCR;	OR	ON	2015/10/09 14:59

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S141	1161	(orbital near2 moment$2)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 20:45
S142	2092	(orbital near6 (spin quant$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 20:45
S143	51	(S142 S141) and (spiral near phase)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 20:45
S144	10	S143 and concentration	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/10/09 20:47

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S129	263	(orbital near6 (spin quant$3 angular)).clm.	US-PGPUB; USPAT	OR	ON	2015/10/08 20:58
S130	34	S129 and (amount concentration).clm.	US-PGPUB; USPAT	OR	ON	2015/10/08 20:58

10/15/2015 8:41:35 PM
C:\Users\gstock\Documents\EAST\Workspaces\14339836.wsp

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK, Gordon J., Jr.
	Attorney Docket Number	NXGN-32196

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Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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Examiner Initial*	Cite No	Publication Number	Kind Code1	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/G.S./	1	20100327866	A1	2010-12-30	Albu, L. et al.	
/G.S./	2	20020164806	A1	2002-11-07	Collins, M.	
/G.S./	3	20080037004	A1	2008-02-14	Shamir, J. et al.	

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Examiner Initial*	Cite No	Foreign Document Number3	Country Code2 i	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T5
	1							☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK, Gordon J., Jr.
	Attorney Docket Number	NXGN-32196

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
/G.S./	1	PCT: International Search Report and Written Opinion of PCT/US2015/019177 (related application), 2015 June 25, 8 pgs.	☐

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EXAMINER SIGNATURE

Examiner Signature	/Gordon Stock Jr/	Date Considered	10/08/2015

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/G.S./	1	8503546	B1	2013-08-06	ASHRAFI, Solyman	
/G.S./	2	8432884	B1	2013-04-30	ASHRAFI, Solyman	
/G.S./	3	8811366	B1	2014-08-19	ASHRAFI, Solyman	
/G.S./	4	9077577	B1	2015-07-07	ASHRAFI, Solyman	
/G.S./	5	3459466	A	1969-08-05	GIORDMAINE, Joseph A.	
/G.S./	6	3614722	A	1971-10-19	JONES, Charles H.	
/G.S./	7	4379409	A	1983-08-12	PRIMBSCH et al.	
/G.S./	8	4503336	A	1985-03-05	HUTCHIN et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

/G.S./	9	4736463	A	1988-04-05	CHAVEZ, Joseph D.	
/G.S./	10	4862115	A	1989-08-29	LEE et al.	
/G.S./	11	5051754	A	1991-09-24	NEWBERG, Irwin L.	
/G.S./	12	5220163	A	1993-06-15	TOUGHLIAN et al.	
/G.S./	13	5222071	A	1993-06-22	PEZESHKI et al.	
/G.S./	14	5272484	A	1993-12-21	LABAAR, Frederik	
/G.S./	15	5543805	A	1996-08-06	THANIYAVARN, Suwat	
/G.S./	16	5555530	A	1996-09-10	MEEHAN, Richard J.	
/G.S./	17	6337659	B1	2002-01-08	KIM, Sang-Gi	
/G.S./	18	6992829	B1	2006-01-31	JENNINGS et al.	
/G.S./	19	7729572	B1	2010-06-01	PEPPER et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	14339836
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/G.S./	20	7792431	B1	2010-09-07	JENNINGS et al.	
/G.S./	21	8559823	B1	2013-10-15	IZADPANAH et al.	
/G.S./	22	7577165	B1	2009-08-18	BARRETT, Terence W.	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
/G.S./	1	20050254826	A1	2005-11-17	JENNINGS et al.	
/G.S./	2	20100013696	A1	2010-01-21	SCHMITT et al.	
/G.S./	3	20140355624	A1	2014-12-04	LI et al.	
/G.S./	4	20150098697	A1	2015-04-09	MAROM et al.	
/G.S./	5	20120207470	A1	2012-08-16	DJORDEVIC et al.	
/G.S./	6	20050259914	A1	2005-11-24	PADGETT et al.	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

/G.S./	7	20130027774	A1	2013-01-31	BOVINO et al.	

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/G.S./	1	SOLYMAN ASHRAFI, Channeling Radiation of Electrons in Crystal Lattices, Essays on Classical and Quantum Dynamics, Gordon and Breach Science Publishers, 1991.	☐
/G.S./	2	SOLYMAN ASHRAFI, Solar Flux Forecasting Using Mutual Information with an Optimal Delay, Advances in the Astronautical Sciences, American Astronautical Society, Vol. 84 Part II, 1993.	☐
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/G.S./	6	SOLYMAN ASHRAFI, Performance Enhancement of an Orbital-Angular-Momentum-Based Free-Space Optical Communication Link through Beam Divergence Controlling, OSA Technical Digest (online), paper M2F.6. The Optical Society, 2015.	☐
/G.S./	7	SOLYMAN ASHRAFI, Experimental demonstration of enhanced spectral efficiency of 1.18 symbols/s/Hz using multiple-layer-overlay modulation for QPSK over a 14-km fiber link. OSA Technical Digest (online), paper JTh2A.63. The Optical Society, 2014.	☐
/G.S./	8	SOLYMAN ASHRAFI, Link Analysis of Using Hermite-Gaussian Modes for Transmitting Multiple Channels in a Free-Space Optical Communication System, The Optical Society, Vol. 2, No. 4, April 2015.	☐
/G.S./	9	SOLYMAN ASHRAFI, Performance Metrics and Design Considerations for a Free-Space Optical Orbital-Angular-Momentum-Multiplexed Communication Link, The Optical Society, Vol. 2, No. 4, April 2015.	☐
/G.S./	10	SOLYMAN ASHRAFI, Demonstration of Distance Emulation for an Orbital-Angular-Momentum Beam. OSA Technical Digest (online), paper STh1F.6. The Optical Society, 2015.	☐
/G.S./	11	SOLYMAN ASHRAFI, Free-Space Optical Communications Using Orbital-Angular-Momentum Multiplexing Combined with MIMO-Based Spatial Multiplexing. Optics Letters, Vol. 40, No.18, September 4, 2015.	☐
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/G.S./	14	SOLYMAN ASHRAFI, Experimental Demonstration of 16-Gbit/s Millimeter-Wave Communications Link using Thin Metamaterial Plates to Generate Data-Carrying Orbital-Angular-Momentum Beams, ICC 2015, London, UK, 2014.	☐
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/G.S./	16	SOLYMAN ASHRAFI, Experimental Measurements of Multipath-Induced Intra- and Inter-Channel Crosstalk Effects in a Millimeter-Wave Communications Link using Orbital-Angular-Momentum Multiplexing, ICC 2015, London, UK, 2014.	☐

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/G.S./	17	SOLYMAN ASHRAFI, Performance Metrics for a Free-Space Communication Link Based on Multiplexing of Multiple Orbital Angular Momentum Beams with Higher Order Radial Indice. OSA Technical Digest (online), paper JTh2A.62. The Optical Society, 2015.	☐
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/G.S./	22	SOLYMAN ASHRAFI, An Information Theoretic Framework to Increase Spectral Efficiency, IEEE Transactions on Information Theory, Vol. XX, No. Y, October 2014, Dallas, Texas.	☐
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/G.S./	25	M. NOURI ET AL., Perturbations of Laguerre-Gaussian Beams by Chiral Molecules (pending publication). No date.	☐

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/G.S./	1	SOLYMAN ASHRAFI, Acoustically induced stresses in elastic cylinders and their visualization, The Journal of the Acoustical Society of America 82(4):1378-1385, September 1987.	☐
/G.S./	2	SOLYMAN ASHRAFI, Splitting of channeling-radiation peaks in strained-layer superlattices, Journal of the Optical Society of America B 8(12), November 1991.	☐

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

CPC

Symbol				Type	Version
G01N		21	/ 17	F	2013-01-01
G01N		21	/ 59	I	2013-01-01
G01N		24	/ 00	I	2013-01-01
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		Total Claims Allowed:	
NONE (Assistant Examiner)	(Date)	30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 (Primary Examiner)	10/16/2015 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED
G	0	1	N	21 / 17 (2006.01.01)	
G	0	1	N	21 / 59 (2006.01.01)	
G	0	1	N	24 / 00 (2006.01.01)	

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 10/16/2015 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
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☐ **Claims renumbered in the same order as presented by applicant** ☐ **CPA** ☐ **T.D.** ☐ **R.1.47**

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
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3	14	27	30												
15	15	-	31												
16	16														

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 (Primary Examiner)	10/16/2015 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

CPC- SEARCHED

Symbol	Date	Examiner
G01N24/00 (text only)	10/16/15	gjs
G01N21/17,59 (text only)	10/8/15	gjs
G01N2021/1765,178 (text only)	10/8/15	gjs

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Symbol	Date	Examiner

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SEARCH NOTES

Search Notes	Date	Examiner
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	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK JR, Gordon J.
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	Art Unit	2886
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	Attorney Docket Number	NXGN-32196

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Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	06-OCT-2015
Filing Date:	24-JUL-2014
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Application Type:	Utility under 35 USC 111(a)

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REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	14/339,836	Filing Date	2014-07-24	Docket Number (if applicable)	NXGN-32196	Art Unit	2886
First Named Inventor	ASRAFI, Solyman			Examiner Name	STOCK JR, Gordon J.		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on ________
- ☐ Other ________

☒ Enclosed

- ☐ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☐ Other ________

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months ________
(Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other ________

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 200780

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature
☐ Applicant Signature

Signature of Registered U.S. Patent Practitioner			
Signature	/Brian D. Walker, Reg. #37751/	Date (YYYY-MM-DD)	2015-09-30
Name	Brian D. Walker	Registration Number	37751

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1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	8503546	B1	2013-08-06	ASHRAFI, Solyman	
	2	8432884	B1	2013-04-30	ASHRAFI, Solyman	
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	5	3459466	A	1969-08-05	GIORDMAINE, Joseph A.	
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Art Unit	2886
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Attorney Docket Number	NXGN-32196

	9	4736463	A	1988-04-05	CHAVEZ, Joseph D.	
	10	4862115	A	1989-08-29	LEE et al.	
	11	5051754	A	1991-09-24	NEWBERG, Irwin L.	
	12	5220163	A	1993-06-15	TOUGHLIAN et al.	
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	16	5555530	A	1996-09-10	MEEHAN, Richard J.	
	17	6337659	B1	2002-01-08	KIM, Sang-Gi	
	18	6992829	B1	2006-01-31	JENNINGS et al.	
	19	7729572	B1	2010-06-01	PEPPER et al.	

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	20	7792431	B1	2010-09-07	JENNINGS et al.	
	21	8559823	B1	2013-10-15	IZADPANAH et al.	
	22	7577165	B1	2009-08-18	BARRETT, Terence W.	

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	1	20050254826	A1	2005-11-17	JENNINGS et al.	
	2	20100013696	A1	2010-01-21	SCHMITT et al.	
	3	20140355624	A1	2014-12-04	LI et al.	
	4	20150098697	A1	2015-04-09	MAROM et al.	
	5	20120207470	A1	2012-08-16	DJORDEVIC et al.	
	6	20050259914	A1	2005-11-24	PADGETT et al.	

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	7	20130027774	A1	2013-01-31	BOVINO et al.	

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	1	SOLYMAN ASHRAFI, Channeling Radiation of Electrons in Crystal Lattices, Essays on Classical and Quantum Dynamics, Gordon and Breach Science Publishers, 1991.	☐
	2	SOLYMAN ASHRAFI, Solar Flux Forecasting Using Mutual Information with an Optimal Delay, Advances in the Astronautical Sciences, American Astronautical Society, Vol. 84 Part II, 1993.	☐
	3	SOLYMAN ASHRAFI, PCS system design issues in the presence of microwave OFS, Electromagnetic Wave Interactions, Series on Stability, Vibration and Control of Systems, World Scientific, January 1996.	☐
	4	SOLYMAN ASHRAFI, Performance Metrics and Design Parameters for an FSO Communications Link Based on Multiplexing of Multiple Orbital-Angular-Momentum Beams, Globecom2014 OWC Workshop, 2014.	☐
	5	SOLYMAN ASHRAFI, Optical Communications Using Orbital Angular Momentum Beams, Adv. Opt. Photon. 7, 66-106, Advances in Optics and Photonic, 2015.	☐

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	6	SOLYMAN ASHRAFI, Performance Enhancement of an Orbital-Angular-Momentum-Based Free-Space Optical Communication Link through Beam Divergence Controlling, OSA Technical Digest (online), paper M2F.6. The Optical Society, 2015.	☐
	7	SOLYMAN ASHRAFI, Experimental demonstration of enhanced spectral efficiency of 1.18 symbols/s/Hz using multiple-layer-overlay modulation for QPSK over a 14-km fiber link. OSA Technical Digest (online), paper JTh2A.63. The Optical Society, 2014.	☐
	8	SOLYMAN ASHRAFI, Link Analysis of Using Hermite-Gaussian Modes for Transmitting Multiple Channels in a Free-Space Optical Communication System, The Optical Society, Vol. 2, No. 4, April 2015.	☐
	9	SOLYMAN ASHRAFI, Performance Metrics and Design Considerations for a Free-Space Optical Orbital-Angular-Momentum-Multiplexed Communication Link, The Optical Society, Vol. 2, No. 4, April 2015.	☐
	10	SOLYMAN ASHRAFI, Demonstration of Distance Emulation for an Orbital-Angular-Momentum Beam. OSA Technical Digest (online), paper STh1F.6. The Optical Society, 2015.	☐
	11	SOLYMAN ASHRAFI, Free-Space Optical Communications Using Orbital-Angular-Momentum Multiplexing Combined with MIMO-Based Spatial Multiplexing. Optics Letters, Vol. 40, No.18, September 4, 2015.	☐
	12	SOLYMAN ASHRAFI, Enhanced Spectral Efficiency of 2.36 bits/s/Hz Using Multiple Layer Overlay Modulation for QPSK over a 14-km Single Mode Fiber Link. OSA Technical Digest (online), paper SW1M.6. The Optical Society, 2015.	☐
	13	SOLYMAN ASHRAFI, Experimental Demonstration of a 400-Gbit/s Free Space Optical Link Using Multiple Orbital-Angular-Momentum Beams with Higher Order Radial Indices. OSA Technical Digest (online), paper SW4M.5. The Optical Society, 2015.	☐
	14	SOLYMAN ASHRAFI, Experimental Demonstration of 16-Gbit/s Millimeter-Wave Communications Link using Thin Metamaterial Plates to Generate Data-Carrying Orbital-Angular-Momentum Beams, ICC 2015, London, UK, 2014.	☐
	15	SOLYMAN ASHRAFI, Experimental Demonstration of Using Multi-Layer-Overlay Technique for Increasing Spectral Efficiency to 1.18 bits/s/Hz in a 3 Gbit/s Signal over 4-km Multimode Fiber. OSA Technical Digest (online), paper JTh2A.63. The Optical Society, 2015.	☐
	16	SOLYMAN ASHRAFI, Experimental Measurements of Multipath-Induced Intra- and Inter-Channel Crosstalk Effects in a Millimeter-Wave Communications Link using Orbital-Angular-Momentum Multiplexing, ICC 2015, London, UK, 2014.	☐

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	17	SOLYMAN ASHRAFI, Performance Metrics for a Free-Space Communication Link Based on Multiplexing of Multiple Orbital Angular Momentum Beams with Higher Order Radial Indice. OSA Technical Digest (online), paper JTh2A.62. The Optical Society, 2015.	☐
	18	SOLYMAN ASHRAFI, 400-Gbit/s Free-Space Optical Communications Link Over 120-meter Using Multiplexing of 4 Collocated Orbital-Angular-Momentum Beams. OSA Technical Digest (online), paper M2F.1. The Optical Society, 2015.	☐
	19	SOLYMAN ASHRAFI, Experimental Demonstration of Two-Mode 16-Gbit/s Free-Space mm-Wave Communications Link Using Thin Metamaterial Plates to Generate Orbital Angular Momentum Beams, Optica, Vol. 1, No. 6, December 2014.	☐
	20	SOLYMAN ASHRAFI, Demonstration of an Obstruction-Tolerant Millimeter-Wave Free-Space Communications Link of Two 1-Gbaud 16-QAM Channels using Bessel Beams Containing Orbital Angular Momentum, Third International Conference on Optical Angular Momentum (ICOAM), 4 - 7 August, 2015, New York USA.	☐
	21	WANG et al: "Terabit free-space data transmission employing orbital angular momentum multiplexing", Nature Photonics, Vol. 6, July 2012, pages 488-496.	☐
	22	SOLYMAN ASHRAFI, An Information Theoretic Framework to Increase Spectral Efficiency, IEEE Transactions on Information Theory, Vol. XX, No. Y, October 2014, Dallas, Texas.	☐
	23	H. YAO et al, Patch Antenna Array for the Generation of Millimeter-wave Hermite-Gaussian Beams, IEEE Antennas and Wireless Propagation Letters, (pending publication).	☐
	24	YONGXIONG REN et al, Experimental Investigation of Data Transmission Over a Graded-index Multimode Fiber Using the Basis of Orbital Angular Momentum Modes (pending publication).	☐
	25	M. NOURI ET AL., Perturbations of Laguerre-Gaussian Beams by Chiral Molecules (pending publication).	☐

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<table>
<tr><td rowspan="6">INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)</td><td colspan="2">Application Number</td><td>14339836</td></tr>
<tr><td colspan="2">Filing Date</td><td>2014-07-24</td></tr>
<tr><td>First Named Inventor</td><td colspan="2">ASHRAFI, Solyman</td></tr>
<tr><td colspan="2">Art Unit</td><td>2886</td></tr>
<tr><td>Examiner Name</td><td colspan="2">STOCK Jr., Gordon J.</td></tr>
<tr><td colspan="2">Attorney Docket Number</td><td>NXGN-32196</td></tr>
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[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK Jr., Gordon J.
	Attorney Docket Number	NXGN-32196

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☒ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Brian D. Walker, Reg. #37751/	Date (YYYY-MM-DD)	2015-10-01
Name/Print	Brian D. Walker	Registration Number	37751

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Electronic Patent Application Fee Transmittal

Application Number:	14339836
Filing Date:	24-Jul-2014
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Filer:	Brian D. Walker
Attorney Docket Number:	NXGN-32196

Filed as Small Entity

Filing Fees for **Utility under 35 USC 111(a)**

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
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Extension-of-Time:				

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Miscellaneous:				
Request for Continued Examination	2801	1	600	600
Submission- Information Disclosure Stmt	2806	1	90	90
	Total in USD ($)			**690**

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EFS ID:	23665917
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	01-OCT-2015
Filing Date:	24-JUL-2014
Time Stamp:	16:30:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

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Payment Type	Deposit Account
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Authorized User	WALKER, BRIAN D.

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15	Non Patent Literature	ExperimentalDemonstrationofUsingMLO.pdf	135311 eb060f395eef56601c788bbb185f3b437670644d	no	2
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Information:

16	Non Patent Literature	ExperimentalMeasurementsof MultipathInduced.pdf	395386 89a2e51606bfd63a8539e82893e75d672f3e389f	no	7

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Information:

17	Non Patent Literature	LinkAnalysisofUsinghermite-GaussianModes.pdf	136464 3e2bb7253cd42a08adaa8004f490cd9f8729a9ed	no	2

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Information:

18	Non Patent Literature	PerformanceMetricsforaFreespaceCommunication.pdf	136759 87adaa9c60f20f5ab59f30d66b0dc93cc546bf94	no	2

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Information:

19	Non Patent Literature	ExperimentalDemonstrationofa400Gbits.pdf	131972 754da47aa7bc06fcd515226d04f0a02d1b1ed2cf	no	2

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Information:

20	Fee Worksheet (SB06)	fee-info.pdf	32504 94ee19ce0dae5e59c6855095f484edfd8039ac32	no	2

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Total Files Size (in bytes):	19465940

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Acknowledgement Receipt

EFS ID:	23666896
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	01-OCT-2015
Filing Date:	24-JUL-2014
Time Stamp:	16:33:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	DemonstrationofanObstructionTolerantMM.pdf	3463207 7f14831fef13f68d26c47bbca123311790185d6f	no	7

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2	Non Patent Literature	WANGTerabitfree-spacedatatransmission.pdf	21480411 e29b9a1febc6b2849c80c02098471da95d2f7742	no	9
Warnings:					
Information:					
3	Non Patent Literature	AnInformationTheoreticFramework.pdf	1867369 f7e02127a96f7a1e81fee75756a086a92c71a849	no	33
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Information:					
4	Non Patent Literature	PatchAntennaArrayfortheGeneration.pdf	186627 a3d4a11e7069f87767cc66cec28ba9e1565fcfe9	no	3
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Information:					
5	Non Patent Literature	ExperimentalInvestigationofDataTransmission.pdf	132363 28c25de5205a1232199be556a22b6dd60e164e09	no	2
Warnings:					
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Information:					
6	Non Patent Literature	PerturbationsofLaguerre-GaussianBeams.pdf	206223 d7c90ca22b50333e734b64c347ce0e1c05ec932e	no	7
Warnings:					
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Information:					
7	Non Patent Literature	ExperimentalDemonstrationofTwoMode16.pdf	417097 abf3ad8b95155a861a6ce79973c443a0affa1868	no	6
Warnings:					
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Information:					
8	Non Patent Literature	400GbitsFreeSpaceOpticalCommunications.pdf	188322 3f492764697d9d908a7f016eff59b60c20f8fb2d	no	3
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Information:	
Total Files Size (in bytes):	27941619

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 09/18/2015

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	

ART UNIT	PAPER NUMBER
2886	

NOTIFICATION DATE	DELIVERY MODE
09/18/2015	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

patents@dalpat.com

Response to Rule 312 Communication	**Application No.** 14/339,836	**Applicant(s)** ASHRAFI ET AL.
	Examiner GORDON J. STOCK JR	**Art Unit** 2886

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address –

1. ☒ The amendment filed on *23 July 2015* under 37 CFR 1.312 has been considered, and has been:

   a) ☒ entered.

   b) ☐ entered as directed to matters of form not affecting the scope of the invention.

   c) ☐ disapproved because the amendment was filed after the payment of the issue fee.
   Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

   d) ☐ disapproved. See explanation below.

   e) ☐ entered in part. See explanation below.

/GORDON J STOCK JR/
Primary Examiner, Art Unit 2886

NXGN-32196 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Serial No.:	14/339,836
Filed:	July 24, 2014
Confirmation No.	3583
Notice of Allowance Mailed:	July 1, 2015
Group:	2886
Examiner:	STOCK Jr., Gordon J.
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

AMENDMENT UNDER RULE 312

In response to the Notice of Allowance dated July 1, 2015, Applicant has carefully reviewed the above-identified application prior to the payment of the Issue Fee. It is requested that the following amendments be entered under the provisions of Rule 312.

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims beginning on page 3 of this paper.

Amendments to the Drawings begin on page 9 of this paper.

Remarks begin on page 10 of this paper.

OK TO ENTER: /G.S./

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196

CONFIRMATION NO. 3583

25883
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

PUBLICATION NOTICE

OC000000077494419

Title:SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Publication No.US-2015-0260650-A1
Publication Date:09/17/2015

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 09/11/2015
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	

ART UNIT	PAPER NUMBER
2886	

NOTIFICATION DATE	DELIVERY MODE
09/11/2015	ELECTRONIC

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patents@dalpat.com

Response to Rule 312 Communication	Application No.	Applicant(s)
	14/339836	
	Examiner	Art Unit

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ The amendment filed on *24 July 2015* under 37 CFR 1.312 has been considered, and has been:

   a) ☒ entered.

   b) ☐ entered as directed to matters of form not affecting the scope of the invention.

   c) ☐ disapproved because the amendment was filed after the payment of the issue fee.
   Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

   d) ☐ disapproved. See explanation below.

   e) ☐ entered in part. See explanation below.

DF

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 07/24/2015
HOWISON & ARNOTT, L.L.P
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DALLAS, TX 75374-1715

EXAMINER
STOCK JR, GORDON J

ART UNIT	PAPER NUMBER
2886	

NOTIFICATION DATE	DELIVERY MODE
07/24/2015	ELECTRONIC

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The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

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Commissioner for Patents
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P.O. Box 1450
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Application No. : 14339836
Applicant : Ashrafi
Filing Date : 07/24/2014
Date Mailed : 07/24/2015

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Notice of Allowance Mailed

This application has been accorded an Allowance Date and is being prepared for issuance. The application, however, is incomplete for the reasons below.

Applicant is given two (2) months from the mail date of this Notice within which to respond. This time period for reply is extendable under 37 CFR 1.136(a) for only TWO additional MONTHS.

The informalities requiring correction are indicated in the attachment(s). If the informality pertains to the abstract, specification (including claims) or drawings, the informality must be corrected with an amendment in compliance with 37 CFR 1.121 (or, if the application is a reissue application, 37 CFR 1.173). Such an amendment may be filed after payment of the issue fee if limited to correction of informalities noted herein. See Waiver of 37 CFR 1.312 for Documents Required by the Office of Patent Publication, 1280 Off. Gaz. Patent Office 918 (March 23, 2004). In addition, if the informality is not corrected until after payment of the issue fee, for purposes of 35 U.S.C. 154(b)(1)(iv), "all outstanding requirements" will be considered to have been satisfied when the informality has been corrected. A failure to respond within the above-identified time period will result in the application being ABANDONED.

See attachment(s).

A copy of this notice <u>MUST</u> be returned with the reply. Please address response to "Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450".

/Midel Geronimo/
Publication Branch
Office of Data Management
(571) 272-4200

Application No. 14339836

IDENTIFICATION OF APPLICATION DEFICIENCIES IN APPLICATION FILED ON OR AFTER SEPTEMBER 16, 2012

- [ ] Applicant must provide legible text for the following item(s).
  - [ ] Specification filed , page(s) .
  - [ ] Claims filed , claim(s) .
  - [ ] Other: .
- [X] Applicant must provide missing information on the following page(s) of the specification by amending the specification to add the missing text. No new matter may be added.
  Page/line no(s). 10, paragraph [0048]
- [ ] The specification refers to one or more applications by attorney docket number and does not show the U.S. application number(s). Applicant must supply the U.S. application number in place of each attorney docket number.
  Page/line no(s).
- [ ] Applicant must provide an Abstract of the Disclosure.
- [ ] The Application Data Sheet (ADS dated) does not supply the inventor's city and/or does not supply the inventor's U.S. state and/or does not supply the inventor's country. Applicant must submit a signed application data sheet that corrects this deficiency. To be in compliance with 37 CFR 1.76, the corrected application data sheet must identify the information being changed by using underlining for additions and strikethroughs or brackets for deletions..
- [ ] The Application Data Sheet (ADS dated) was not properly signed. Applicant must submit an application data sheet that is properly signed in accordance with 37 CFR 1.76(e) and 1.33(b). If the unsigned application data sheet shows foreign priority information or domestic benefit information, and if the Office does not show foreign priority information or domestic benefit information on the filing receipt, applicant may need to file a petition under 37 CFR 1.55 or 1.78 for delayed claim for priority or benefit if the claim for priority or benefit has not been filed in accordance with the time periods set forth in 37 CFR 1.55 or 1.78.
- [ ] Other:

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Serial No.:	14/339,836
Filed:	July 24, 2014
Confirmation No.	3583
Notice of Allowance Mailed:	July 1, 2015
Group:	2886
Examiner:	STOCK Jr., Gordon J.
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

AMENDMENT UNDER RULE 312

In response to the Notice to File Corrected Application Papers dated July 24, 2015, Applicant has carefully reviewed the above-identified application prior to the payment of the Issue Fee. It is requested that the following amendments be entered under the provisions of Rule 312.

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims beginning on page 3 of this paper.

Remarks begin on page 9 of this paper.

In the Specification

Please replace paragraph [0048] with the following amended paragraph:

[0048] Thus, the momentum of each photon 202 within the light beam 104 has an azimuthal component. A detailed calculation of the momentum involves all of the electric fields and magnetic fields within the light beam, particularly those electric and magnetic fields in the direction of propagation of the beam. For points within the beam, the ratio between the azimuthal components and the z components of the momentum is found to be l/kr. ~~(where l=_____; k=______; r=______.)~~ The linear momentum of each photon 202 within the light beam 104 is given by $\hbar k$, so if we take the cross product of the azimuthal component within a radius vector, r, we obtain an orbital momentum for a photon 202 of $l\hbar$. Note also that the azimuthal component of the wave vectors is l/r and independent of the wavelength.

In the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Previously Presented) An apparatus that measures a concentration of a material within a sample, comprising:

signal generation circuitry that generates a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample;

a detector that receives the first signal after the first signal passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

2. (Previously Presented) The apparatus of Claim 1, wherein the signal generation circuitry further comprises:

an emitting source that emits the first signal comprising a plurality of plane waves;

orbital angular momentum generation circuitry that receives the first signal and that applies the at least one orbital angular momentum to the plane waves of the first signal.

3. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry that applies a fixed orbital angular momentum to the first signal.

4. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry further includes a hologram that applies the at least one orbital angular momentum to the plane waves of the first signal.

5. (Previously Presented) The apparatus of Claim 4, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

6. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry that applies a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

7. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter that converts the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter that converts the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

8. (Previously Presented) The apparatus of Claim 1 further including amplifying circuitry that receives the first signal after the first signal passes through the sample and that amplifies a first portion of the first signal having the detected value of the orbital angular momentum associated therewith.

9. (Previously Presented) The apparatus of Claim 8, wherein the amplifying circuitry further includes a hologram that amplifies the orbital angular momentum associated with the concentration of the material in the sample.

10. (Previously Presented) The apparatus of Claim 1, wherein the detector further comprises:

an orbital angular momentum detector that determines the detected value of the orbital angular momentum within the first signal from the sample; and

a processor that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

11. (Previously Presented) The apparatus of Claim 10 further including a user interface associated with the processor comprising:

a set of computer instructions that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database that stores concentration data from concentrations determined by the processor.

12. (Previously Presented) The apparatus of Claim 11, wherein the user interface further includes a wireless interface that communicates the concentration data to a remote location.

13. (Previously Presented) The apparatus of Claim 1, wherein differing values of the concentration indicate different concentrations of the material within the sample.

14. (Original) The apparatus of Claim 1, wherein the first signal comprises a light beam.

15. (Previously Presented) An apparatus that measures a concentration of a material within a sample, comprising:

an emitting source that emits a first light beam comprising a plurality of plane waves;

orbital angular momentum generation circuitry that receives the first light beam and that applies at least one orbital angular momentum to the plurality of plane waves of the first light beam;

amplifying circuitry that receives the first light beam after the first light beam passes through the sample and that amplifies a first portion of the first light beam having a predetermined value of the orbital angular momentum associated therewith;

a detector that receives the first light beam after the first light beam passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith.

16. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry that applies a fixed orbital angular momentum to the first light beam.

17. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plurality of plane waves of the first light beam.

18. (Previously Presented) The apparatus of Claim 17, wherein the hologram comprises a pair of superimposed holograms comprising a composite vortex grid.

19. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry that applies a selected orbital angular momentum to the first light beam responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

20. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first light beam from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first light beam in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

21. (Previously Presented) The apparatus of Claim 15 further comprising a processor that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

22. (Previously Presented) The apparatus of Claim 21 further including a user interface associated with the processor comprising:

a set of computer instructions that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database that stores concentration data from concentrations determined by the processor.

23. (Previously Presented) The apparatus of Claim 22, wherein the user interface further includes a wireless interface that communicates the concentration data to a remote location.

24. (Previously Presented) The apparatus of Claim 15, wherein differing values of the concentration indicate different concentrations of the material within the sample.

25. (Previously Presented) A method for measuring a concentration of a material within a sample, comprising:

generating a first signal having at least one orbital angular momentum applied thereto;

applying the first signal to the sample;

receiving the first signal after the first signal passes through the sample;

detecting a value of the orbital angular momentum within the received first signal; and

determining the concentration of the material within the sample based on the detected value of orbital angular momentum with the first signal received from the sample.

26. (Original) The method of Claim 25, wherein the step of generating further comprises:

emitting the first signal comprising a plurality of plane waves;

receiving the first signal; and

applying the at least one orbital angular momentum to the plane waves of the first signal.

27. (Original) The method of Claim 26, wherein the step of applying further comprises applying a fixed orbital angular momentum to the first signal.

28. (Original) The method of Claim 26, wherein the step of applying further comprises applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

29. (Previously Presented) The method of Claim 25 further including:

receiving the first signal after the first signal passes through the sample; and

amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

30. (Previously Presented) The method of Claim 25 further including storing concentration data from concentrations that are determined.

31. (Canceled)

Remarks

In response to the Notice to File Corrected Application Papers of July 24, 2015, Applicant has corrected the informalities in the specification, listed on page 10, paragraph [0048]. No new matter is added.

Subsequent to the receipt of a Notice of Allowance, this application was carefully reviewed prior to payment of the Issue Fee. The errors noted during this review have been corrected by this Amendment Under Rule 312. It is respectfully submitted that the foregoing amendments do not affect the merits of the application and are proper subject matter for an Amendment Under Rule 312.

Entry of this Amendment is respectfully requested.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
Attorneys for Applicant(s)

/Brian D. Walker, Reg. #37751/

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July 24, 2015

Electronic Acknowledgement Receipt

EFS ID:	23014968
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	24-JUL-2015
Filing Date:	24-JUL-2014
Time Stamp:	17:16:34
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		NXG32196312AMD2.pdf	111913 6a866b107df1bed9fbf4635c3fc87a6278c701bd	yes	9

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Amendment after Notice of Allowance (Rule 312)	1	1
Specification	2	2
Claims	3	8
Applicant Arguments/Remarks Made in an Amendment	9	9

Warnings:

Information:

Total Files Size (in bytes):	111913

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Serial No.:	14/339,836
Filed:	July 24, 2014
Confirmation No.	3583
Notice of Allowance Mailed:	July 1, 2015
Group:	2886
Examiner:	STOCK Jr., Gordon J.
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

AMENDMENT UNDER RULE 312

In response to the Notice of Allowance dated July 1, 2015, Applicant has carefully reviewed the above-identified application prior to the payment of the Issue Fee. It is requested that the following amendments be entered under the provisions of Rule 312.

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims beginning on page 3 of this paper.

Amendments to the Drawings begin on page 9 of this paper.

Remarks begin on page 10 of this paper.

In the Specification

Please replace paragraph [0074] with the following amended paragraph:

[0074] A plane wave shining through the holographic images 1402 will have a predetermined orbital angular momentum shift applied thereto after passing through the holographic image 1402. OAM generator ~~1102~~ 1302 is fixed in the sense that a same image is used and applied to the beam being passed through the holographic image. Since the holographic image 1402 does not change, the same orbital angular momentum is always applied to the beam being passed through the holographic image 1402. While Fig. 14a-14e illustrate a number of embodiments of various holographic images that might be utilized within the orbital angular momentum generator ~~1102~~ 1302, it will be realized that any type of holographic image 1402 may be utilized in order to achieve the desired orbital angular momentum within an beam being shined through the image 1402.

In the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Previously Presented) An apparatus that measures a concentration of a material within a sample, comprising:

signal generation circuitry that generates a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample;

a detector that receives the first signal after the first signal passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

2. (Previously Presented) The apparatus of Claim 1, wherein the signal generation circuitry further comprises:

an emitting source that emits the first signal comprising a plurality of plane waves;

orbital angular momentum generation circuitry that receives the first signal and that applies the at least one orbital angular momentum to the plane waves of the first signal.

3. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry that applies a fixed orbital angular momentum to the first signal.

4. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry further includes a hologram that applies the at least one orbital angular momentum to the plane waves of the first signal.

5. (Previously Presented) The apparatus of Claim 4, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

6. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry that applies a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

7. (Previously Presented) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter that converts the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter that converts the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

8. (Previously Presented) The apparatus of Claim 1 further including amplifying circuitry that receives the first signal after the first signal passes through the sample and that amplifies a first portion of the first signal having the detected value of the orbital angular momentum associated therewith.

9. (Previously Presented) The apparatus of Claim 8, wherein the amplifying circuitry further includes a hologram that amplifies the orbital angular momentum associated with the concentration of the material in the sample.

10. (Previously Presented) The apparatus of Claim 1, wherein the detector further comprises:

an orbital angular momentum detector that determines the detected value of the orbital angular momentum within the first signal from the sample; and

a processor that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

11. (Previously Presented) The apparatus of Claim 10 further including a user interface associated with the processor comprising:

a set of computer instructions that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database that stores concentration data from concentrations determined by the processor.

12. (Previously Presented) The apparatus of Claim 11, wherein the user interface further includes a wireless interface that communicates the concentration data to a remote location.

13. (Previously Presented) The apparatus of Claim 1, wherein differing values of the concentration indicate different concentrations of the material within the sample.

14. (Original) The apparatus of Claim 1, wherein the first signal comprises a light beam.

15. (Currently Amended) An apparatus that measures a concentration of a material within a sample, comprising:

an emitting source that emits a first light beam comprising a plurality of plane waves;

orbital angular momentum generation circuitry that receives the first light beam and that applies at least one orbital angular momentum to the <u>plurality of</u> plane waves of the first light beam;

amplifying circuitry that receives the first light beam after the first light beam passes through the sample and that amplifies a first portion of the first light beam having a predetermined value of the orbital angular momentum associated therewith;

a detector that receives the first light beam after the first light beam passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith.

16. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry that applies a fixed orbital angular momentum to the first light beam.

17. (Currently Amended) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plurality of plane waves of the first light beam.

18. (Currently Amended) The apparatus of Claim 17, wherein the hologram ~~comprise~~ comprises a pair of superimposed holograms comprising a composite vortex grid.

19. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry that applies a selected orbital angular momentum to the first light beam responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

20. (Previously Presented) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first light beam from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first light beam in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

21. (Previously Presented) The apparatus of Claim 15 further comprising a processor that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

22. (Previously Presented) The apparatus of Claim 21 further including a user interface associated with the processor comprising:

a set of computer instructions that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database that stores concentration data from concentrations determined by the processor.

23. (Previously Presented) The apparatus of Claim 22, wherein the user interface further includes a wireless interface that communicates the concentration data to a remote location.

24. (Previously Presented) The apparatus of Claim 15, wherein differing values of the concentration indicate different concentrations of the material within the sample.

25. (Previously Presented) A method for measuring a concentration of a material within a sample, comprising:

generating a first signal having at least one orbital angular momentum applied thereto;

applying the first signal to the sample;

receiving the first signal after the first signal passes through the sample;

detecting a value of the orbital angular momentum within the received first signal; and

determining the concentration of the material within the sample based on the detected value of orbital angular momentum with the first signal received from the sample.

26. (Original) The method of Claim 25, wherein the step of generating further comprises:

emitting the first signal comprising a plurality of plane waves;

receiving the first signal; and

applying the at least one orbital angular momentum to the plane waves of the first signal.

27. (Original) The method of Claim 26, wherein the step of applying further comprises applying a fixed orbital angular momentum to the first signal.

28. (Original) The method of Claim 26, wherein the step of applying further comprises applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

29. (Previously Presented) The method of Claim 25 further including:

receiving the first signal after the first signal passes through the sample; and

amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

30. (Previously Presented) The method of Claim 25 further including storing concentration data from concentrations that are determined.

31. (Canceled)

In the Drawings

In Fig. 2, the light beam axis 204 as mentioned in paragraph [0044] of the description has been included in the drawings.

In Fig. 13, holographic image 1402 as mentioned in paragraph [0074] of the description has been included in the drawings.

In Fig. 18, reference number 1802 has been included to properly identify a plurality of holographic images as mentioned in paragraph [0078].

Also in Fig. 18, the box encompassing 1802, 1804 and 1806 has been labelled 1702, as mentioned in paragraph [0078] of the disclosure.

Attachments: Replacement Sheets (21 sheets, i.e., full set)
Annotated Sheets (3 sheets)

Remarks

In response to the Notice of Allowance of July 1, 2015, Applicant has corrected the objections to the drawings as indicated by the Examiner. Applicant submits herewith the required Replacement Sheets, along with Annotated Sheets to clearly indicate the changes made to the drawings.

The change to the Specification is to correct a typographical error found in paragraph [0074]. No new matter is added.

Subsequent to the receipt of a Notice of Allowance, this application was carefully reviewed prior to payment of the Issue Fee. The errors noted during this review have been corrected by this Amendment Under Rule 312. It is respectfully submitted that the foregoing amendments do not affect the merits of the application and are proper subject matter for an Amendment Under Rule 312.

Entry of this Amendment is respectfully requested.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
Attorneys for Applicant(s)

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Fax: 972-479-0464
July 23, 2015

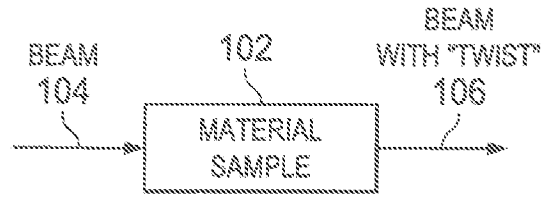


FIG. 1

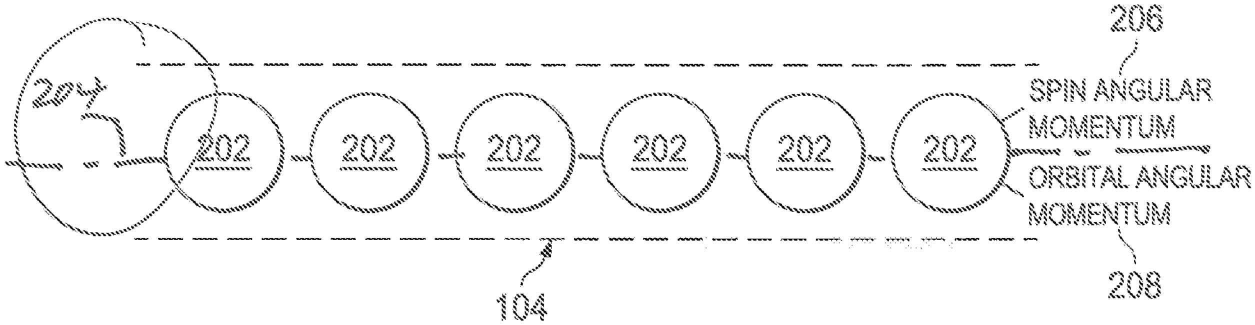


FIG. 2

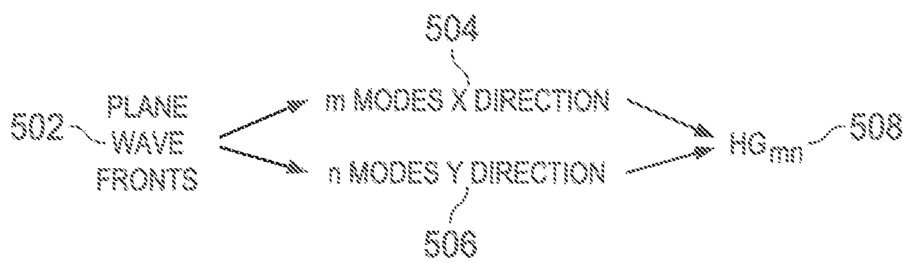


FIG. 5

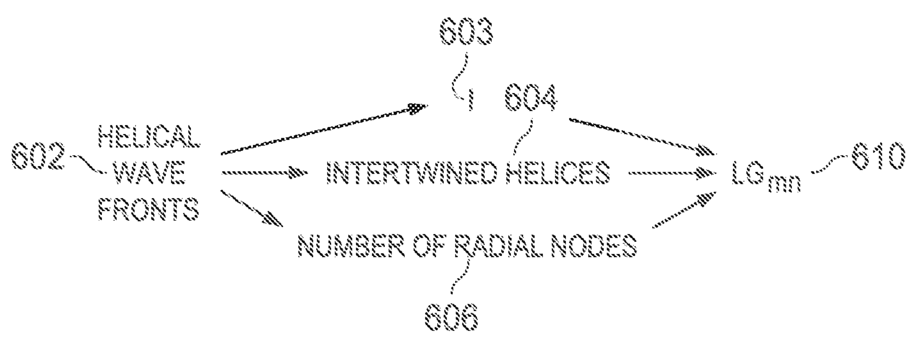


FIG. 6

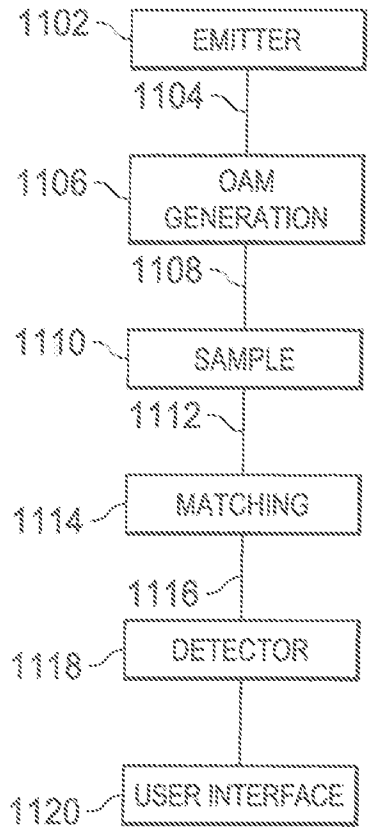


FIG. 11

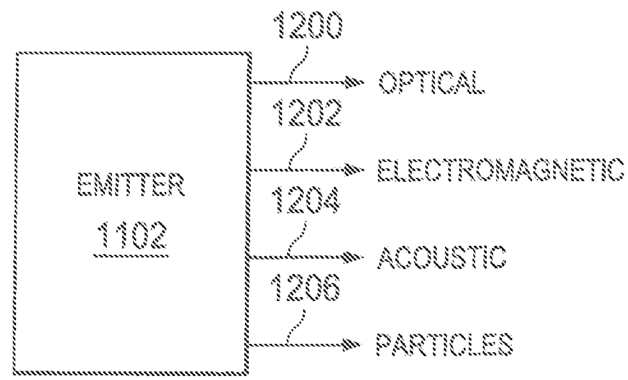


FIG. 12

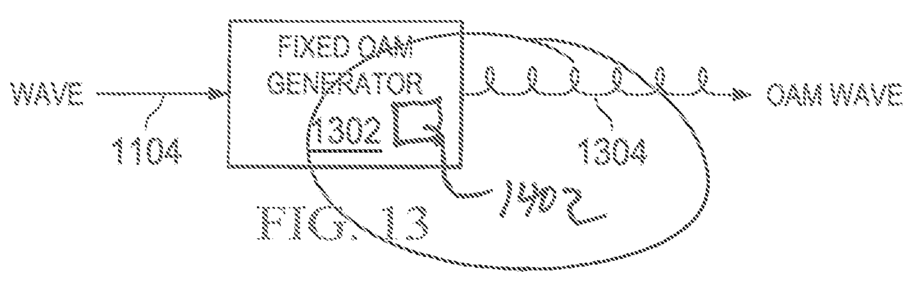


FIG. 13

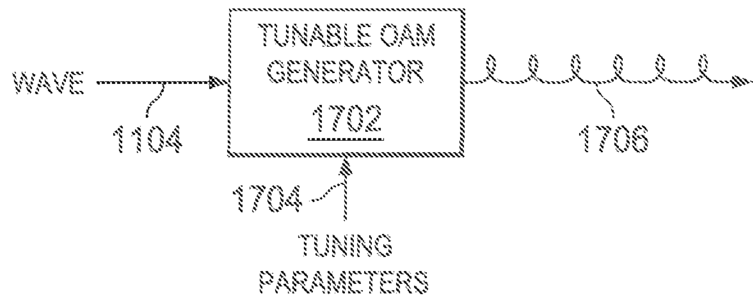

TUNABLE OAM GENERATOR
1702
WAVE
1104
1706
1704
TUNING PARAMETERS

FIG. 17

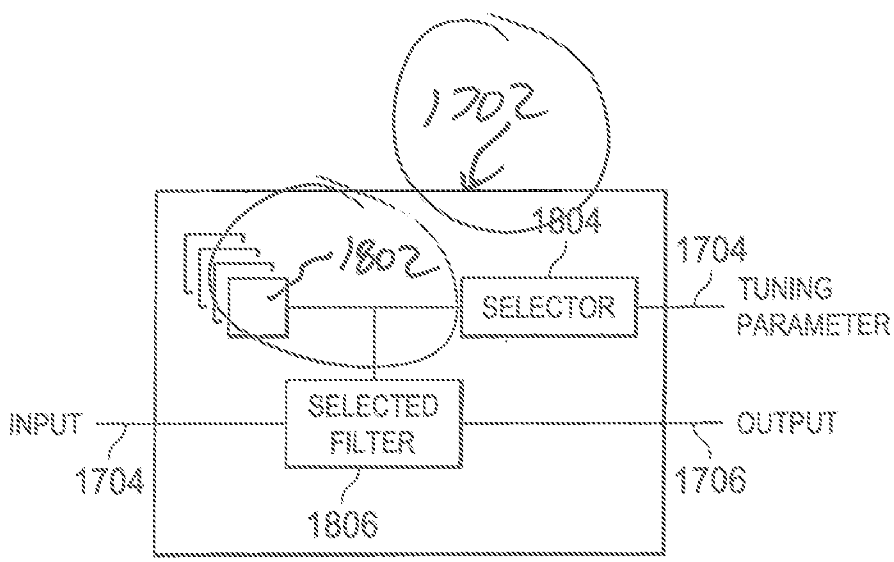

1702
1802
1804
SELECTOR
1704
TUNING PARAMETER
INPUT
SELECTED FILTER
OUTPUT
1704
1706
1806

FIG. 18

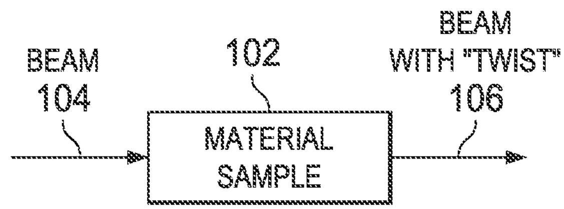


FIG. 1

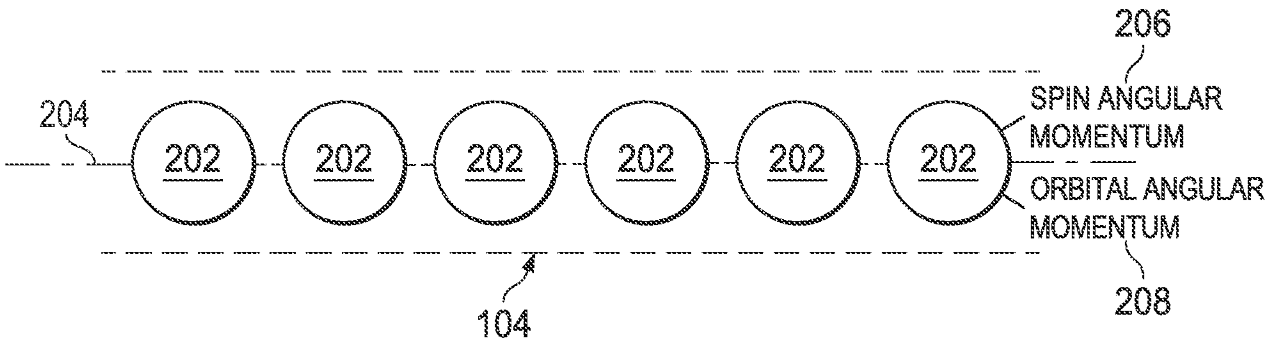


FIG. 2

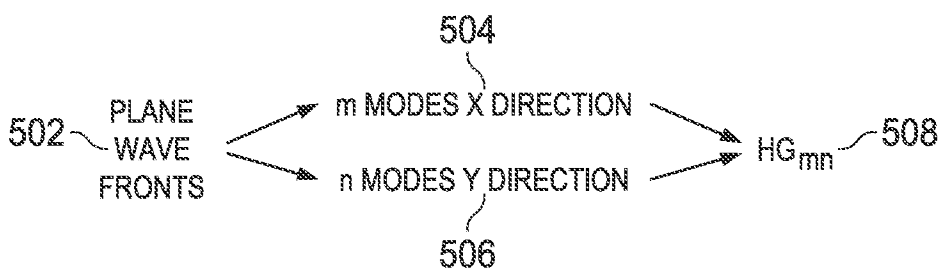


FIG. 5

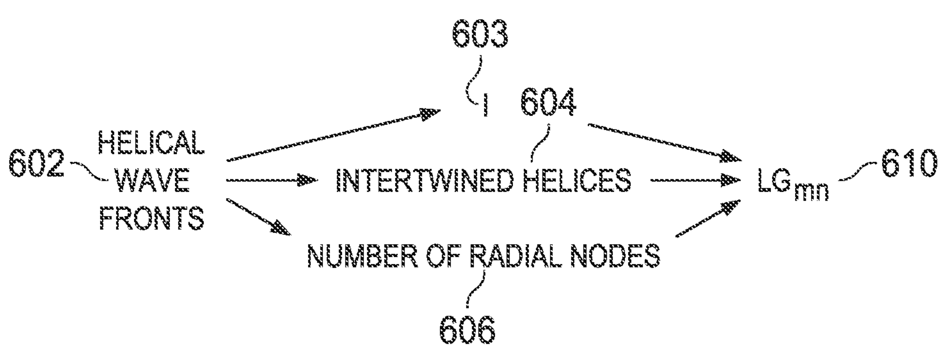


FIG. 6

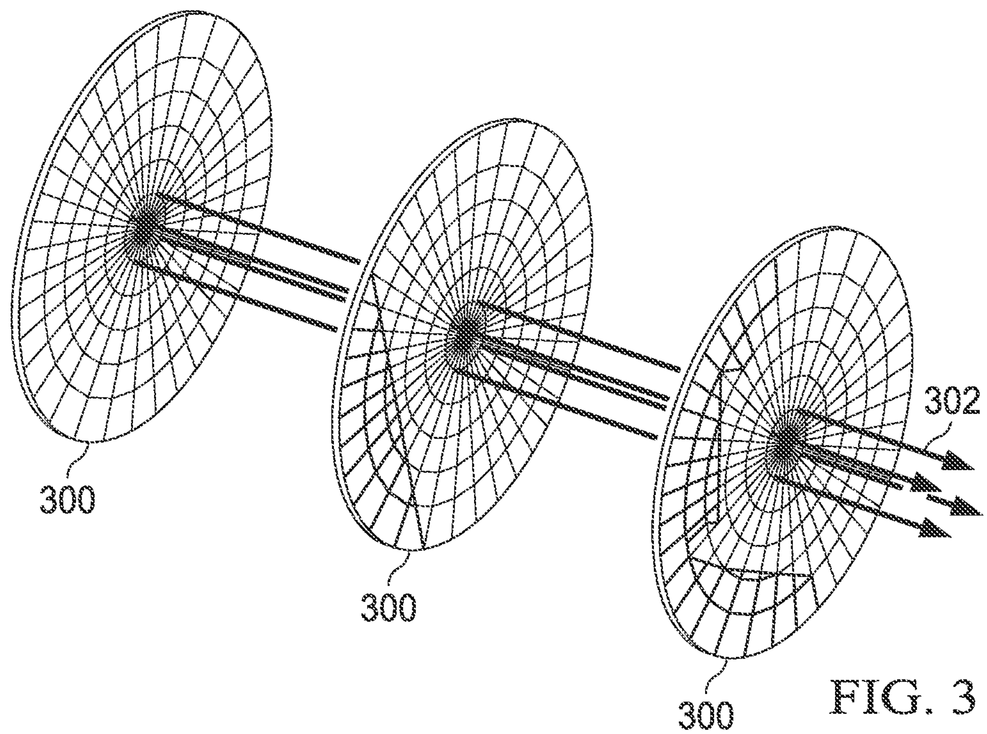


FIG. 3

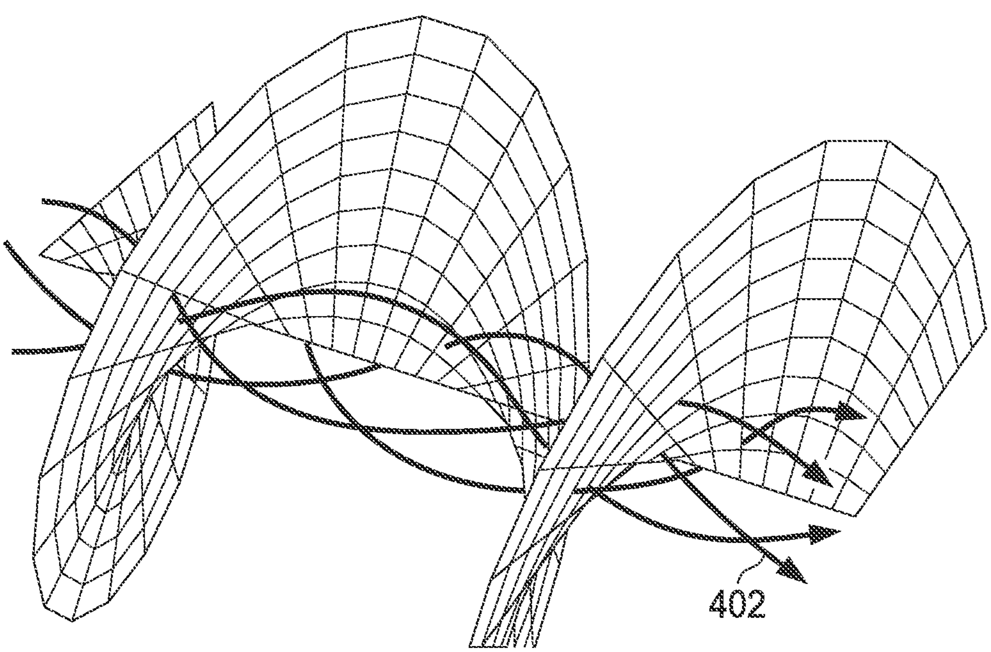


FIG. 4

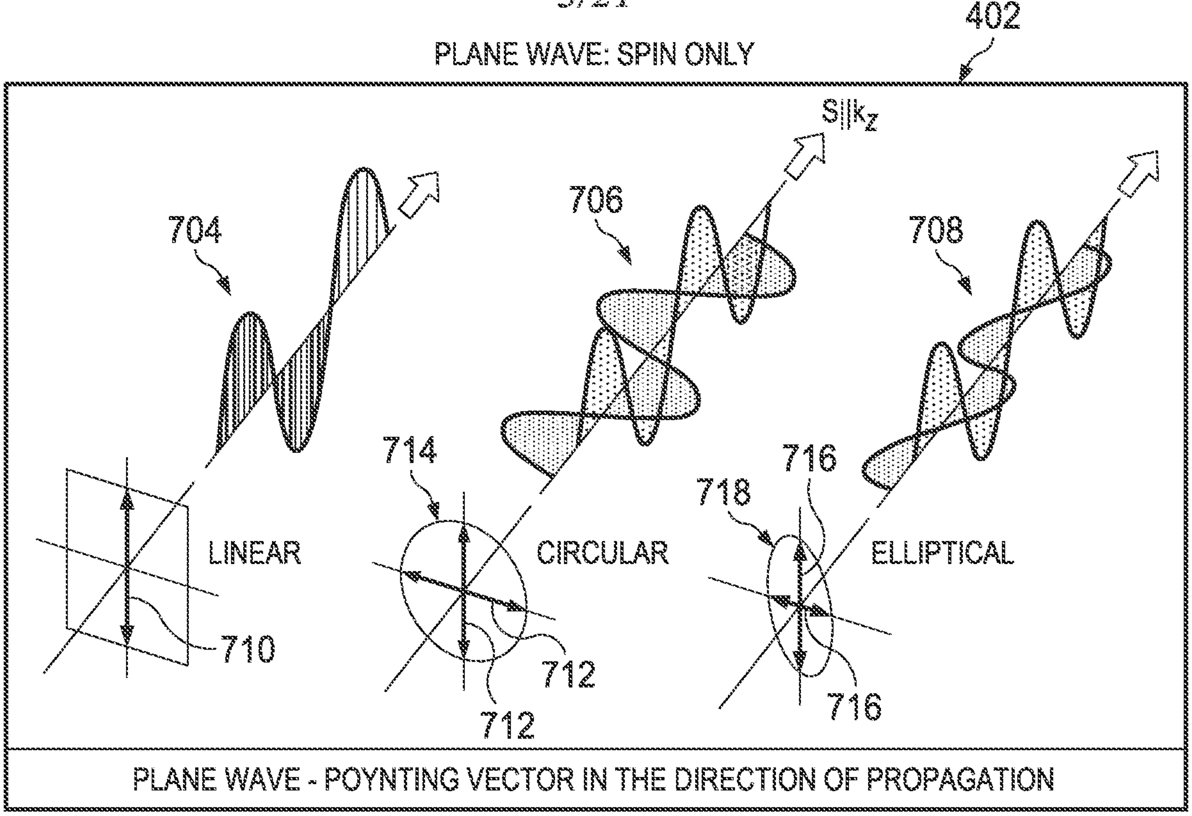

PLANE WAVE: SPIN ONLY
402
S||k_z
704
706
708
714
716
718
LINEAR
CIRCULAR
ELLIPTICAL
710
712
712
716
PLANE WAVE - POYNTING VECTOR IN THE DIRECTION OF PROPAGATION

FIG. 7

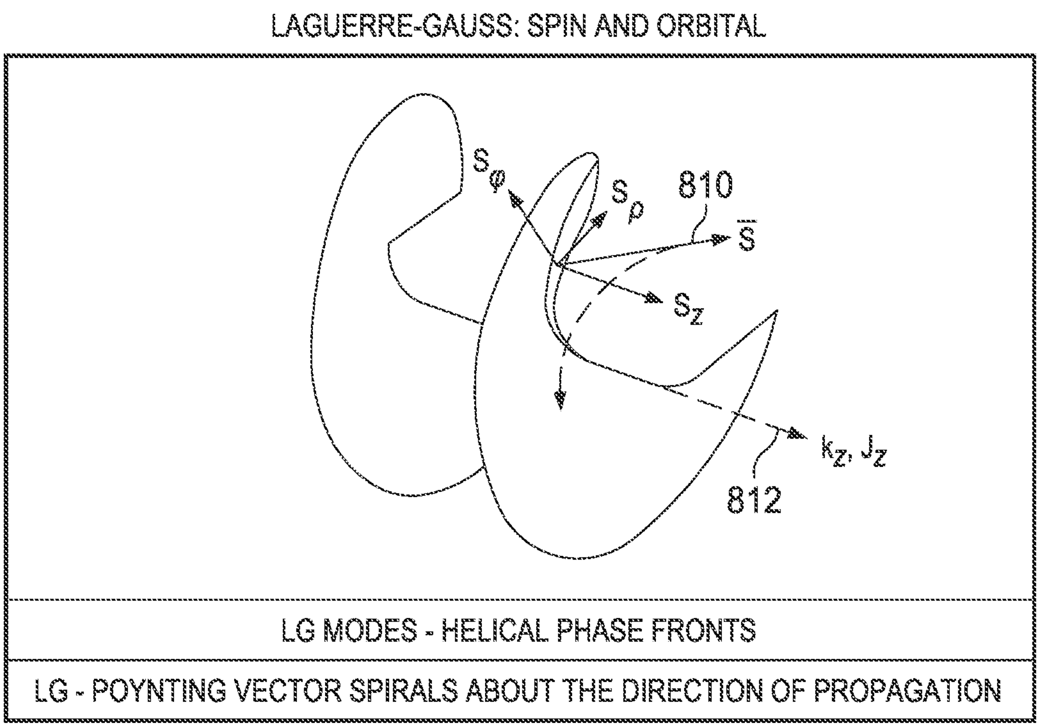

LAGUERRE-GAUSS: SPIN AND ORBITAL
S_φ
S_ρ
810
S̄
S_z
k_z, J_z
812
LG MODES - HELICAL PHASE FRONTS
LG - POYNTING VECTOR SPIRALS ABOUT THE DIRECTION OF PROPAGATION

FIG. 8

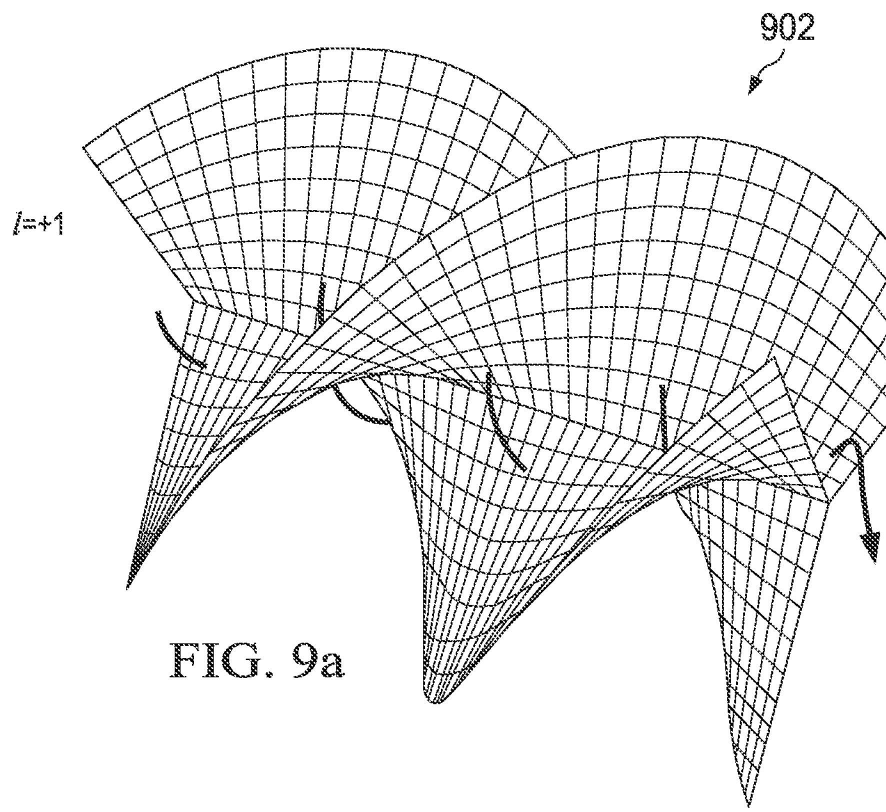


FIG. 9a

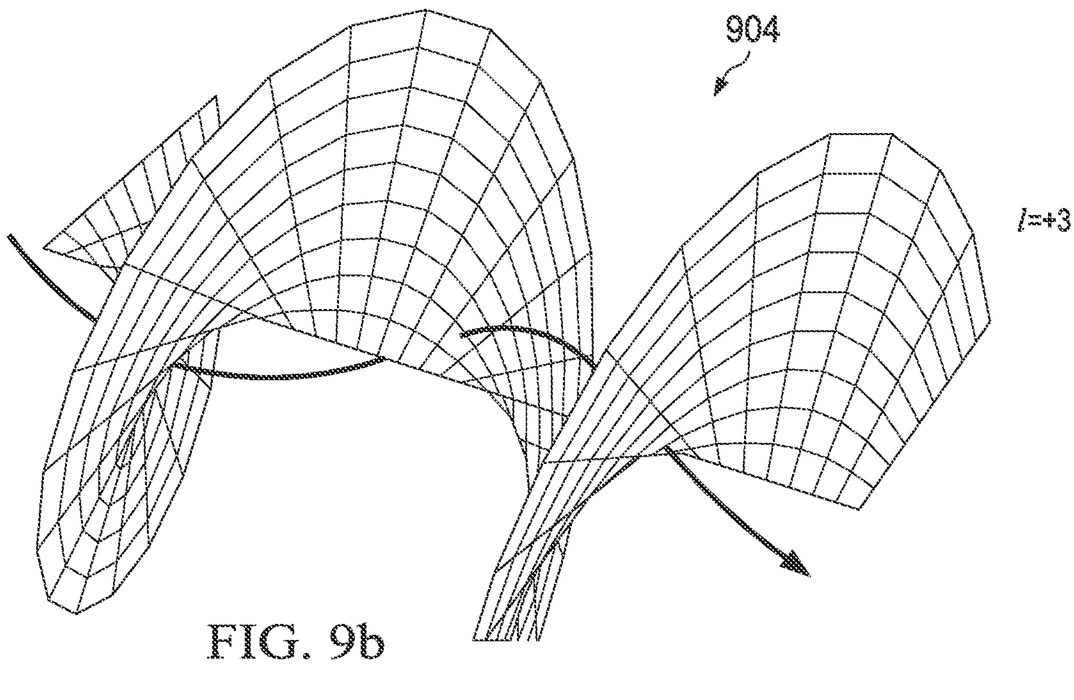


FIG. 9b

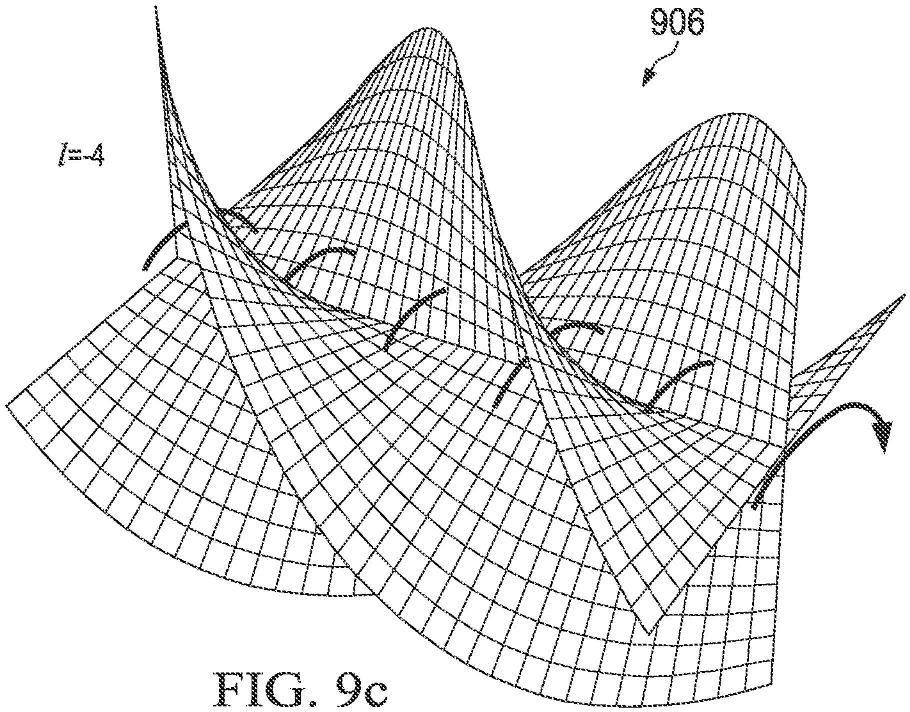


FIG. 9c

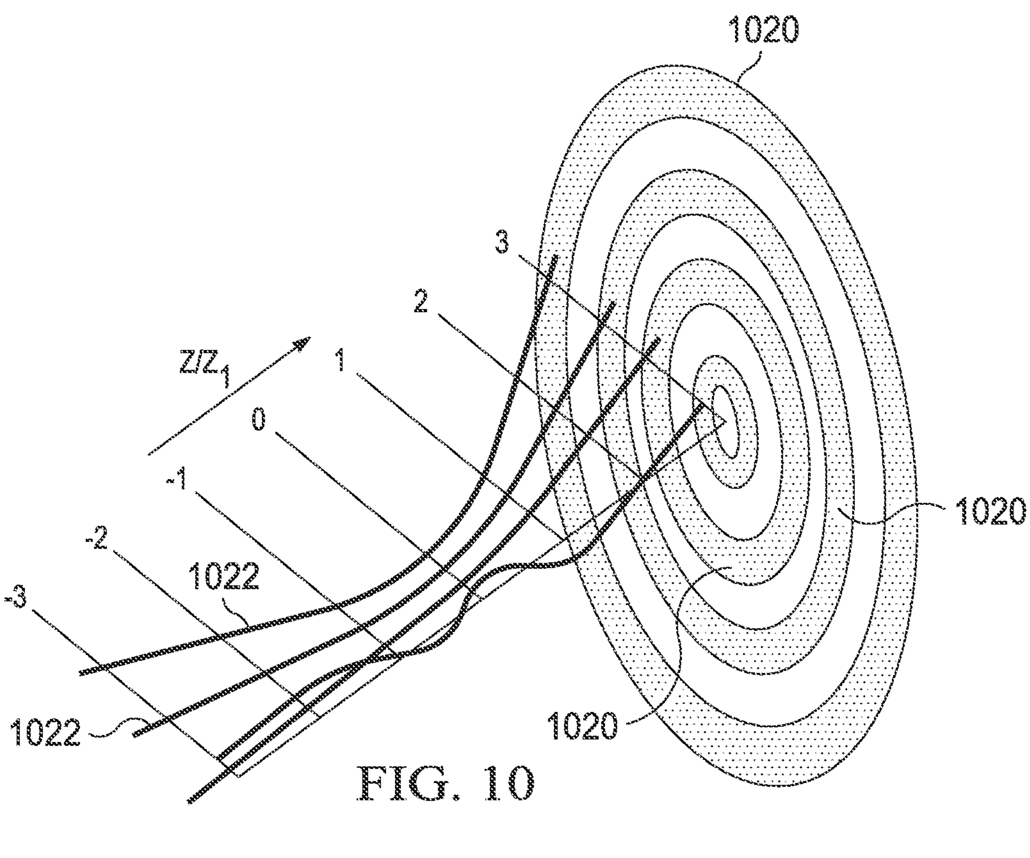


FIG. 10

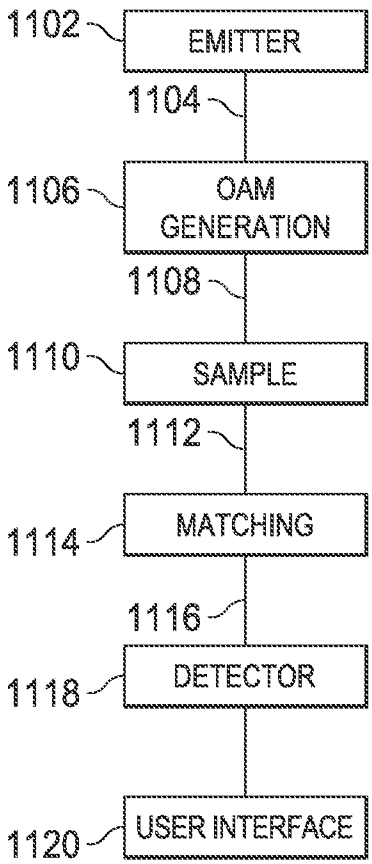


FIG. 11

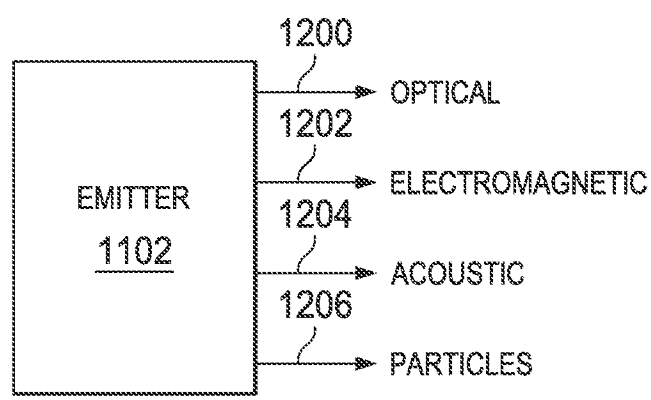


FIG. 12

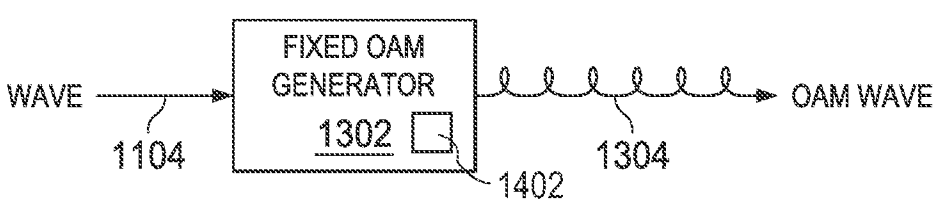


FIG. 13

FIG. 14a

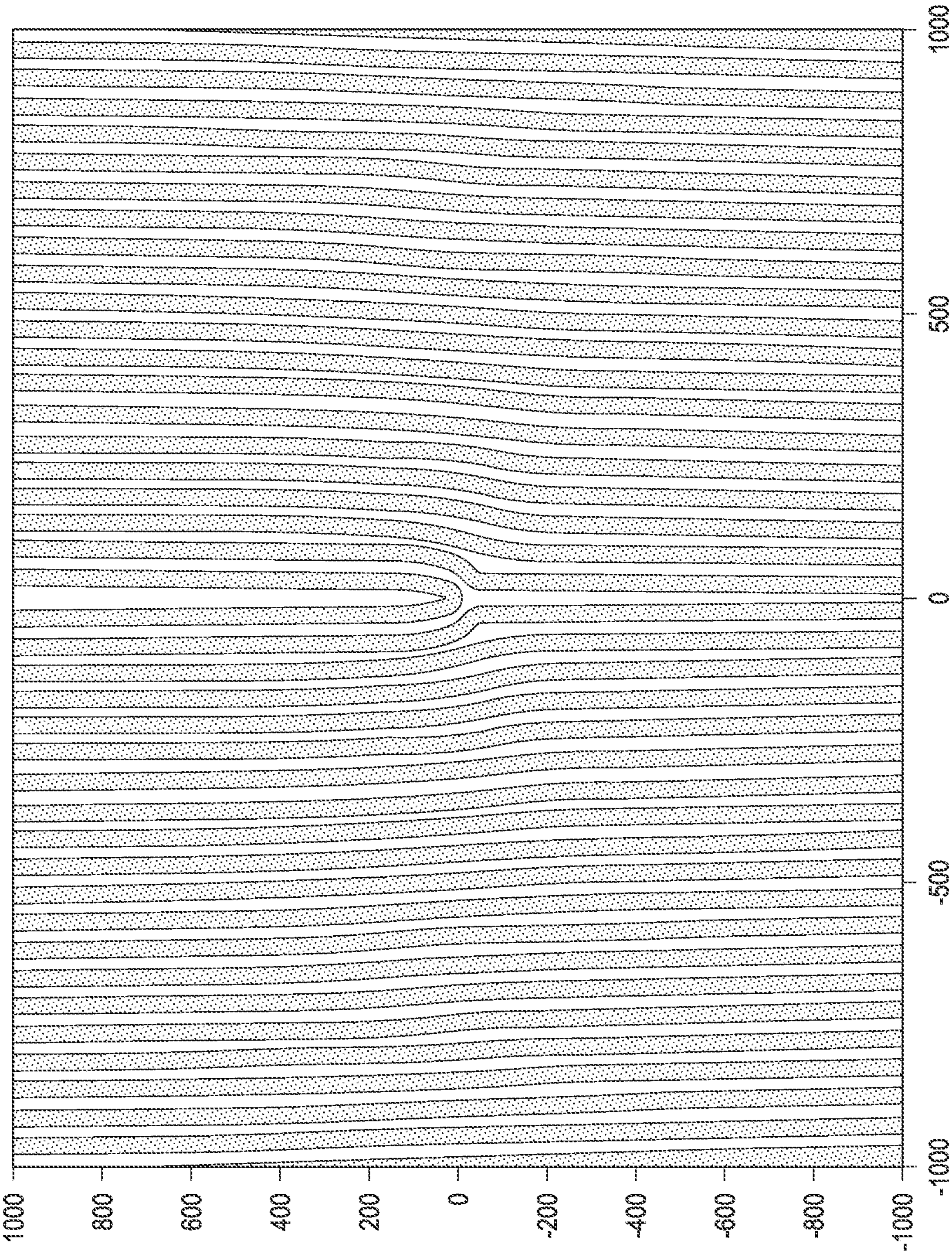


FIG. 14b

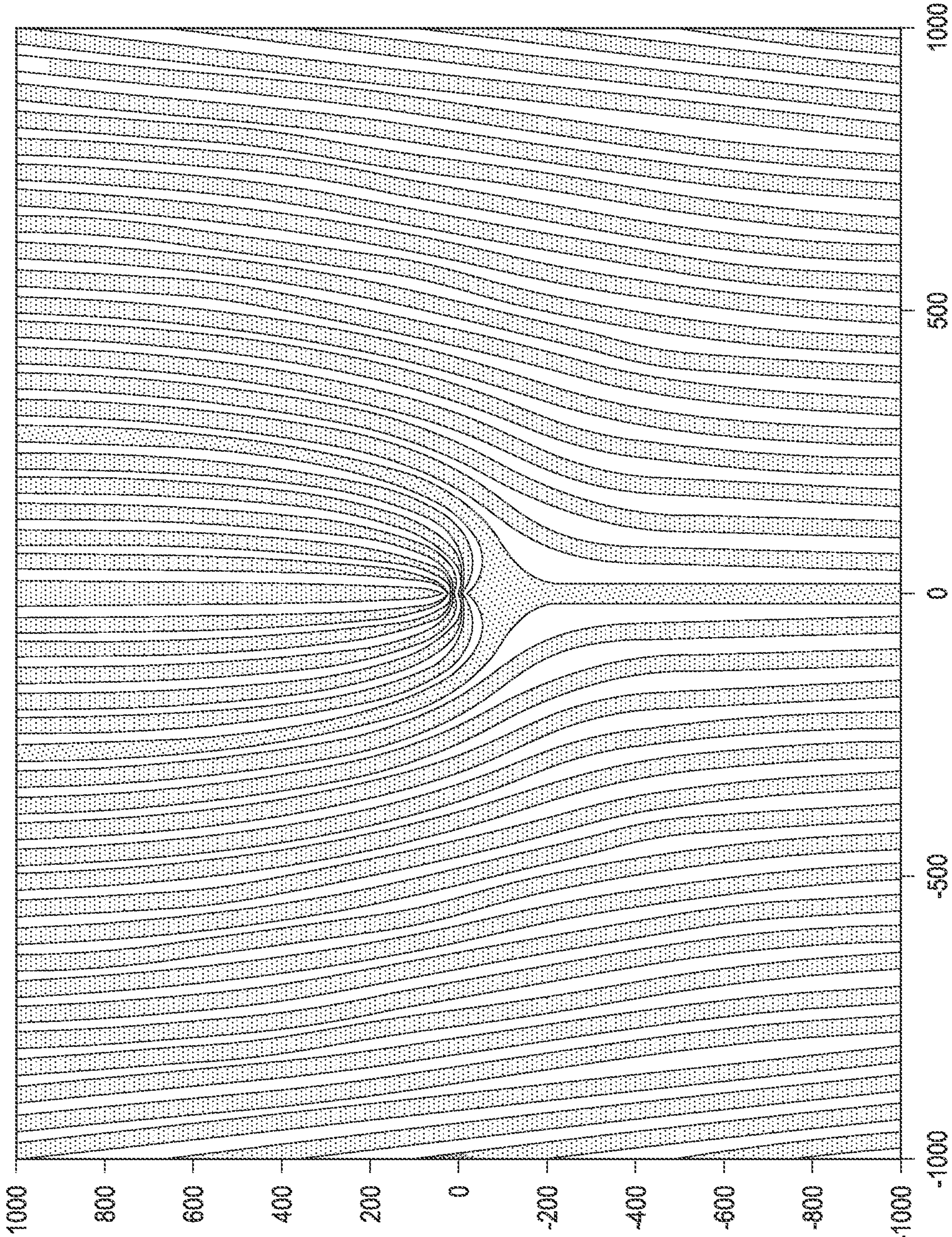


FIG. 14c

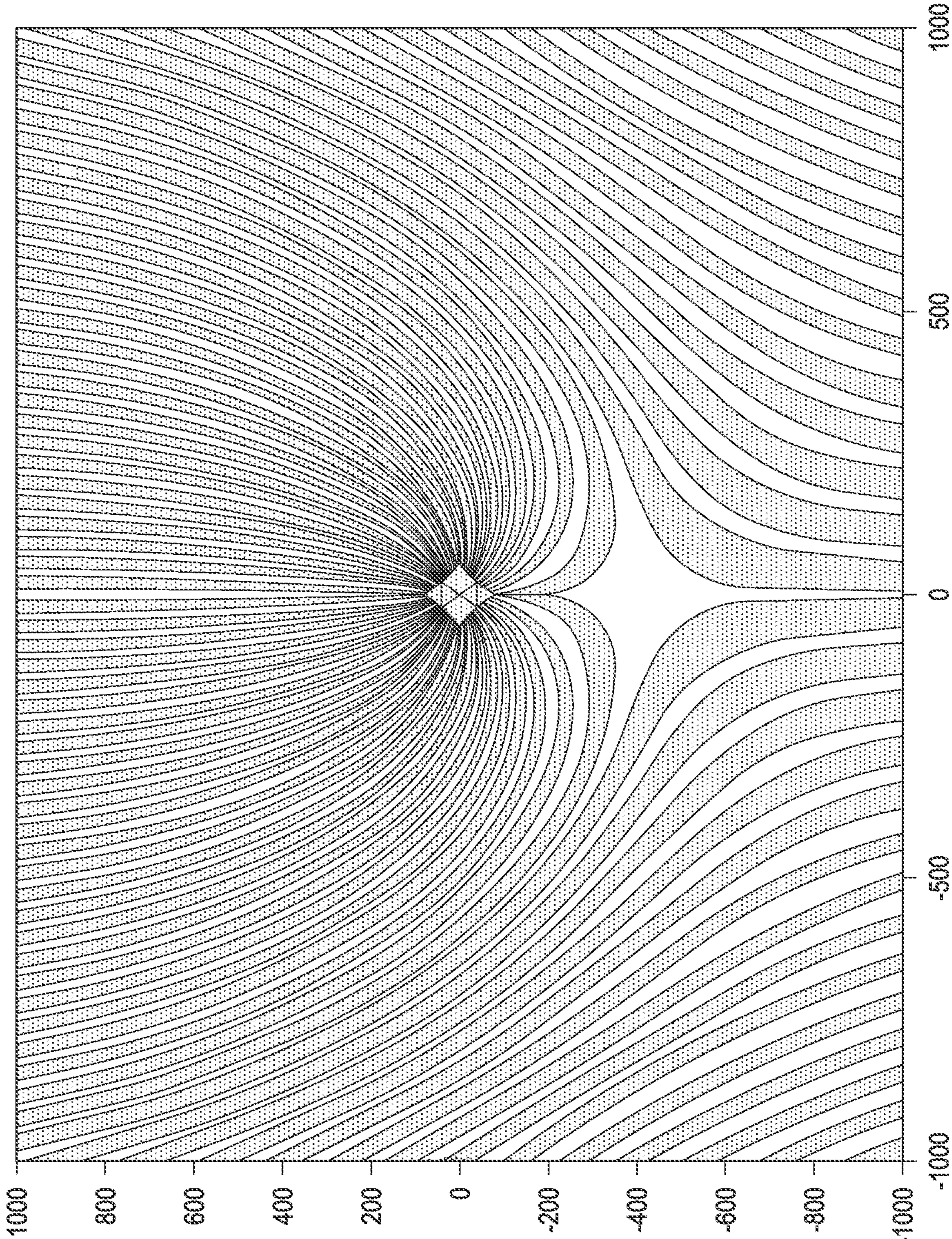
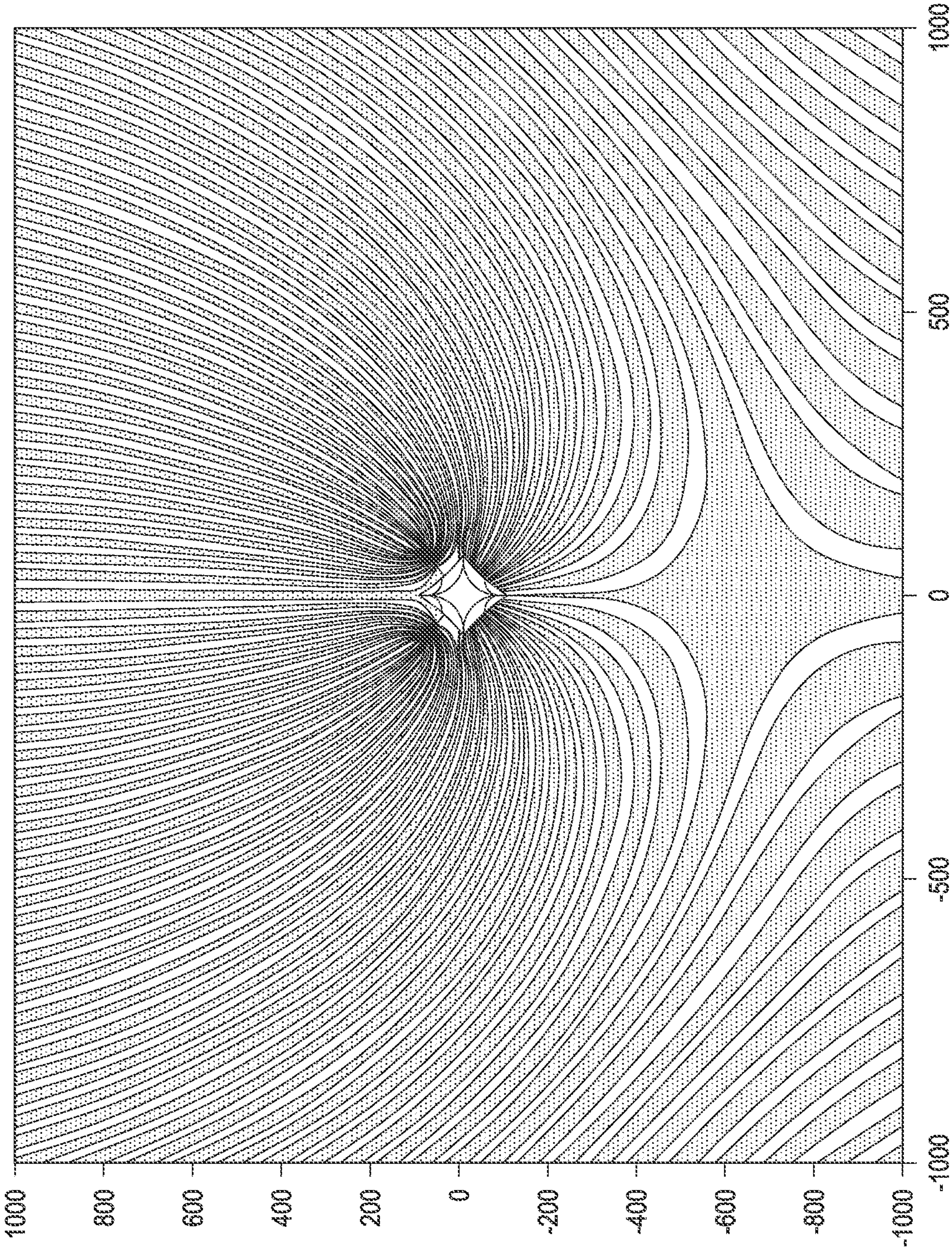


FIG. 14d



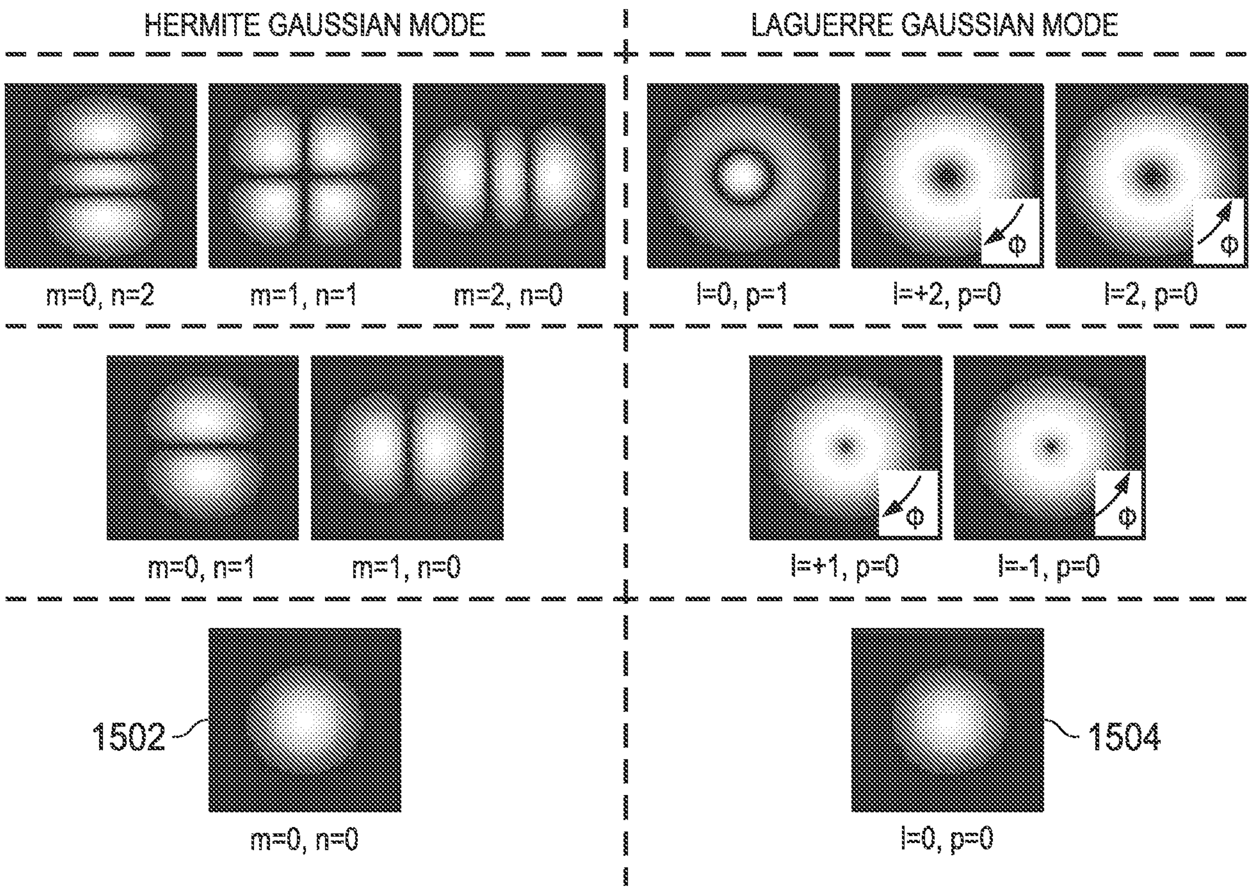
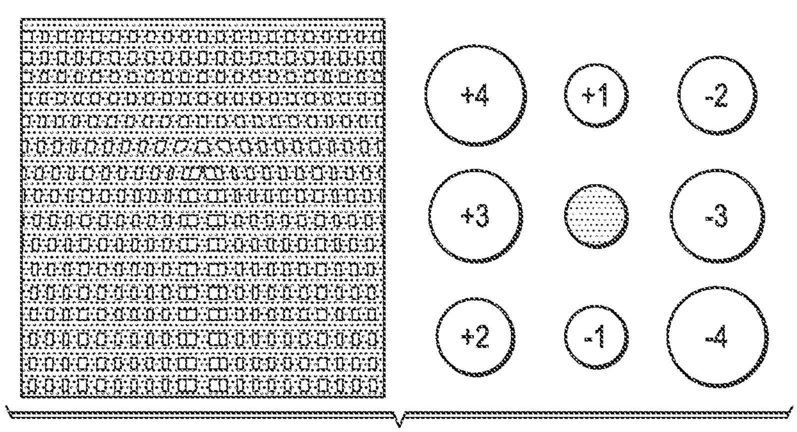

HERMITE GAUSSIAN MODE
LAGUERRE GAUSSIAN MODE
m=0, n=2
m=1, n=1
m=2, n=0
l=0, p=1
l=+2, p=0
l=2, p=0
m=0, n=1
m=1, n=0
l=+1, p=0
l=-1, p=0
1502
m=0, n=0
1504
l=0, p=0

FIG. 15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+3
-3
+2
-1
-4

FIG. 16

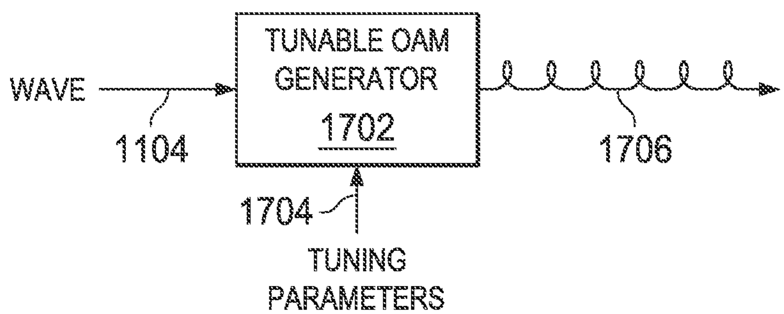
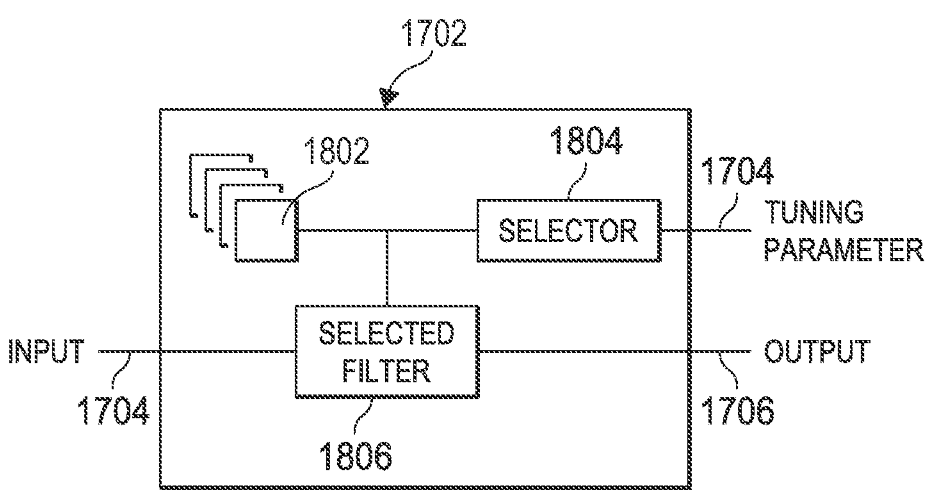

TUNABLE OAM GENERATOR
1702
WAVE
1104
1706
1704
TUNING PARAMETERS

FIG. 17


1702
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1804
SELECTOR
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TUNING PARAMETER
INPUT
1704
SELECTED FILTER
OUTPUT
1706
1806

FIG. 18

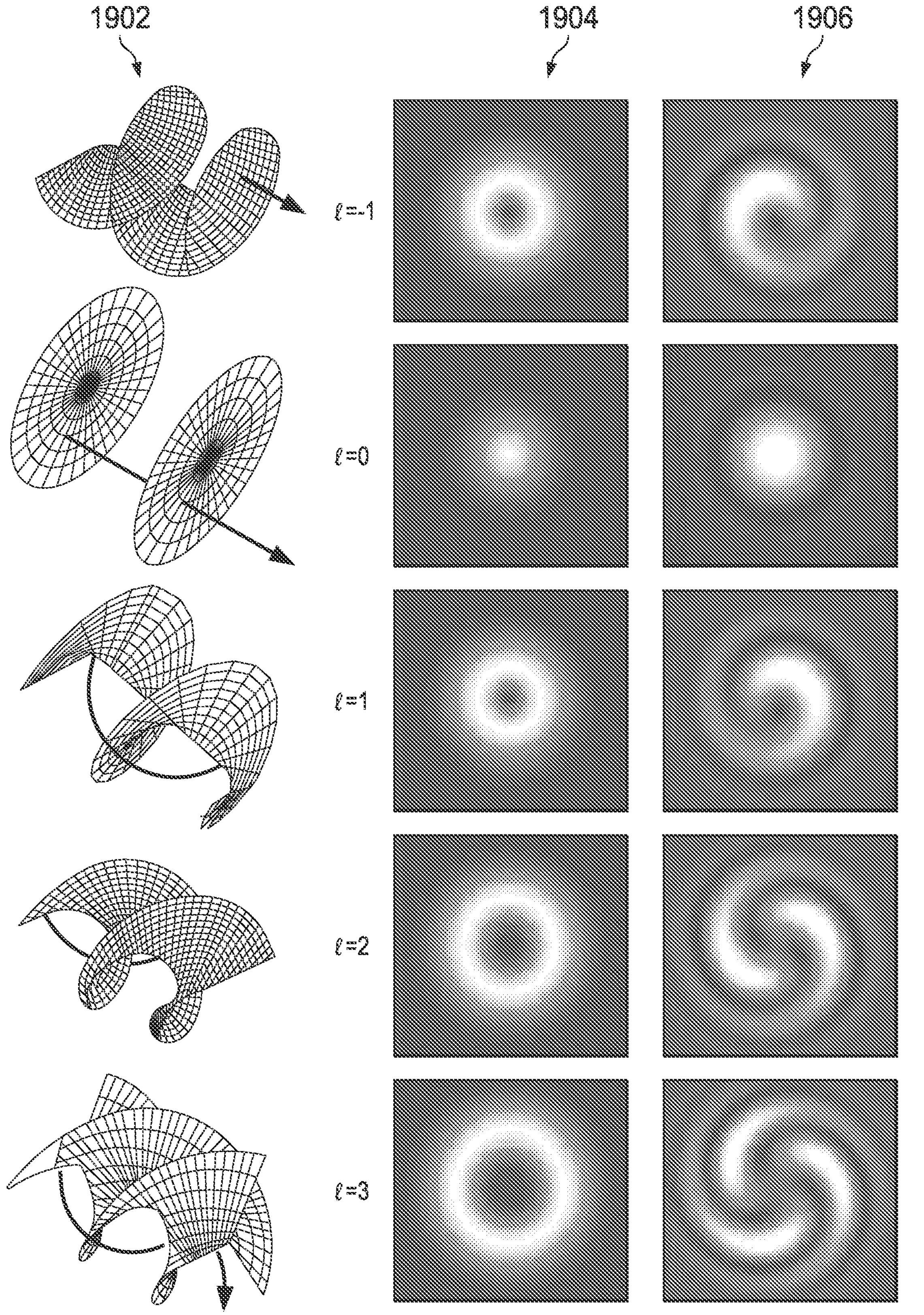

FIG. 19

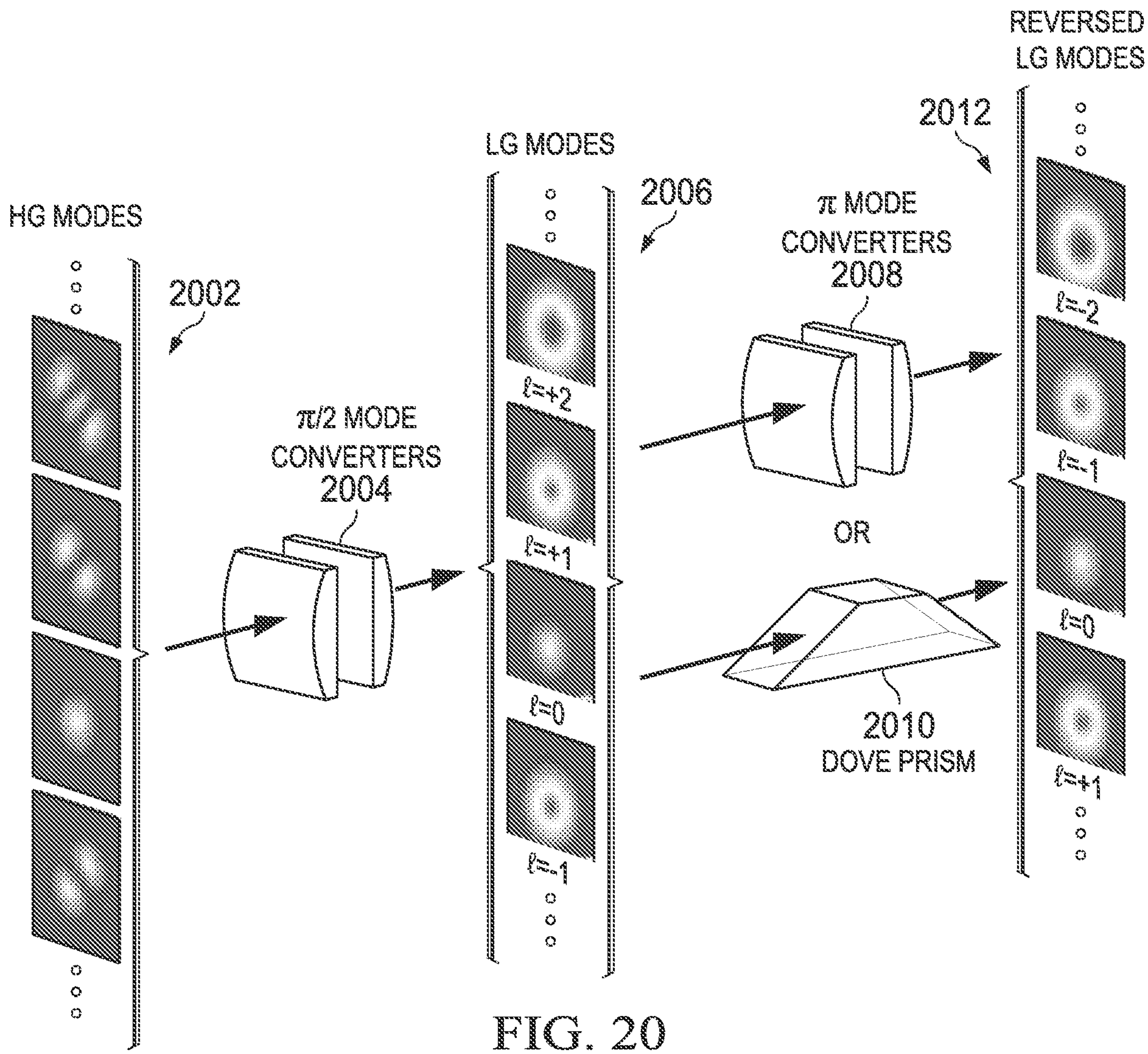
HG MODES
2002
π/2 MODE
CONVERTERS
2004
LG MODES
2006
ℓ=+2
ℓ=+1
ℓ=0
ℓ=-1
π MODE
CONVERTERS
2008
OR
2010
DOVE PRISM
2012
REVERSED
LG MODES
ℓ=-2
ℓ=-1
ℓ=0
ℓ=+1

FIG. 20

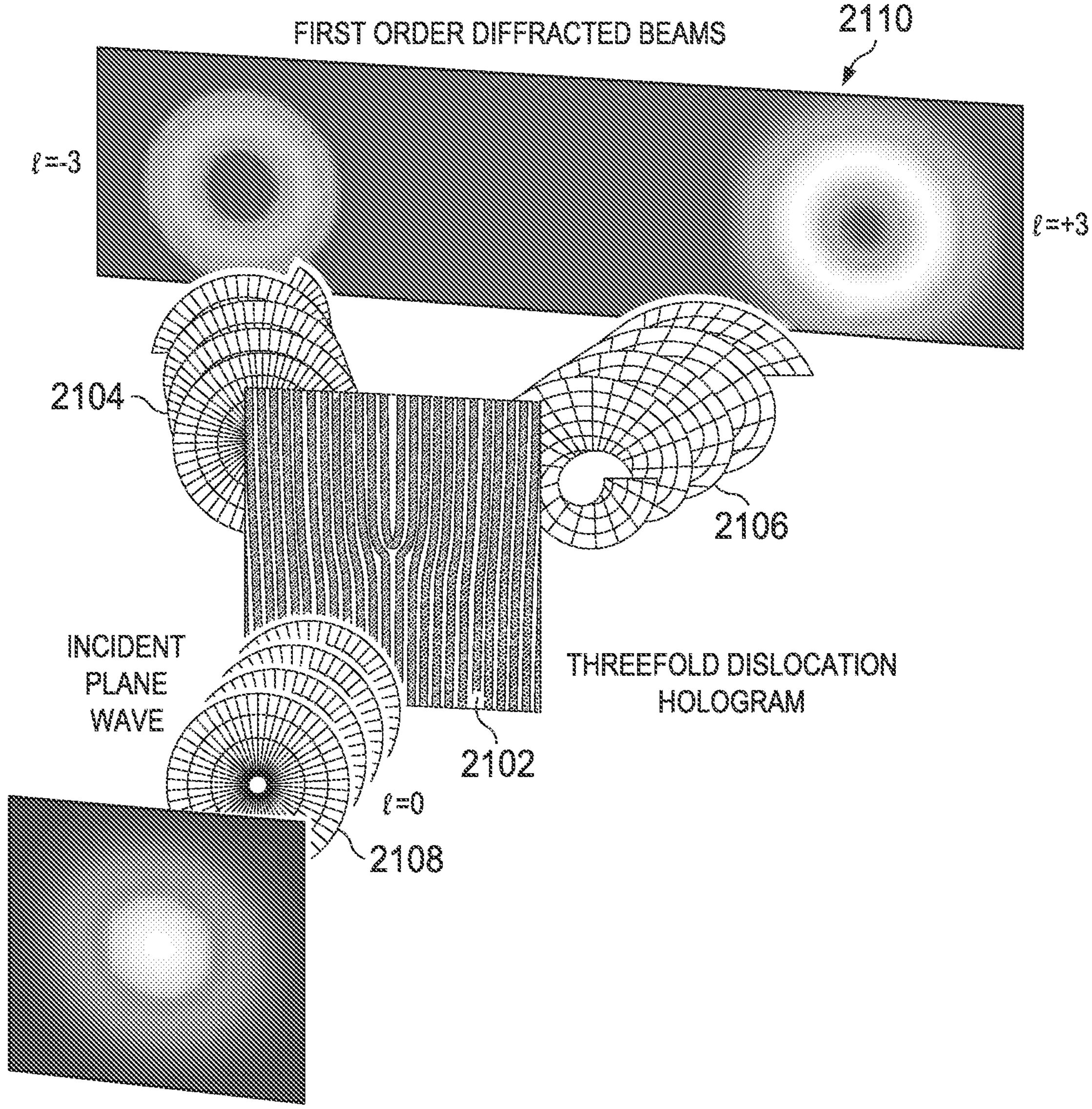
FIRST ORDER DIFFRACTED BEAMS
2110
ℓ=-3
ℓ=+3
2104
2106
INCIDENT
PLANE
WAVE
THREEFOLD DISLOCATION
HOLOGRAM
2102
ℓ=0
2108

FIG. 21


INPUT
OAM WAVE
1108
SAMPLE
1110
1112
OUTPUT
OAM WAVE

FIG. 22

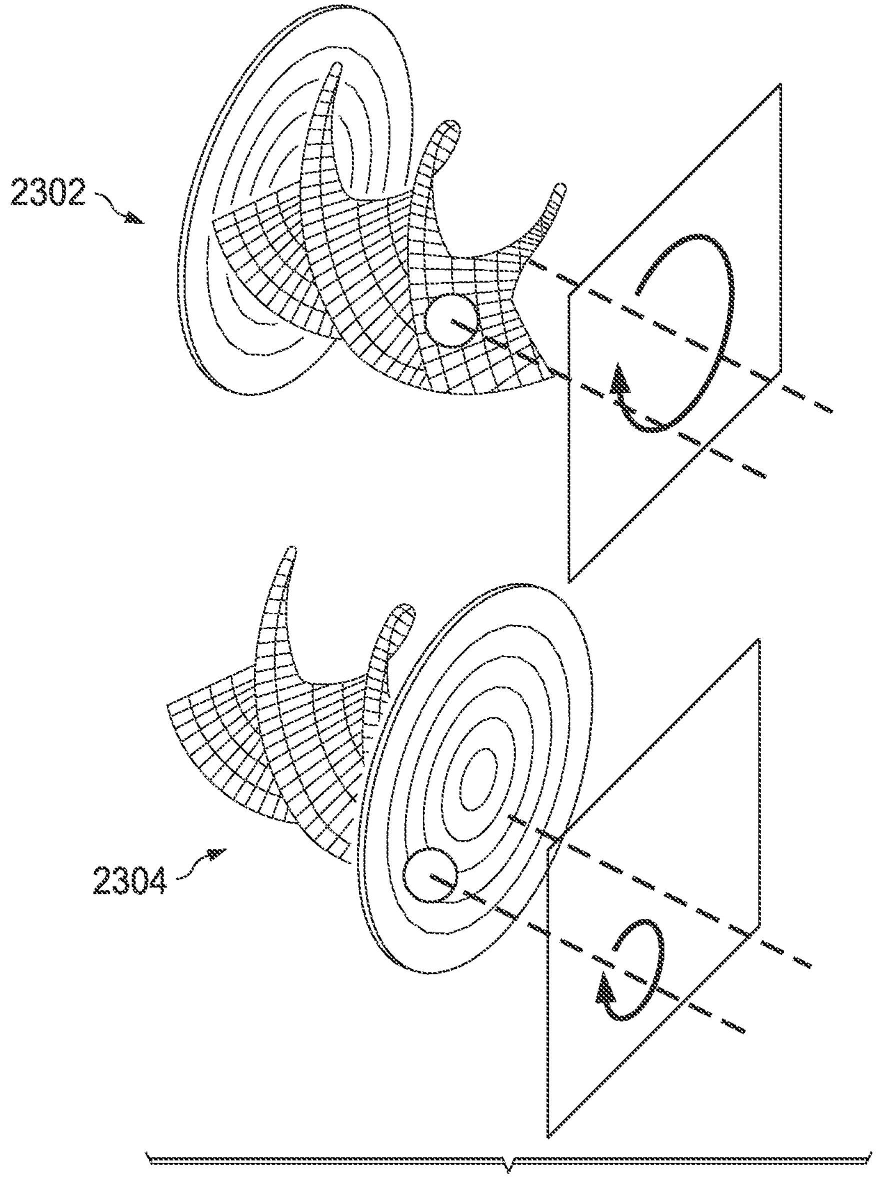
2302
2304

FIG. 23

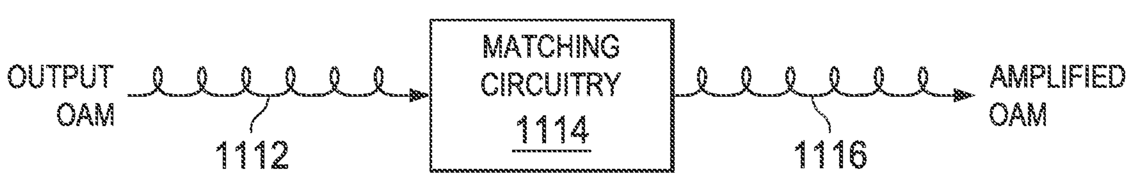
OUTPUT
OAM
1112
MATCHING
CIRCUITRY
1114
1116
AMPLIFIED
OAM

FIG. 24

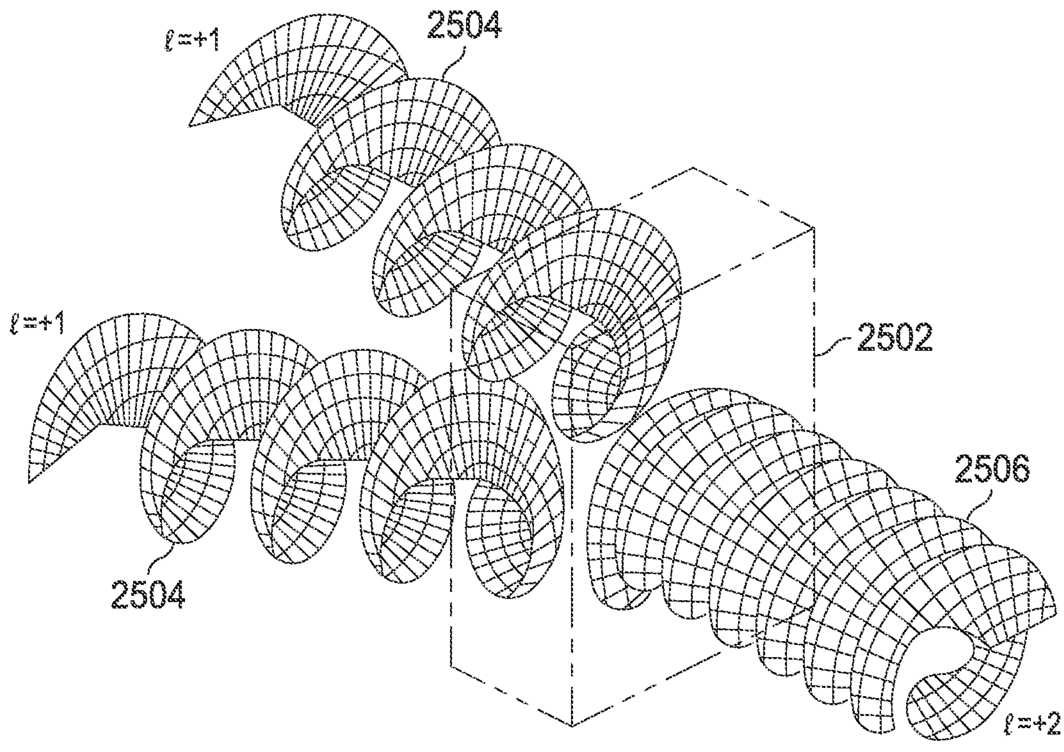
ℓ=+1
2504
ℓ=+1
2502
2504
2506
ℓ=+2

FIG. 25

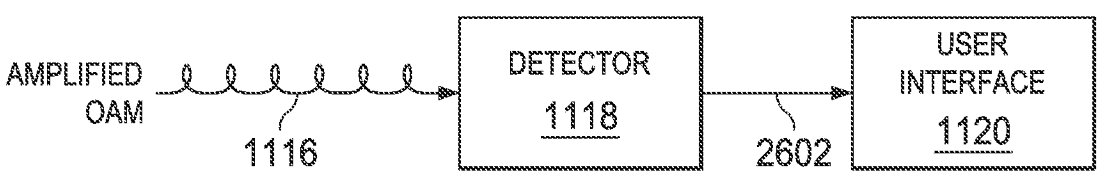
AMPLIFIED
OAM
1116
DETECTOR
1118
2602
USER
INTERFACE
1120

FIG. 26

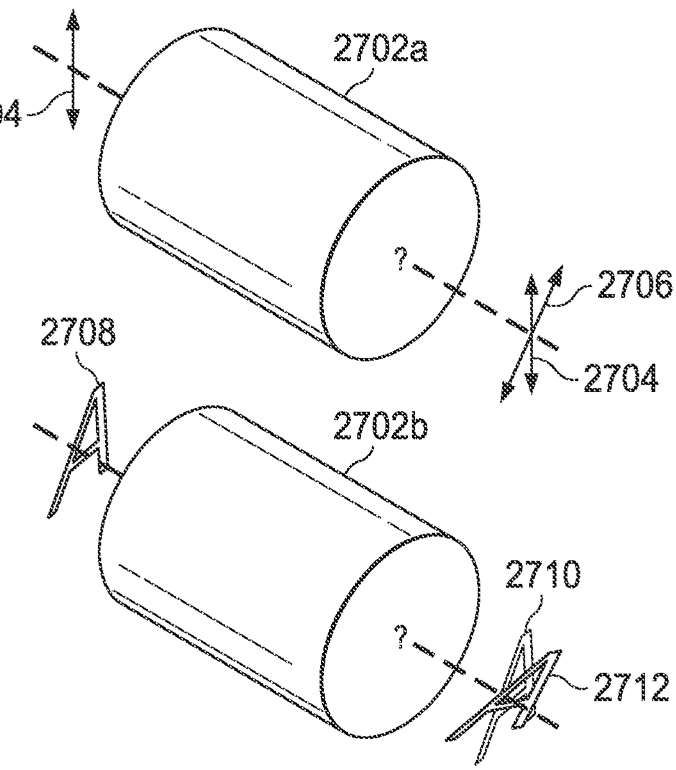
2702a
2704
2706
2704
2708
2702b
2710
2712

FIG. 27

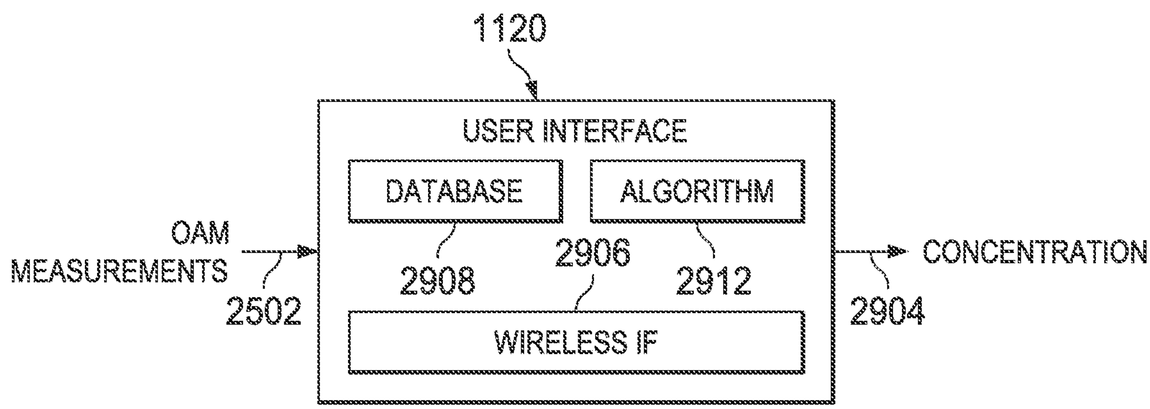
1120
USER INTERFACE
DATABASE
ALGORITHM
OAM
MEASUREMENTS
2502
2908
2906
2912
WIRELESS IF
CONCENTRATION
2904

FIG. 29

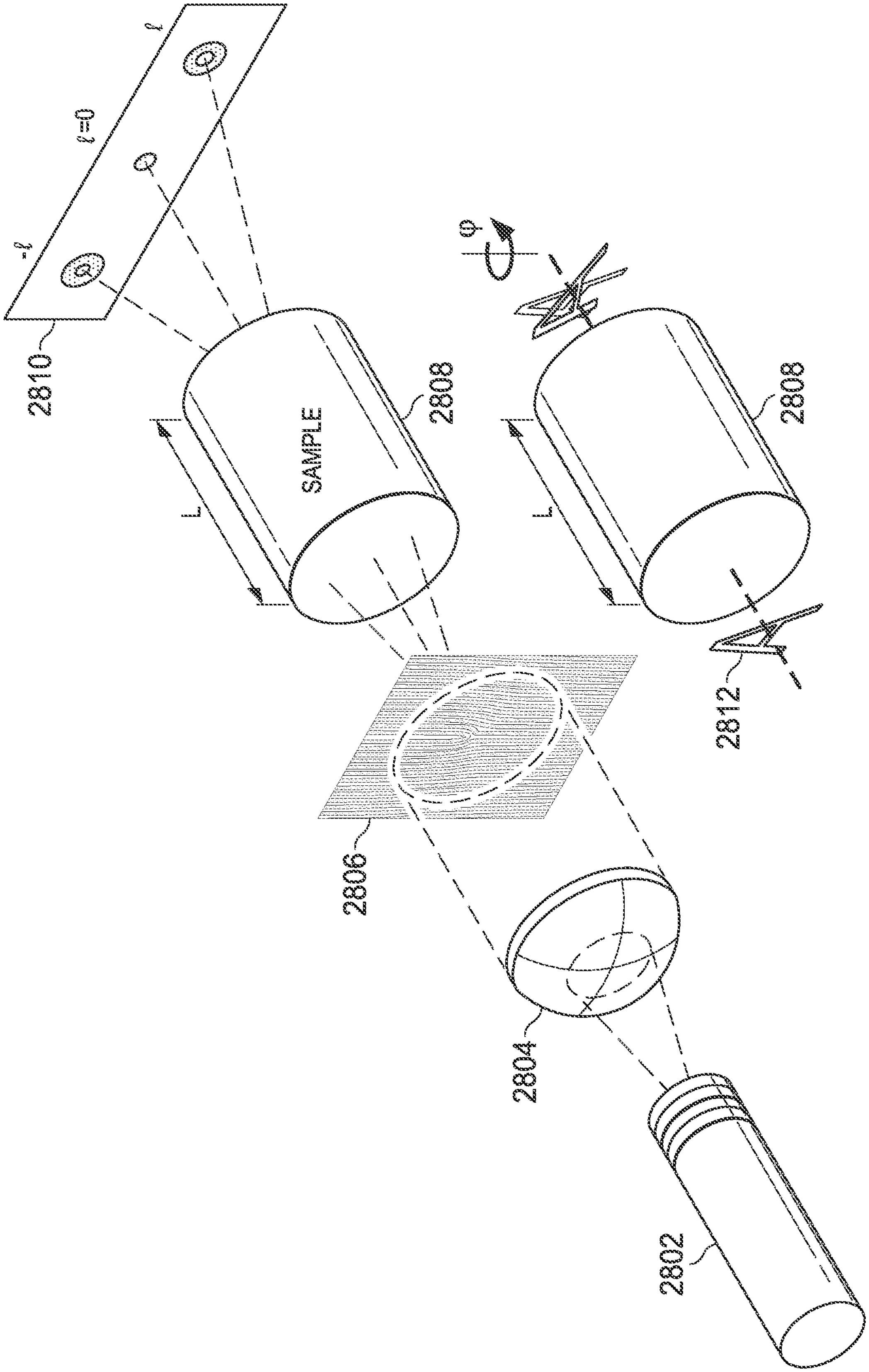

FIG. 28

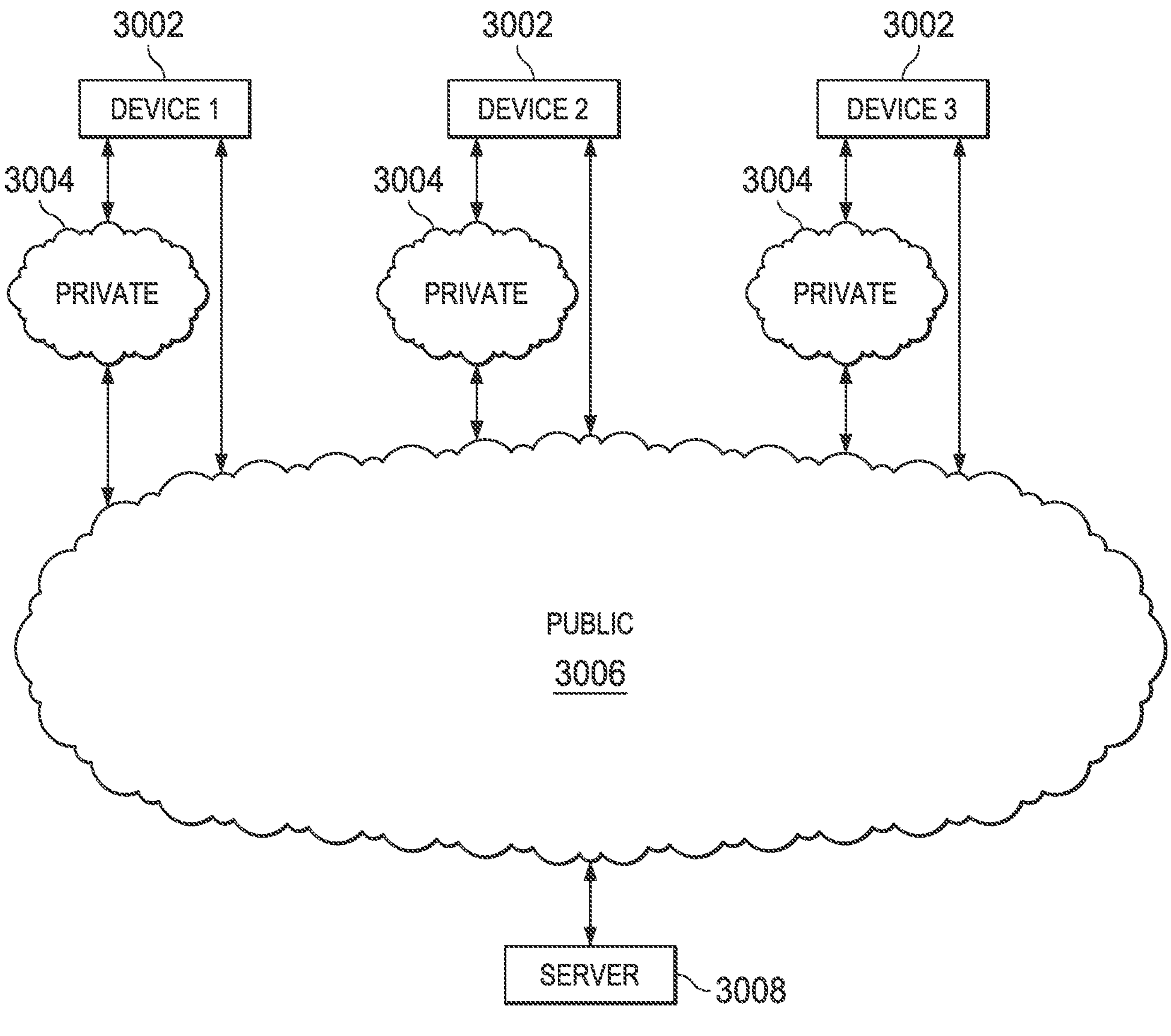
3002
DEVICE 1
3002
DEVICE 2
3002
DEVICE 3
3004
PRIVATE
3004
PRIVATE
3004
PRIVATE
PUBLIC
3006
SERVER
3008

FIG. 30

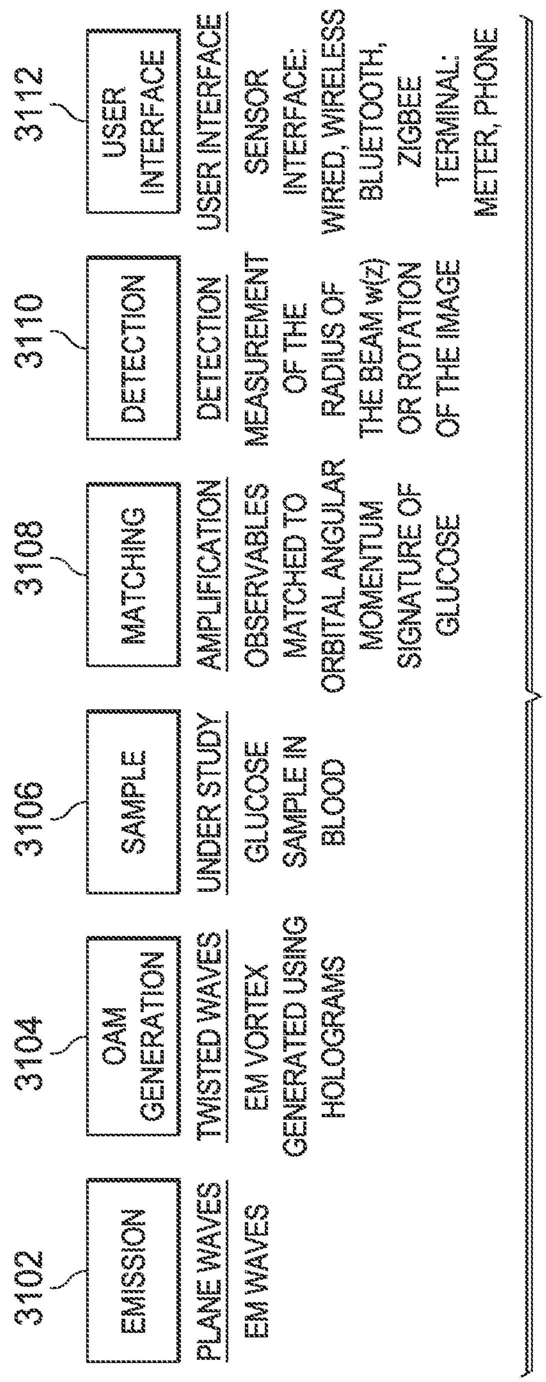
3102
EMISSION
PLANE WAVES
EM WAVES
3104
OAM GENERATION
TWISTED WAVES
EM VORTEX GENERATED USING HOLOGRAMS
3106
SAMPLE
UNDER STUDY
GLUCOSE SAMPLE IN BLOOD
3108
MATCHING
AMPLIFICATION
OBSERVABLES MATCHED TO ORBITAL ANGULAR MOMENTUM SIGNATURE OF GLUCOSE
3110
DETECTION
DETECTION
MEASUREMENT OF THE RADIUS OF THE BEAM w(z) OR ROTATION OF THE IMAGE
3112
USER INTERFACE
USER INTERFACE
SENSOR INTERFACE: WIRED, WIRELESS BLUETOOTH, ZIGBEE
TERMINAL: METER, PHONE

FIG. 31

Electronic Acknowledgement Receipt

EFS ID:	23000177
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	23-JUL-2015
Filing Date:	24-JUL-2014
Time Stamp:	12:20:40
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		NXG32196312AMD.pdf	101319 6ba5ed046c63c38a89d227830c55cb7691b563f1	yes	10

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment after Notice of Allowance (Rule 312)	1	1
	Specification	2	2
	Claims	3	8
	Drawings-only black and white line drawings	9	9
	Applicant Arguments/Remarks Made in an Amendment	10	10

Warnings:

Information:

2	Drawings-only black and white line drawings	NXG32196AnnotatedSheets.pdf	152438 9951e4cfc517645e13fe57deb89d53fd4573bb36	no	3

Warnings:

Information:

3	Drawings-only black and white line drawings	NXG32196ReplacementSheets.pdf	1292005 7f4faaf68abea34587de6a01f90e8840820b4ea4	no	21

Warnings:

Information:

Total Files Size (in bytes):	1545762

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

DocCode - SCORE

SCORE Placeholder Sheet for IFW Content

Application Number: 14339836 Document Date: 07/23/2015

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions below.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://Score.uspto.gov/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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NOTICE OF ALLOWANCE AND FEE(S) DUE

25883 7590 07/01/2015

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	
ART UNIT	PAPER NUMBER
2886	

DATE MAILED: 07/01/2015

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

TITLE OF INVENTION: SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	10/01/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

25883 7590 07/01/2015
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

TITLE OF INVENTION: SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	10/01/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
STOCK JR, GORDON J	2886	356-432000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
   (1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
   (2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
   1 ____________________
   2 ____________________
   3 ____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)
   PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.
   (A) NAME OF ASSIGNEE
   (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies ____________________

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29
  NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27
  NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ❑ Applicant changing to regular undiscounted fee status.
  NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature ______________________________ Date ______________________________

Typed or printed name ______________________________ Registration No. ______________________________

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 07/01/2015

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	

ART UNIT	PAPER NUMBER
2886	

DATE MAILED: 07/01/2015

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	**Application No.** 14/339,836	**Applicant(s)** ASHRAFI ET AL.	
	Examiner GORDON J. STOCK JR	**Art Unit** 2886	**AIA (First Inventor to File) Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *amendment received on 5/13/15*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on______.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-30*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. ______ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☒ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☒ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date 20150321.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☒ Interview Summary (PTO-413), Paper No./Mail Date *20150623* .
5. ☒ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

DETAILED ACTION

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

2. The Amendment received on May 13, 2015 has been entered into the record.

EXAMINER'S COMMENT

3. As cited on page 9 of the previous office action (see Action: 20150321):

The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they do not include the following reference sign(s) mentioned in the description: '204' of Fig. 2; '1402' of paragraph 0074; and '1802' of Fig. 18. Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either "Replacement Sheet" or "New Sheet" pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

Fig. 18 is objected to for the following: it appears from applicant's disclosure that the box encompassing 1804 and 1806 should be labelled -1702-. Correction is required.

EXAMINER'S AMENDMENT

4. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR

1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given by telephone by Attorney Brian Walker on June 23, 2015. Please see attached PTOL-413B. **Claims 11, 22, and 30** will be amended.

The Application will be amended as follows:

Claim 11 lines 6-7 is amended from 'from the concentration determined' to read –from concentrations determined-.

Claim 22 lines 6-7 is amended from 'from the concentrations determined' to read –from concentrations determined-.

Claim 30 line 2 is amended from 'from the concentrations that' to read –from concentrations that-.

Allowable Subject Matter

5. **Claims 1-30** are allowed.

The following is an examiner's statement of reasons for allowance:

As to **claim 1**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample 'a detector that receives the first signal after the first signal passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample,' in combination with the rest of the limitations of **claim 1. Claims 2-14** are allowed by virtue of their dependency from **claim 1.**

As to **claim 15**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample 'a detector that receives the first light beam after the first light beam passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the first light beam having the predetermined value of the orbital angular momentum associated therewith,' in combination with the rest of the limitations of **claim 15.** **Claims 16-24** are allowed by virtue of their dependency from **claim 15.**

As to **claim 25**, the prior art of record, taken alone or in combination, fails to disclose or render obvious a method for measuring a concentration of a material within a sample 'determining the concentration of the material within the sample based on the detected value of orbital angular momentum with the first signal received from the sample,' in combination with the rest of the limitations of **claim 25.** **Claims 26-30** are allowed by virtue of their dependency from **claim 25.**

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Response to Arguments

6. Applicant's arguments, see Remarks pages 12-13, filed May 13, 2015, with respect to the previous objections to the claims and drawings and rejections under 35 USC 112(b) in view of the amendment to the claims and specification have been fully considered and are persuasive.

The previous rejections and objections to the drawings and claims have been withdrawn except for the drawings corrections mentioned above. Please refer to Examiner's Comment above.

Fax/Telephone Numbers

If the applicant wishes to send a fax dealing with either a proposed amendment or a discussion with a phone interview, then the fax should:

1) Contain either a statement "DRAFT" or "PROPOSED AMENDMENT" on the fax cover sheet; and

2) Should be unsigned by the attorney or agent.

This will ensure that it will not be entered into the case and will be forwarded to the examiner as quickly as possible.

Papers related to the application may be submitted to Group 2800 by fax transmission. The fax phone number for Patent Technology Center 2800 is 571-273-8300.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Gordon J. Stock, Jr. whose telephone number is (571) 272-2431. The examiner can normally be reached on Monday-Friday, 8:00 a.m. - 6:30 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Tarifur R. Chowdhury, can be reached at 571-272-2287.

Information regarding the status of an application may be obtained from the Patent Application lnformation Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private Pair system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

/GORDON J STOCK JR/

Primary Examiner, Art Unit 2886

Examiner-Initiated Interview Summary	**Application No.** 14/339,836	**Applicant(s)** ASHRAFI ET AL.	
	Examiner GORDON J. STOCK JR	**Art Unit** 2886	

All participants (applicant, applicant's representative, PTO personnel):

(1) *GORDON J. STOCK JR*. (3)_____.

(2) *ATTORNEY BRIAN WALKER*. (4)_____.

Date of Interview: *6/23/15*.

Type: ☒ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☒ No.
If Yes, brief description: _____.

Issues Discussed ☐101 ☒112 ☐102 ☐103 ☒Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: *11,22,30*.

Identification of prior art discussed: *non applicable*.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

The Examiner left a phone message on June 22, 2015 requesting an examiner's amendment to claims 11, 22, 30 to correct lack of antecedent basis issues as well as to provide language consistency. The Examiner also mentioned that drawing corrections would be necessary with regards to '204' of Fig. 2; '1402' of paragraph 0074, '1802' of Fig. 18 (#4 of page 9 of previous office action) and #5 of page 9 with regards to '1702' of Fig. 18. The Attorney called back on June 23, 2015 authorizing the proposed examiner's amendment to claims 11, 22, 30..

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/GORDON J STOCK JR/
Primary Examiner, Art Unit 2886

# *Search Notes*	Application/Control No. 14339836	Applicant(s)/Patent Under Reexamination ASHRAFI ET AL.
	Examiner GORDON J STOCK JR	Art Unit 2886

CPC- SEARCHED

Symbol	Date	Examiner
G01N24/00 (text only)	6/23/15	gjs
G01n21/17,59 (text only)	6/23/15	gjs
G01n2021/1765,178 (text only)	6/23/15	gjs

CPC COMBINATION SETS - SEARCHED

Symbol	Date	Examiner

US CLASSIFICATION SEARCHED

Class	Subclass	Date	Examiner

SEARCH NOTES

Search Notes	Date	Examiner
INSPEC using: "optical angular momentum" AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPEC using: "optical angular momentum" AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPECusing: ((detect[*3] or sens[*3] or measure[*5] or determine[*5]) near/4 "orbital angular momentum") AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPEC using: "orbital angular momentum" and (concentration near measur$6)	3/31/15	gjs
INSPEC using: "optical angular momentum" and (concentration near measur$6)	3/31/15	gjs
EAST (uspat, usocr, uspgpub, epo, jpo, derwent, ibm_tdb, fprs) see search history printout	3/18/15; 3/23/15; 3/24/15; 3/31/15	gjs
EAST (uspat, usocr, uspgpub, epo, jpo, derwent, ibm_tdb, fprs) see search history printout	6/23/15	gjs
356/432-444 (text only) see search history printout	6/23/15	gjs

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
	interference search printout	6/23/15	gjs

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Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 3583

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
14/339,836	07/24/2014 **RULE**	356	2886	NXGN-32196

APPLICANTS

INVENTORS

SOLYMAN ASHRAFI, PLANO, TX;
ROGER LINQUIST, DALLAS, TX;
NIMA ASHRAFI, PLANO, TX;

** **CONTINUING DATA** ************************* ok /GS/ 6/23/15

This appln claims benefit of 61/951,834 03/12/2014

** **FOREIGN APPLICATIONS** ************************* none /GS/ 6/23/15

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **

Foreign Priority claimed / 35 USC 119(a-d) conditions met / Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ❑ Yes ☑ No 35 USC 119(a-d) conditions met ❑ Yes ☑ No Verified and Acknowledged /GORDON J STOCK JR/ Examiner's Signature	❑ Met after Allowance Initials	TX	21	30 ~~31~~	3

ADDRESS /GS/ 6/23/15

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715
UNITED STATES

TITLE

SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

FILING FEE RECEIVED	FEES	
1170	FEES: Authority has been given in Paper No.________ to charge/credit DEPOSIT ACCOUNT No.________ for following:	❑ All Fees ❑ 1.16 Fees (Filing) ❑ 1.17 Fees (Processing Ext. of time) ❑ 1.18 Fees (Issue) ❑ Other ________ ❑ Credit

/GS/

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	2026	(orbital near6 (spin quant$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 10:38
L2	773	(orbital near angular) near moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 10:39
L3	459	(1 2) and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 10:39
L4	2	(1 2) and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 10:39
L5	301	(g01n24/00).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:00
L6	1274	(g01n21/17).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:00
L7	3320	(g01n21/59).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:00
L8	254	(g01n2021/1765).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:01
L9	147	(g01n2021/178).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:01
L10	0	(6 7 8 9) and (1 2)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:01
L11	1179	(6 7 8 9) and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 11:02
L12	9676	(356/432-444).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/23 11:10

L13	3	12 and (1 2)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/06/23 11:10

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L14	257	(orbital near6 (spin quant$3 angular)).clm.	US-PGPUB; USPAT; UPAD	OR	ON	2015/06/23 11:11
L15	33	14 and (amount concentration).clm.	US-PGPUB; USPAT; UPAD	OR	ON	2015/06/23 11:12

6/23/2015 11:15:15 AM
C:\Users\gstock\Documents\EAST\Workspaces\14339836.wsp

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

CPC					
Symbol				**Type**	**Version**
G01N	21	/	17	F	2013-01-01
G01N	21	/	59	I	2013-01-01
G01N	24	/	00	I	2013-01-01
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CPC Combination Sets							
Symbol				**Type**	**Set**	**Ranking**	**Version**
		/					
		/					

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 (Primary Examiner)	06/23/2015 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED				
G	0	1	N	21 / 17 (2006.01.01)					
G	0	1	N	21 / 59 (2006.01.01)					
G	0	1	N	24 / 00 (2006.01.01)					

NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 (Primary Examiner)	06/23/2015 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

Issue Classification	Application/Control No. 14339836	Applicant(s)/Patent Under Reexamination ASHRAFI ET AL.
	Examiner GORDON J STOCK JR	Art Unit 2886

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	20	17												
6	2	22	18												
10	3	17	19												
13	4	18	20												
14	5	21	21												
11	6	23	22												
12	7	24	23												
4	8	19	24												
7	9	25	25												
5	10	28	26												
8	11	29	27												
9	12	30	28												
2	13	26	29												
3	14	27	30												
15	15	-	31												
16	16														

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 30	
/GORDON J STOCK JR/ Primary Examiner.Art Unit 2886 (Primary Examiner)	06/23/2015 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 11

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99**)		
	Application Number	14339836
	Filing Date	2014-07-24
	First Named Inventor	ASHRAFI, Solyman
	Art Unit	2886
	Examiner Name	STOCK, Gordon J., Jr.
	Attorney Docket Number	NXGN-32196

U.S.PATENTS

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Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20100327866	A1	2010-12-30	Albu, L. et al.	
	2	20020164806	A1	2002-11-07	Collins, M.	
	3	20080037004	A1	2008-02-14	Shamir, J. et al.	

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FOREIGN PATENT DOCUMENTS

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number		14339836
	Filing Date		2014-07-24
	First Named Inventor	ASHRAFI, Solyman	
	Art Unit		2886
	Examiner Name	STOCK, Gordon J., Jr.	
	Attorney Docket Number		NXGN-32196

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NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
	1	PCT: International Search Report and Written Opinion of PCT/US2015/019177 (related application), 2015 June 25, 8 pgs.	☐

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number		14339836
	Filing Date		2014-07-24
	First Named Inventor	ASHRAFI, Solyman	
	Art Unit		2886
	Examiner Name	STOCK, Gordon J., Jr.	
	Attorney Docket Number		NXGN-32196

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☒ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Brian D. Walker, Reg. #37751/	Date (YYYY-MM-DD)	2015-06-30
Name/Print	Brian D. Walker	Registration Number	37751

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PATENT COOPERATION TREATY REC'D JUN 30 2015

From the INTERNATIONAL SEARCHING AUTHORITY

To: Brian D. Walker
Howison & Arnott, L.L.P.
P.O. Box 741715
Dallas, TX 75374-1715
United States of America

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*)
Applicant's or agent's file reference: NXGN-32526	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No.: PCT/US15/19177	International filing date (*day/month/year*): 06 March 2015 (06.03.2015)
Applicant: Solyman Ashrafi	

1. [X] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to any protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:**
   - [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within 19 months from the priority date, the applicant may request that a supplementary international search be carried out by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

REC'D JUN 30 2015

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Brian D. Walker
Howison & Arnott, L.L.P.
P.O. Box 741715
Dallas, TX 75374-1715
United States of America

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (day/month/year) 25 JUN 2015
Applicant's or agent's file reference NXGN-32526	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US15/19177	International filing date (day/month/year) 06 March 2015 (06.03.2015)
Applicant Solyman Ashrafi	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Within 19 months from the priority date, the applicant may request that a supplementary international search be carried out by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

REC'D JUN 30 2015

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference NXGN-32526	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US15/19177	International filing date *(day/month/year)* 06 March 2015 (06.03.2015)	(Earliest) Priority Date *(day/month/year)* 12 March 2014 (12.03.2014)
Applicant Solyman Ashrafi		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed.
      ☐ a translation of the international application into ______________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.*6bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (see Box No. II).
3. ☐ **Unity of invention is lacking** (see Box No. III).
4. With regard to the **title**,
   ☐ the text is approved as submitted by the applicant.
   ☒ the text has been established by this Authority to read as follows:

SAMPLE CONCENTRATION MEASUREMENTS USING ORBITAL ANGULAR MOMENTUM

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      ☐ as suggested by the applicant.
      ☒ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

REC'D JUN 30 2015

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/19177

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G01N 24/08, 24/10, 24/12 (2015.01)
CPC - G01N 24/006, 24/082, 24/10
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): G01N 24/00, 24/08, 24/10, 24/12 (2015.01)
CPC: G01N 24/006, 24/082, 24/10, 24/12; USPC: 324/300, 304, 306, 307

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google; Google Scholar; ProQuest; KEYWORDS: measure concentration material sample signal generation circuitry orbital angular momentum detector light beam predetermined value amplifying circuitry

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0327868 A1 (ALBU, L. et al.) December 30, 2010; claim 1	1-31
A	US 2002/0164806 A1 (COLLINS, M.) November 7, 2002; paragraph [0022]; claim 1	1-31
A	US 2008/0037004 A1 (SHAMIR, J. et al.) February 14, 2008; abstract; claim 1; paragraph [0074]	1-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2015 (17.05.2015)	25 JUN 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

REC'D JUN 30 2015

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: Brian D. Walker
Howison & Arnott, L.L.P.
P.O. Box 741715
Dallas, TX 75374-1715
United States of America

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing (*day/month/year*) 25 JUN 2015

Applicant's or agent's file reference		FOR FURTHER ACTION
NXGN-32526		See paragraph 2 below
International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/US15/19177	06 March 2015 (06.03.2015)	12 March 2014 (12.03.2014)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - G01N 24/08, 24/10, 24/12 (2015.01)
CPC - G01N 24/006, 24/082, 24/10

Applicant Solyman Ashrafi

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	17 May 2015 (17.05.2015)	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/19177

Box No. I Basis of this opinion

1. With regard to the language, this opinion has been established on the basis of:
   - [x] the international application in the language in which it was filed.
   - [ ] a translation of the international application into ______________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. [ ] With regard to any nucleotide and/or amino acid sequence disclosed in the international application, this opinion has been established on the basis of a sequence listing:
   a. [ ] forming part of the international application as filed:
      - [ ] in the form of an Annex C/ST.25 text file.
      - [ ] on paper or in the form of an image file.

   b. [ ] furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. [ ] furnished subsequent to the international filing date for the purposes of international search only:
      - [ ] in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).
      - [ ] on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/19177

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-31	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	1-31	YES
	Claims	NONE	NO
Industrial applicability (IA)	Claims	1-31	YES
	Claims	NONE	NO

2. Citations and explanations:

Claim 1 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest an apparatus for measuring the concentration of a material within a sample, comprising: signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample; a detector for receiving the first signal after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. US 2010/0327866 A1 to ALBU, L. et al. (hereinafter "Albu") discloses an apparatus for measuring a material within a sample (a free induction decay signal is detected for extracting characteristics of a sample therefrom; claim 1 of Albu), comprising: signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample (a light source produces light which has orbital angular momentum applied to it, where a sample is then illuminated with light from light source; claim 1 of Albu); a detector for receiving the first signal after it passes through the sample (a free induction decay signal is detected via detection of interaction between incident light and sample; claim 1 of Albu). However, while Albu discloses broadly measuring characteristics of a sample via detection of interaction between light and sample, Albu fails to disclose an apparatus for measuring the concentration of a material within a sample; determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. US 2002/0184606 A1 to COLLINS, M. (hereinafter "Collins") discloses an apparatus for measuring the concentration of a material within a sample (rapidly and accurately determining the fat and oil content of a sample; claim 1 of Collins), comprising: signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample (RF magnetic field is produced carrying angular momentum and is applied to a sample; paragraph [0022]; claim 1 of Collins); a detector for receiving the first signal after it passes through the sample (NMR response from applied RF magnetic field to sample is measured; claim 1 of Collins). However, Collins fails to disclose determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. US 2008/0037004 A1 to SHAMIR, J. et al. (hereinafter "Shamir") discloses an apparatus for measuring the concentration of a material within a sample (method of particle size and concentration measurement within a sample; abstract), comprising: signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample (laser beam having angular momentum is produced and applied to a sample; paragraph [0065]; claim 1 of Shamir); a detector for receiving the first signal after it passes through the sample (detection of scattered light from incident laser beam; paragraph [0074]). However, Shamir fails to disclose determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. Further, it would not have been obvious at the time of invention to include the elements of the instant claim in the manner recited by Applicant.

Claims 2-14 meet the criteria set out in PCT Article 33(2)-(3), because they depend from claim 1.

-***-Continued Within the Next Supplemental Box-***-

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US15/19177

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

-***-Continued from Box V: Citations and Explanations-***-
Claim 15 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest an apparatus for measuring the concentration of a material within a sample, comprising: an emitting source for emitting a first light beam comprising a plurality of plane waves; orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam; amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith; a detector for receiving the first light after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith. Albu discloses an apparatus for measuring a material within a sample (a free induction decay signal is detected for extracting characteristics of a sample therefrom; claim 1 of Albu), comprising: an emitting source for emitting a first light beam comprising a plurality of plane waves (a light source produces light which has orbital angular momentum applied to it, where a sample is then illuminated with light from light source; claim 1 of Albu); a detector for receiving the first signal after it passes through the sample (a free induction decay signal is detected via detection of interaction between incident light and sample; claim 1 of Albu). However, while Albu discloses broadly measuring characteristics of a sample via detection of interaction between light and sample, Albu fails to disclose an apparatus for measuring the concentration of a material within a sample; orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam; amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith. Collins discloses an apparatus for measuring the concentration of a material within a sample (rapidly and accurately determining the fat and oil content of a sample; claim 1 of Collins), comprising: an emitting source for emitting a first light beam comprising a plurality of plane waves (RF magnetic field is produced carrying angular momentum and is applied to a sample; paragraph [0022]; claim 1 of Collins); a detector for receiving the first signal after it passes through the sample (NMR response from applied RF magnetic field to sample is measured; claim 1 of Collins). However, Collins fails to disclose orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam; amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith. Shamir discloses an apparatus for measuring the concentration of a material within a sample (method of particle size and concentration measurement within a sample; abstract), comprising: an emitting source for emitting a first light beam comprising a plurality of plane waves (laser beam having angular momentum is produced and applied to a sample; paragraph [0068]; claim 1 of Shamir); a detector for receiving the first signal after it passes through the sample (detection of scattered light from incident laser beam; paragraph [0074]). However, Shamir fails to disclose orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam; amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith. Further, it would not have been obvious at the time of invention to include the elements of the instant claim in the manner recited by Applicant.

Claims 16-24 meet the criteria set out in PCT Article 33(2)-(3), because they depend from claim 15.
Claim 25 meets the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest a method for measuring the concentration of a material within a sample, comprising: generating a first signal having at least one orbital angular momentum applied thereto; applying the first signal to the sample; receiving the first signal after it passes through the sample; detecting a value of the orbital angular momentum within the received first signal; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. Albu discloses a method for measuring a material within a sample (a free induction decay signal is detected for extracting characteristics of a sample therefrom; claim 1 of Albu), comprising: generating a first signal having at least one orbital angular momentum applied thereto; applying the first signal to the sample (a light source produces light which has orbital angular momentum applied to it, where a sample is then illuminated with light from light source; claim 1 of Albu). However, while Albu discloses broadly measuring characteristics of a sample via detection of interaction between light and sample, Albu fails to disclose a method for measuring the concentration of a material within a sample; detecting a value of the orbital angular momentum within the received first signal; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. Collins discloses a method for measuring the concentration of a material within a sample (rapidly and accurately determining the fat and oil content of a sample; claim 1 of Collins), comprising: generating a first signal having at least one orbital angular momentum applied thereto; applying the first signal to the sample (RF magnetic field is produced carrying angular momentum and is applied to a sample; paragraph [0022]; claim 1 of Collins). However, Collins fails to disclose detecting a value of the orbital angular momentum within the received first signal; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. Shamir discloses a method for measuring the concentration of a material within a sample (method of particle size and concentration measurement within a sample; abstract), comprising: generating a first signal having at least one orbital angular momentum applied thereto; applying the first signal to the sample (laser beam having angular momentum is produced and applied to a sample; paragraph [0068]; claim 1 of Shamir). However, Shamir fails to disclose detecting a value of the orbital angular momentum within the received first signal; and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample. Further, it would not have been obvious at the time of invention to include the elements of the instant claim in the manner recited by Applicant.

Claims 26-31 meet the criteria set out in PCT Article 33(2)-(3), because they depend from claim 25.

Claims 1-31 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

Electronic Acknowledgement Receipt

EFS ID:	22787285
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	30-JUN-2015
Filing Date:	24-JUL-2014
Time Stamp:	17:36:59
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	NXG32196IDS.pdf	611885 ed35e9752333741aa83a9ff458e565232ebd2f6b	no	4

Warnings:

Information:

2	Non Patent Literature	NXG32196ISRWO2.pdf	5732909 4d47076a92d2ddc6c3eec1bcb95b053d9b5b9cf8	no	8

Warnings:

Information:

Total Files Size (in bytes):	6344794

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	SOLYMAN, Ashrafi
Serial No.:	14/339,836
Confirmation No.:	3583
Filed:	July 24, 2014
Group:	2886
Examiner:	STOCK, Gordon J. Jr.
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop AMENDMENT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

AMENDMENT AND RESPONSE TO OFFICE ACTION

This communication is responsive to the Examiner's Office Action dated April 17, 2015. Reconsideration is respectfully requested.

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims beginning on page 6 of this paper.

Remarks/Arguments begin on page 12 of this paper.

In the Specification

Please replace paragraph [0060] with the following amended paragraph:

[0060] In the plane wave situation, illustrated in Fig. 7, when only the spin vector of the plane wave is altered, the transmitted signal may take on one of three configurations. When the spin vectors are in the same direction, a linear signal is provided as illustrated generally at 704. It should be noted that while 704 illustrates the spin vectors being altered only in the x direction to provide a linear signal, the spin vectors can also be altered in the y direction to provide a linear signal that appears similar to that illustrated at 704 but in a perpendicular orientation to the signal illustrated at 704. In linear polarization such as that illustrated at [[704]] <u>710</u>, the vectors for the signal are in the same direction and have a same magnitude.

Please replace paragraph [0061] with the following amended paragraph:

[0061] Within a circular polarization as illustrated at 706, the signal vectors 712 are 90 degrees to each other but have the same magnitude. This causes the signal to propagate as illustrated at 706 and provide the circular polarization 714 illustrated in Fig. 7. Within an elliptical polarization 708, the signal vectors 716 are also 90 degrees to each other but have differing magnitudes. This provides the elliptical polarizations 718 illustrated for the signal propagation [[408]] <u>708</u>. For the plane waves illustrated in Fig. 7A, the Poynting vector is maintained in a constant direction for the various signal configurations illustrated therein.

Please replace paragraph [0065] with the following amended paragraph:

[0065] Referring now to Fig. 11, there is illustrated a block diagram of the apparatus for providing concentration measurements of various materials responsive to the orbital angular momentum detected by the apparatus in accordance with the principles described herein above. An emitter 1102 transmits wave energy 1104 that comprises a series of plane waves. The emitter 1102 may provide a series of plane waves such as those describes previously with respect to Fig. 3. The orbital angular momentum generation circuitry 1106 generates a series of waves having an orbital angular momentum applied to the waves 1108 in a known manner. The orbital angular momentum generation circuitry [[706]] <u>1106</u> may utilize holograms or some other type of orbital angular momentum generation process as will be more fully described herein below. The orbital angular momentum twisted waves [[708]] <u>1108</u> are applied to a sample material 1110 under test. The sample material 1110 contains a material, and the concentration of the material is determined via a concentration detection apparatus in accordance with the process described herein.

Please replace paragraph [0066] with the following amended paragraph:

[0066] A series of output waves 1112 from the sample material [[710]] <u>1110</u> exit the sample and have a particular orbital angular momentum imparted thereto as a result of the concentration of the particular material under study within the sample material [[710]] <u>1110</u>. The output waves 1112 are applied to a matching module 1114 that includes a mapping aperture for amplifying a particular orbital angular momentum generated by the specific material under study. The matching module 1114 will amplify the orbital angular momentums associated with the particular concentration of material that is detected by the apparatus. The amplified OAM waves 1116 are provided to a detector 1118. The detector 1118 detects OAM waves relating to the concentration of a material within the sample and provides this concentration information to a user ~~interface~~ <u>interface/processor</u> 1120. The user ~~interface~~ <u>interface/processor</u> 1120 interprets the concentration information and provides relevant concentration indication to an individual or a recording device.

Please replace paragraph [0077] with the following amended paragraph:

[0077] This may be achieved in any number of fashions. In one embodiment, illustrated in Fig. 18, the tunable orbital angular momentum generator ~~1002~~ <u>1702</u> may include multiple hologram images 1802 within the tunable OAM generator 1702. The tuning parameters 1704 enable selection of one of the holographic images 1806 in order to provide the desired OAM wave twisted output signal 1706 through a selector circuit 1804. Alternatively, the gridded holographic image such as that described in Fig. 16 may be utilized and the beam shined on a portion of the gridded image to provide the desired OAM output. The tunable OAM generator 1702 has the advantage of being controlled to apply a particular orbital angular momentum to the output orbital angular momentum wave 1706 depending upon the provided input parameter 1704. This enables the concentrations of a variety of different materials to be monitored, or alternatively, for various different concentrations of the same material to be monitored.

Please replace paragraph [0090] with the following amended paragraph:

[0090] Fig. 27 illustrates the difference in impact between spin angular polarization and orbital angular polarization due to passing of a beam of light through a sample ~~2702~~ 2702a/2702b. In sample 2702a, there is illustrated the manner in which spin angular polarization is altered responsive to a beam passing through the sample 2702a. The polarization of a wave having a particular spin angular momentum 2704 passing through the sample 2702a will rotate from a position 2704 to a new position 2706. The rotation occurs within the same plane of polarization. In a similar manner, as illustrated with respect to sample 2702b, an image appears as illustrated generally at 2708 before it passes through the sample 2702b. Upon passing the image through the sample 2702b the image will rotate from the position illustrated at 2710 to a rotated position illustrated at 2712. The amount of rotation is dependent upon the level of concentration of the material being detected within the sample 2702. Thus, as can be seen with respect to the sample 2702 of Fig. 27, both the spin angular polarization and the orbital angular momentum will change based upon the concentration of materials within the sample 2702. By measuring the amount of rotation of the image caused by the change in orbital angular momentum, the concentration of a particular material may be determined.

Please replace paragraph [0093] with the following amended paragraph:

[0093] The above equation may be utilized within the user interface more particularly illustrated in Fig. 29. The user ~~interface~~ interface/processor 1120 processes the OAM measurements 2502 using an internal algorithm ~~2902~~ 2912 that provides for the generation of concentration information 2904 that may be displayed in some type of user display. The algorithm would in one embodiment utilize that equation described herein above in order to determine the concentration based upon the length of a sample and the detected variation in orbital angular momentum. The process for calculating the concentration may be done in a laboratory setting where the information is transmitted wirelessly to the lab or the user interface can be associated with a wearable device connected to a meter or cell phone running an application on the cell phone connected via a local area network or wide area network to a personal or public cloud. The user interface ~~2920~~ 1120 of the device can either have a wired or wireless connection utilizing Bluetooth, ZigBee or other wireless protocols.

Please replace paragraph [0096] with the following amended paragraph:

[0096] Thus, the user interface 1120 in addition to including the algorithm ~~2902~~ 2912 for determining concentration information 2904 will include a wireless interface 2906 enabling the collected information to be wirelessly transmitted over the public or private cloud as described with respect to Fig. 30. Alternatively, the user interface may comprise a storage database 2908 enabling the collected information to be locally stored rather than transmitted wirelessly to a remote location.

Please replace paragraph [0097] with the following amended paragraph:

[0097] Referring now to Fig. 31, there is illustrated a particular example of a block diagram of a particular apparatus for measuring the concentration of glucose using the orbital angular momentum of photons of a light beam shined through a glucose sample. The process creates a second-order harmonic with helical light beam using a non-linear crystal such as that described with respect to Fig. 25. The emission module ~~2402~~ 3102 generates plain electromagnetic waves that are provided to an OAM generation module 3104. The OAM generation module 3104 generates light waves having an orbital angular momentum applied thereto using holograms to create a wave having an electromagnetic vortex. The OAM twisted waves are applied to the sample 3106 that is under study in order to detect the glucose concentration within a sample of blood. A rotated signature exits the sample 3106 in the manner described previously with respect to Figs. 27-28 and is provided to the matching module 3108. The matching module 3108 will amplify the orbital angular momentum such that the observed concentrations may be calculated from the orbital momentum of the signature of the glucose. These amplified signals are provided to detection module 3110 which measures the radius of the beam w(z) or the rotation of the image provided to the sample via the light beam. This detected information is provided to the user interface that include a sensor interface wired or wireless Bluetooth or ZigBee connection to enable the provision of the material to a reading meter or a user phone for the display of concentration information with respect to the sample.

In the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Currently Amended) An apparatus ~~for measuring the~~ that measures a concentration of a material within a sample, comprising:

signal generation circuitry ~~for generating~~ that generates a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample;

a detector ~~for receiving~~ that receives the first signal after [[it]] the first signal passes through the sample and ~~determining~~ that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

2. (Currently Amended) The apparatus of Claim 1, wherein the signal generation circuitry further comprises:

an emitting source ~~for emitting~~ that emits the first signal comprising a plurality of plane waves;

orbital angular momentum generation circuitry ~~for receiving~~ that receives the first signal and ~~applying~~ that applies the at least one orbital angular momentum to the plane waves of the first signal.

3. (Currently Amended) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry ~~for applying~~ that applies a fixed orbital angular momentum to the first signal.

4. (Currently Amended) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry further includes a hologram ~~for applying~~ that applies the at least one orbital angular momentum to the plane waves of the first signal.

5. (Original) The apparatus of Claim 4, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

6. (Currently Amended) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry ~~for applying~~ that applies a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

7. (Currently Amended) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter ~~for converting~~ that converts the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter ~~for converting~~ that converts the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

8. (Currently Amended) The apparatus of Claim 1 further including amplifying circuitry ~~for receiving~~ that receives the first signal after the first signal passes through the sample and ~~amplifying~~ that amplifies a first portion of the first signal having the detected value of the orbital angular momentum associated therewith.

9. (Currently Amended) The apparatus of Claim 8, wherein the amplifying circuitry further includes a hologram ~~for amplifying~~ that amplifies the orbital angular ~~momentums~~ momentum associated with the concentration of the material in the sample.

10. (Currently Amended) The apparatus of Claim 1, wherein the detector further comprises:

an orbital angular momentum detector ~~for determining~~ that determines the detected value of the orbital angular momentum within the first signal from the sample; and

a processor ~~for determining a~~ that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

11. (Currently Amended) The apparatus of Claim 10 further including a user interface associated with the processor comprising:

a set of computer instructions ~~for configuring~~ that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database ~~for storing~~ that stores concentration data from the ~~concentrations~~ concentration determined by the processor.

12. (Currently Amended) The apparatus of Claim 11, wherein the user interface further includes a wireless interface ~~for communicating~~ that communicates the concentration data to a remote location.

13. (Currently Amended) The apparatus of Claim 1, wherein differing values of the ~~detected value of the~~ concentration indicate different concentrations of the material within the sample.

14. (Original) The apparatus of Claim 1, wherein the first signal comprises a light beam.

15. (Currently Amended) An apparatus ~~for measuring the~~ that measures a concentration of a material within a sample, comprising:

an emitting source ~~for emitting~~ that emits a first light beam comprising a plurality of plane waves;

orbital angular momentum generation circuitry ~~for receiving~~ that receives the first light beam and ~~applying~~ that applies at least one orbital angular momentum to the plane waves of the first light beam;

amplifying circuitry ~~for receiving~~ that receives the first light beam after the first light beam passes through the sample and ~~amplifying~~ that amplifies a first portion of the first light beam having a predetermined value of the orbital angular momentum associated therewith;

a detector ~~for receiving~~ that receives the first light beam after [[it]] the first light beam passes through the sample and ~~determining~~ that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith.

16. (Currently Amended) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry ~~for applying~~ that applies a fixed orbital angular momentum to the first ~~signal~~ light beam.

17. (Currently Amended) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plane waves of the first ~~signal~~ light beam.

18. (Original) The apparatus of Claim 17, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

19. (Currently Amended) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry ~~for applying~~ that applies a selected orbital angular momentum to the first ~~signal~~ light beam responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

20. (Currently Amended) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first ~~signal~~ light beam from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first ~~signal~~ light beam in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

21. (Currently Amended) The apparatus of Claim 15 further comprising a processor ~~for determining a~~ that determines the concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

22. (Currently Amended) The apparatus of Claim 21 further including a user interface associated with the processor comprising:

a set of computer instructions ~~for configuring~~ that configures the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database ~~for storing~~ that stores concentration data from the concentrations determined by the processor.

23. (Currently Amended) The apparatus of Claim 22, wherein the user interface further includes a wireless interface ~~for communicating~~ that communicates the concentration data to a remote location.

24. (Currently Amended) The apparatus of Claim 15, wherein differing values of ~~the detected value of~~ the concentration indicate different concentrations of the material within the sample.

25. (Currently Amended) A method for measuring [[the]] a concentration of a material within a sample, comprising:

generating a first signal having at least one orbital angular momentum applied thereto;

applying the first signal to the sample;

receiving the first signal after [[it]] the first signal passes through the sample;

detecting a value of the orbital angular momentum within the received first signal; and

determining the concentration of the material within the sample based on [[a]] the detected value of orbital angular momentum with the first signal received from the sample.

26. (Original) The method of Claim 25, wherein the step of generating further comprises:

emitting the first signal comprising a plurality of plane waves;

receiving the first signal; and

applying the at least one orbital angular momentum to the plane waves of the first signal.

27. (Original) The method of Claim 26, wherein the step of applying further comprises applying a fixed orbital angular momentum to the first signal.

28. (Original) The method of Claim 26, wherein the step of applying further comprises applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

29. (Currently Amended) The method of Claim 25 further including:

receiving the first signal after the first signal passes through the sample; and

amplifying a first portion of the <u>first</u> signal having the detected value of the orbital angular momentum associated therewith.

30. (Currently Amended) The method of Claim 25 further including storing concentration data from the ~~determined~~ concentrations <u>that are determined</u>.

31. (Canceled)

REMARKS

Applicant has carefully reviewed the Office Action dated April 17, 2015. Applicant has amended Claims 1-4, 6-17, 19-25 and 29-30 to more clearly point out the present inventive concept. Reconsideration and favorable action is respectfully requested.

In response to the various comments within the Official Action related to the Examiner's Comment section, the Applicant has amended the claims in the manner referenced by the Official Action that the claims were interpreted. Applicant believes that this addresses all of the issues raised by the Examiner's Comment section. Should additional amendments be necessary, Applicant would be willing to discuss further amendments to the claims in order to overcome any potential rejections.

Various objections to the claims and the specification were made in the Official Action. Applicant has amended the specification and claims, where necessary, to overcome the objections. In cases where the Applicant disagrees with the objection, the Applicant provides comments below. With respect to the objection regarding the orbital angular momentum detector of Claim 10 not being shown in the drawings, Applicant respectfully points the Examiner's attention to Figs. 11, 26 and 31 and reference numbers 1118 and 3110, respectively, and the discussions of these within the figures.

Claims 8, 10, 15, 21, 25 and 29 were objected to for various informalities. Applicant has amended these claims, where necessary, to overcome the objections. Withdrawal of the objections is respectfully requested.

Claims 1-30 were rejected under 35 U.S.C. § 112(b), second paragraph as being indefinite for failing to particularly point out and distinctly claim the subject matter of the invention. Applicant has amended the claims, where necessary, to more particularly point out and distinctly claim the subject matter of the invention. Withdrawal of the rejections is respectfully request.

In view of the foregoing amendments and comments and the indication of allowable subject matter for Claims 1-30 if the § 112(b) issues were overcome, Applicant respectfully submits that all pending claims are distinguishable from the art of record and a Notice of Allowance is respectfully requested.

Applicant has now made an earnest attempt in order to place this case in condition for allowance. For the reasons stated above, Applicant respectfully requests full allowance of the claims as amended. Please charge any additional fees or deficiencies in fees or credit any overpayment to Deposit Account No. 20-0780/NXGN-32196 of HOWISON & ARNOTT, L.L.P.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
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May 13, 2015

Electronic Acknowledgement Receipt

EFS ID:	22338134
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	13-MAY-2015
Filing Date:	24-JUL-2014
Time Stamp:	16:53:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		NXG32196AMD.pdf	115418 2c2cbb5aa088da4eff89460a0d01fab233e69175	yes	13

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Specification	2	5
	Claims	6	11
	Applicant Arguments/Remarks Made in an Amendment	12	13
Warnings:			
Information:			
	Total Files Size (in bytes):	115418	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/339,836	Filing Date 07/24/2014	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter “0” in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	05/13/2015	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 30	Minus	** 31	= 0	x $40 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	x $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write “0” in column 3.
** If the “Highest Number Previously Paid For” IN THIS SPACE is less than 20, enter “20”.
*** If the “Highest Number Previously Paid For” IN THIS SPACE is less than 3, enter “3”.
The “Highest Number Previously Paid For” (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/MARGARET BYARS/

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 04/17/2015

HOWISON & ARNOTT, L.L.P
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DALLAS, TX 75374-1715

EXAMINER	
STOCK JR, GORDON J	

ART UNIT	PAPER NUMBER
2886	

NOTIFICATION DATE	DELIVERY MODE
04/17/2015	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

patents@dalpat.com

Office Action Summary	Application No. 14/339,836	Applicant(s) ASHRAFI ET AL.	
	Examiner GORDON J. STOCK JR	Art Unit 2886	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *7/24/14;10/1/14*.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-30* is/are pending in the application.
5a) Of the above claim(s) _____ is/are withdrawn from consideration.
6)☐ Claim(s) _____ is/are allowed.
7)☒ Claim(s) *1-30* is/are rejected.
8)☐ Claim(s) _____ is/are objected to.
9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☒ The specification is objected to by the Examiner.
11)☒ The drawing(s) filed on *7/24/14* is/are: a)☐ accepted or b)☒ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
Certified copies:
a)☐ All b)☐ Some** c)☐ None of the:
1.☐ Certified copies of the priority documents have been received.
2.☐ Certified copies of the priority documents have been received in Application No. _____.
3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.
3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
4) ☐ Other: _____.

DETAILED ACTION

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

EXAMINER'S COMMENT

2. As for **claim 1**, 'for measuring (line 1);'for generating … applying (lines 3-4);' and 'for receiving … determining (lines 5-6)' all appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 1** on its merits, the Examiner will be interpreting **claim 1** as reading as having the recitations positively cited in the form of -that measures; that generates … that applies; that receives … that determines-.

As for **claim 2**, 'for emitting (line 3)' and 'for receiving … applying (lines 5-6)' appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 2** on its merits, the Examiner will be interpreting **claim 2** as reading as having the recitations positively cited in the form of –that emits; that receives … that applies

As for **claim 3**, 'for applying (line 2)' appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 3** on its merits, the Examiner will be interpreting **claim 3** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 4** ‘for applying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 4** on its merits, the Examiner will be interpreting **claim 4** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 6**, ‘for applying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 6** on its merits, the Examiner will be interpreting **claim 6** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 7**, ‘for converting (line 3)’ and ‘for converting (line 5) appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 7** on its merits, the Examiner will be interpreting **claim 7** as reading as having the recitation positively cited in the form of -that converts (line 3)- and -that converts (line 5).

As for **claim 8**, ‘for receiving …amplifying (lines 1-2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 8** on its merits, the Examiner will be interpreting **claim 8** as reading as having the recitation positively cited in the form of -that receives (line 1) … that amplifies (line 2)-.

As for **claim 9**, ‘for amplifying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 9** on its merits, the Examiner will be interpreting **claim 9** as reading as having the recitation positively cited in the form of -that amplifies-.

As for **claim 10**, ‘for determining (line 2)’ and ‘for determining (line 4) appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 10** on its merits, the Examiner will be interpreting **claim 10** as reading as having the recitations positively cited in the form of -that determines (line 2)- and –that determines (line 4)-.

As for **claim 11**, ‘for configuring (line 3)’ and ’for storing (line 6) appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 11** on its merits, the Examiner will be interpreting **claim 11** as reading as having the recitations positively cited in the form of -that configures- and –that stores-

As for **claim 12** ‘for communicating (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 12** on its merits, the Examiner will be interpreting **claim 12** as reading as having the recitation positively cited in the form of -that communicates-.

As for **claim 15**, ‘for measuring (line 1);’’for emitting (line 3);’ ‘for receiving … applying (lines 5-6);’ ‘for receiving ... amplifying (lines 8-9);' ‘for receiving … determining (lines 11-12)’ all appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 15** on its merits, the Examiner will be interpreting **claim 15** as reading as having the recitations positively cited in the form of –that measures-; -that emits-; -that receives (line 5)-; -that applies (line 6)-; -that receives (line 8)-; -that amplifies (line 9)-; -that receives (line 11)-; and -that determines (line 12)-.

As for **claim 16**, ‘for applying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 16** on its merits, the Examiner will be interpreting **claim 16** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 17** ‘for applying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 17** on its merits, the Examiner will be interpreting **claim 17** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 19**, ‘for applying (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 19** on its merits, the Examiner will be interpreting **claim 19** as reading as having the recitation positively cited in the form of -that applies-.

As for **claim 20**, ‘for converting (line 3)’ and ‘for converting (line 5) appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 20** on its merits, the Examiner will be interpreting **claim 20** as reading as having the recitation positively cited in the form of -that converts (line 3)- and -that converts (line 5).

As for **claim 21**, ‘for determining (line 1)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 21** on its merits, the Examiner will be interpreting **claim 21** as reading as having the recitation positively cited in the form of –that determines-.

As for **claim 22**, ‘for configuring (line 3)’ and ’for storing (line 6) appear to be intended use recitations. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 22** on its merits, the Examiner will be interpreting **claim 22** as reading as having the recitations positively cited in the form of -that configures- and –that stores-

As for **claim 23** ‘for communicating (line 2)’ appears to be an intended use recitation. It has been held that a recitation with respect to the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior art apparatus satisfying the claimed structural limitations. Ex Parte Masham, 2 USPQ F.2d 1647 (1987).

When treating **claim 23** on its merits, the Examiner will be interpreting **claim 23** as reading as having the recitation positively cited in the form of -that communicates-.

Drawings and Specification

3. The drawings are objected to under 37 CFR 1.83(a). The drawings must show every feature of the invention specified in the claims. Therefore, the ‘orbital angular momentum detector (**claim 10**);’ 'processor **(claim 10**);' and 'processor (**claim 21**)' must be shown or the feature(s) canceled from the claim(s). No new matter should be entered.

Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. The figure or figure number of an amended drawing should not be labeled as “amended.” If a drawing figure is to be canceled, the appropriate figure must be removed from the replacement sheet, and where necessary, the remaining figures must be renumbered and appropriate changes made to the brief description of the several views of the drawings for consistency. Additional replacement sheets may be necessary to show the renumbering of the remaining figures. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either “Replacement Sheet” or “New Sheet” pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

4. The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they do not include the following reference sign(s) mentioned in the description: ‘204' of Fig. 2; ‘1402’ of paragraph 0074; '1802' of Fig. 18; ‘2702’ of Fig. 27; Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either “Replacement Sheet” or “New Sheet” pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

5. Fig. 18 is objected to for the following: it appears from applicant's disclosure that the box encompassing 1804 and 1806 should be labelled -1702-. Correction is required.

6. The Specification is objected to for the following: on line 7 of paragraph 0060 ‘such as that illustrated at 704' should read -such as that illustrated at 710-. Correction is required.

7. The Specification is objected to for the following: on line 6 of paragraph 0061 ‘408' should read -708-. Correction is required.

8. The Specification is objected to for the following: on line 8 of paragraph 0065 ‘706’ should read -1106- and on line 10 ‘708’ should read -1108-. Corrections are required.

9. The Specification is objected to for the following: on lines 1 and 3 of paragraph 0066 '710' should read -1110-. Corrections are required.

10. The Specification is objected to for the following: on line 2 of paragraph 0077 '1002' should read -1702-. Correction is required.

11. The Specification is objected to for the following: on line 3 of paragraph 0093 ‘2902’ should read -2912-. Correction is required.

12. The Specification is objected to for the following: on line 10 of paragraph 0093 ‘2920’ should read -1120-. Correction is required.

13. The Specification is objected to for the following: on line 1 of paragraph 0096 ‘2902’ should read -2912-. Correction is required.

14. The Specification is objected to for the following: on line 5 of paragraph 0097 '2402' should read -3102-. Correction is required.

Claim Objections

15. **Claim 8** is objected to for the following: on line 3 'the signal' should read -the first signal-. Correction is required. **Claim 9** is objected to by virtue of its dependency from **claim 8.**

16. **Claim 10** is objected to for the following: on line 4 ‘a concentration’ should read –the concentration-. Correction is required. **Claims 11-12** are objected to by virtue of their dependency from **claim 10.**

17. **Claim 15** is objected to for the following: on line 9 ‘the light beam' should read –the first light beam-; on line 11 ‘the first light’ should read –the first light beam-; and on line 13 'the light beam‘ should read –the first light beam-. Corrections are required. **Claims 16-24** are objected to by virtue of their dependency from **claim 15**.

18. **Claim 21** is objected to for the following: on lines 1-2 ‘a concentration’ should read –the concentration-. Correction is required. **Claims 22-23** are objected to by virtue of their dependency from **claim 21**.

19. **Claim 25** is objected to for the following: on lines 9-10 'a detected value’ should read –the detected value-. Correction is required. **Claims 26-30** are objected to by virtue of their dependency from **claim 25**.

20. **Claim 29** is objected to for the following: on line 3 ‘the signal’ should read –the first signal-. Correction is required.

Claim Rejections - 35 USC § 112

21. The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

22. **Claims 1-30** are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

As for **claim 1**, on line 1 ‘the concentration’ lacks proper antecedent basis.

As for **claim 1**, on line 5 ‘it’ is indefinite, for it is unclear as to what 'it' refers. When treating the claims further on their merits, the Examiner will be interpreting 'it' as reading as -the first signal-. **Claims 2-14** are rejected by virtue of their dependency from **claim 1**.

As for **claim 9**, on line 2 'the orbital angular momentums' lack proper antecedent basis.

As for **claim 11**, on line 6 ‘the concentrations’ lack proper antecedent basis. **Claim 12** is rejected by virtue of its dependency from **claim 11**.

As for **claim 13**, ‘the detected value of the concentration’ lacks proper antecedent basis.

As for **claim 15**, on line 1 ‘the concentration’ lacks proper antecedent basis.

As for **claim 15**, on line 11 ‘it’ is indefinite, for it is unclear as to what 'it' refers. When treating the claims further on their merits, the Examiner will be interpreting 'it' as reading as -the first light beam-. **Claims 16-24** are rejected by virtue of their dependency from **claim 15**.

As for **claim 16**, on line 3 ‘the first signal’ lacks proper antecedent basis.

As for **claim 17**, on line 3 ‘the first signal’ lacks proper antecedent basis. **Claim 18** is rejected by virtue of its dependency from **claim 17**.

As for **claim 19**, on line 3 ‘the first signal’ lacks proper antecedent basis.

As for **claim 20**, on line 3 ‘the first signal’ lacks proper antecedent basis. The Examiner notes that ‘the first signal’ is located also on line 5 of **claim 20**.

As for **claim 22**, on line 6 ‘the concentrations’ lacks proper antecedent basis. **Claim 23** is rejected by virtue of its dependency from **claim 22**.

As for **claim 24**, ‘the detected value of the concentration’ lacks proper antecedent basis.

As for **claim 25**, on line 1 ‘the concentration' lacks proper antecedent basis.

As for **claim 25**, on line 6 ‘it’ is indefinite, for it is unclear as to what 'it' refers. When treating the claims further on their merits, the Examiner will be interpreting 'it' as reading as -the first signal-. **Claims 26-30** are rejected by virtue of their dependency from **claim 25**.

As for **claim 30**, 'the determined concentrations' lacks proper antecedent basis.

Allowable Subject Matter

23. **Claims 1-30** would be allowable if rewritten or amended to overcome the rejection(s) under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), 2nd paragraph, and objections set forth in this Office action.

As to **claim 1**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample ‘a detector that receives the first signal after the first signal passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample,’ in combination with the rest of the limitations of **claim 1. Claims 2-14** would be allowable by virtue of their dependency from **claim 1.**

As to **claim 15**, the prior art of record, taken alone or in combination, fails to disclose or render obvious an apparatus that measures a concentration of a material within a sample ‘a detector that receives the first light beam after the first light beam passes through the sample and that determines the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the first light beam having the predetermined value of the orbital angular momentum associated therewith,’ in combination with the rest of the limitations of **claim 15. Claims 16-24** would be allowable by virtue of their dependency from **claim 15.**

As to **claim 25**, the prior art of record, taken alone or in combination, fails to disclose or render obvious a method for measuring a concentration of a material within a sample ‘determining the concentration of the material within the sample based on the detected value of orbital angular momentum with the first signal received from the sample,' in combination with the rest of the limitations of **claim 25. Claims 26-30** would be allowable by virtue of their dependency from **claim 25.**

Conclusion

24. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure: please see attached PTO-892.

Fax/Telephone Numbers

If the applicant wishes to send a fax dealing with either a proposed amendment or a discussion with a phone interview, then the fax should:

1) Contain either a statement "DRAFT" or "PROPOSED AMENDMENT" on the fax cover sheet; and

2) Should be unsigned by the attorney or agent.

This will ensure that it will not be entered into the case and will be forwarded to the examiner as quickly as possible.

Papers related to the application may be submitted to Group 2800 by fax transmission. The fax phone number for Patent Technology Center 2800 is 571-273-8300.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Gordon J. Stock, Jr. whose telephone number is (571) 272-2431. The examiner can normally be reached on Monday-Friday, 8:00 a.m. - 6:30 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Tarifur R. Chowdhury, can be reached at 571-272-2287.

Information regarding the status of an application may be obtained from the Patent Application lnformation Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private Pair system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

/GORDON J STOCK JR/

Primary Examiner, Art Unit 2886

Notice of References Cited	Application/Control No. 14/339,836	Applicant(s)/Patent Under Reexamination ASHRAFI ET AL.	
	Examiner GORDON J. STOCK JR	Art Unit 2886	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2014/0353475	12-2014	MEYERS et al.	250/216
*	B	US-2010/0317959	12-2010	Elgort et al.	600/410
*	C	US-2006/0126183	06-2006	Hasman, Erez	359/573
*	D	US-2004/0196465	10-2004	Arnold et al.	356/432
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N	WO 2012172471 A2	12-2012	World Intellect	ALBU L R et al.	
	O	WO 2011028109 A1	03-2011	World Intellect	LUCASSEN G W et al.	
	P	WO 2013179023 A1	12-2013	WIPO	YU et al.	
	Q	WO 2013186648 A2	12-2013	WIPO	ALBU L R et al.	
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Daria et al., "Optical twisters: beams having twists in both phase and amplitude," 2010, Complex Light and Optical Forces IV, edited by Galvez et al., Proc. of SPIE Vol. 7613, pages 761304-1 to 761304-8.
	V	Zhang et al., "High-dimensional orbital angular momentum entanglement concentration based on Laguerre-Gaussian mode selection," 2013, Laser Physics Letters, 10, 5 pages.
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: OPTICAL ANGULAR MOMENTUM INDUCED HYPERPOLARISATION IN INTERVENTIONAL APPLICATIONS

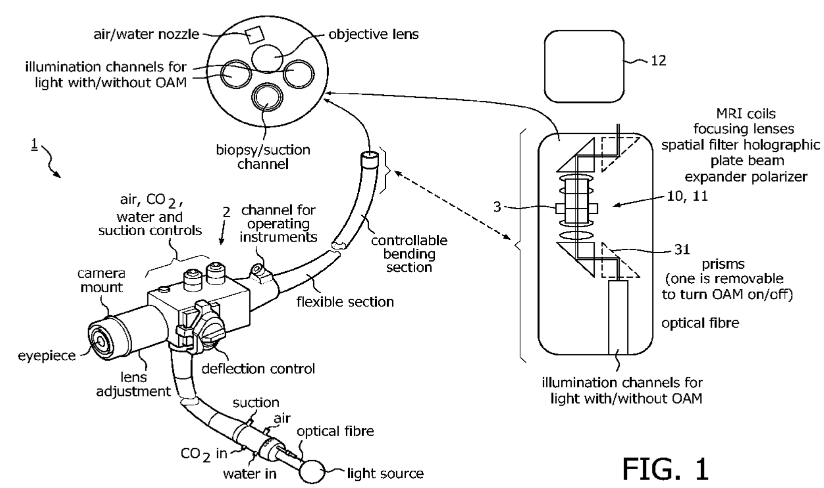

FIG. 1

(57) Abstract: A magnetic resonance spectroscopy assembly includes a magnet to generate a steady magnetic field, an RF transmit/receive antenna to transmit an RF excitation field into an examination region and acquire magnetic resonance signals from the examination region and a magnetic resonance spectrometer coupled to the RF transmit/receive antenna to collect magnetic resonance spectroscopy data from the magnetic resonance signals. An interventional instrument is provided with the assembly. The interventional instruments carries an optical module to generate photonic radiation endowed with orbital optical momentum (OAM).

WO 2012/172471 A2

Optical angular momentum induced hyperpolarisation in interventional applications

FIELD OF THE INVENTION

The invention pertains to a magnetic resonance spectroscopy assembly including a magnet to generate a steady magnetic field and a magnetic resonance spectrometer to collect magnetic resonance spectroscopy data.

BACKGROUND OF THE INVENTION

Such a magnetic resonance assembly is known from the paper The use of 1-H magnetic resonance spectroscopy in inflammatory bowel diseases: distinguishing ulcerative colitis from Crohn's disease. Bezabeh T, Somorjai RL, Smith IC, Nikulin AE, Dolenko B, Bernstein CN**.** 2001, Am J Gastroenterol, Vol. **96**, pp. 442-448.

The known magnetic resonance assembly uses proton(^{1}H) magnetic resonance spectroscopy to detect early inflammation of the gastrointestinal tract of tissue samples of small animals. In particular, the known magnetic resonance assembly is able to differentiate between Crohn’s disease and ulcerative colitis.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a magnetic resonance assembly that allows access to the small intestines to acquire magnetic resonance signals. This object is achieved by the magnetic resonance assembly including

- a magnet to generate a steady magnetic field
- an RF transmit/receive antenna to transmit an RF excitation field into an examination region and acquire magnetic resonance signals from the examination region
- a magnetic resonance spectrometer coupled to the RF transmit/receive antenna to collect magnetic resonance spectroscopy data from the magnetic resonance signals and
- an interventional instrument carrying
- an optical module to generate photonic radiation endowed with orbital optical momentum (OAM).

The photonic radiation endowed with orbital angular momentum couples with molecules and atoms in tissue that is irradiated with the OAM photonic radiation. As a consequence, nuclear magnetic hyperpolarisation is generated in the irradiated tissue. From these hyperpolarised nuclei, magnetic resonance signals can be generated by applying an RF excitation field by the RF T/R antenna and subsequently receiving magnetic resonance signals with the RF T/R antenna. The magnet generates a stationary magnetic field to establish a nuclear processional frequency. Typically, the field strength of the stationary magnetic field is in the range of 0.05-3 T.

These and other aspects of the invention will be further elaborated with reference to the embodiments defined in the dependent Claims.

The optical module to generate the OAM light can be built small enough to fit in the distal end (catheter tip) of an interventional instrument. This is achieved in that a photonic, e.g. optical, source beam is brought to the tip of the device via a fibre optic waveguide. A set of miniature optical elements are arranged at the tip of the fibre, which include: polarisers, beam expander (to enable the beam to fill a forked hologram), a diffractive grating with the forked hologram pattern, a spatial filter (to select the diffraction component with the OAM), and focusing lenses. To ensure the optical system works for high values of the optical angular momentum of the photonic beam (l-values, the size of the spatial filter and the aperture of the other optical elements will need to be increased in accordance with the radius of the photonic beam with OAM increasing with l-value). As a relatively weak stationary magnetic field is needed only to establish the precession frequency of the hyperpolarised nuclei (i.e. hyperpolarised nuclear spin moments), only a simple magnet is sufficient which can be employed outside of the body of the patient to be examined or may even be integrated in the distal end of the interventional instrument. From the acquired magnetic resonance signals magnetic resonance spectral data are derived by the magnetic resonance spectrometer. In this way the invention enables to access the small intestines to perform magnetic resonance spectroscopy locally to gather data which enable a physician to assess the state of health in the small intestines. The generation of the magnetic resonance signals from the OAM photonic beam is known per se from the international application WO 2009/081360-A1.

In an aspect of the invention, the optical module combines the functions of generating OAM photonic radiation to generate hyperpolarisation of the tissue, with optical imaging of that tissue. The optical imaging can also be employed to navigate the interventional instrument through the anatomy, such as the gastrointestinal tract, of the patient to be examined.

In another aspect of the invention, a rotatable or moveable reflector, e.g. a rotatable of movable mirror or prism is employed to switch the optical module between optical imaging and generating OAM photonic radiation. The purpose of the rotatable prisms, or mirrors could be used instead, are so that the photonic beam can be sent out the distal end of the interventional instrument with OAM or without OAM (without OAM it will presumable be used for illuminating the anatomy in front of the interventional instrument to aid visual inspection or video imaging). Preferably, several prisms can be employed, where one of the prisms may have its position physically translated or rotated so that it no longer blocks the photonic beam coming out of the fibre optic wave guide.

In a further embodiment of the invention, the RF T/R antenna is formed by a micro coil that is mounted on the distal end of the interventional instrument. Such a small sized micro coil can be mounted on the distal end of the interventional instrument which is thin enough to be able to navigate through the small intestines. , For example the micro-coil' size may be in the range of 4-20mm diameter, An arrangement of multiple (e.g. three orthogonal) MR coils would be advantageous to ensure that the interventional instrument has sensitivity to the MR signal, which resides in the plane perpendicular to the static magnetic field. In clinical practice, the physical orientation of the endoscope relative to the static field may change during the procedure, so a set of three orthogonal coils will endure that the full MR signal can be reconstruct. Alternatively, the set of coils could be a two orthogonal loop coils, possibly with multiple turns to increase the inductance of the coil, to provide sensitivity to the left/right and to the top/bottom of the tip at the distal end of the interventional instrument, and a solenoid coil to provide sensitivity in front of the tip. In an alternative embodiment of the invention, the RF T/R antenna is formed by an surface coil that can be placed on the patient's body, in close proximity to the region to be examined, and thus close to the position of the distal end of the interventional instrument. Thus, the interventional instrument does not need to carry the RF T/R micro coil and can be smaller so that is navigates through the small intestines easier.

These and other aspects of the invention will be elucidated with reference to the embodiments described hereinafter and with reference to the accompanying drawing wherein

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic representation of the magnetic resonance spectroscopy assembly of the invention and

Fig. 2 shows a schematic representation of details of the optical module of the magnetic resonance assembly of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 1 shows a schematic representation of the magnetic resonance spectroscopy assembly of the invention. In this example the magnetic resonance spectroscopy assembly 1 is integrated in part in the interventional instrument 2. At the distal end of the interventional instrument 2, i.e. the part that is inserted in the body of the patient to be examined, the optical module 3 is mounted with the magnet 10 to generate a steady magnetic field and RF transmit/receive antenna 11 to acquire the magnetic resonance signals generated by the OAM photonic beam. A magnetic resonance spectrometer 12 is coupled to the output of the RF transmit receive antenna. The magnetic resonance spectrometer 12 incorporates a digital signal acquisition system (DAS) and a magnetic resonance spectrometer 12. The DAS receives the signals acquired by the RF coil and converts them into digital signals that are input to the magnetic resonance spectrometer 12 which derives magnetic resonance spectral data from the input digital signals. On the basis of the magnetic resonance spectral data a magnetic resonance spectrum can be displayed. Because the signals acquired by the RF coil originate from hyperpolarised tissue generated by the OAM photonic beam produced by the optical module, the magnetic resonance spectrum represents the compounds in the hyperpolarised tissue. Thus, the magnetic resonance spectrometer 12, incorporated (in part) in the interventional instrument is able to generate a local magnetic resonance spectrum of the tissue at the distal end of the interventional instrument. Thus, the invention achieves to acquire a magnetic resonance spectrum from the internal anatomy of a patient in a minimal invasive manner. In the example shown, the distal end is formed as a controllable bending section that can easily navigate through the patient’s anatomy.

A light source is provided at the proximal end of the interventional instrument and optical fibres are provided to guide the light from the light source to the optical module 3.

Figure 2 shows a schematic representation of details of the optical module of the magnetic resonance assembly of the invention. With reference now to Figure 2, an exemplary arrangement of optical elements is shown for endowing light with OAM. It is to be understood that any electromagnetic radiation can be endowed with OAM, not necessarily only visible light. The described embodiment uses visible light, which interacts with the molecules of interest, and has no damaging effect on living tissue. Light/radiation above or below the visible spectrum, however, is also contemplated. A white light source 22 produces visible white light that is sent to a beam expander 24. In alternate embodiments, the frequency and coherence of the light source can be used to manipulate the signal if chosen carefully, but such precision is not essential. The beam expander includes an entrance collimator 251 for collimating the emitted light into a narrow beam, a concave or dispersing lens 252, a refocusing lens 253, and an exit collimator 254 through which the least dispersed frequencies of light are emitted. In one embodiment, the exit collimator 254 narrows the beam to a 1 mm beam.

After the beam expander 24, the light beam is circularly polarized by a linear polarizer 26 followed by a quarter wave plate 28. The linear polarizer 26 takes unpolarised light and gives it a single linear polarization. The quarter wave plate 28 shifts the phase of the linearly polarized light by ¼ wavelength, circularly polarizing it. Using circularly polarized light is not essential, but it has the added advantage of polarizing electrons.

Next, the circularly polarized light is passed through a phase hologram 30. The phase hologram 30 imparts OAM and spin to an incident beam. The value “l” of the OAM is a parameter dependent on the phase hologram 30. In one embodiment, an OAM value l = 40 is imparted to the incident light, although higher values of l are theoretically possible. The phase hologram 30 is a computer generated element and is physically embodied in a spatial light modulator, such as a liquid crystal on silicon (LCoS) panel, 1280x720 pixels, 20x20 μm2, with a 1 μm cell gap. Alternately, the phase hologram 30 could be embodied in other optics, such as combinations of cylindrical lenses or wave plates. The spatial light modulator has the added advantage of being changeable, even during a scan, with a simple command to the LCoS panel.

Not all of the light that passes through the holographic plate 30 is imparted with OAM and spin. Generally, when electromagnetic waves with the same phase pass through an aperture, it is diffracted and projected into a pattern of concentric circles some distance away from the aperture (Airy pattern). The bright spot (Airy disk) in the middle represents the 0th order diffraction, in this case, that is light with no OAM. Circles adjacent the bright spot represent diffracted beams of different harmonics that carry OAM. This distribution results because the probability of OAM interaction with molecules falls to zero at points far from the centre of the light beam or in the centre of the light beam. The greatest chance for interaction occurs on a radius corresponding to the maximum field distribution, that is, for circles close to the Airy disk. Therefore, the maximum probability of OAM interaction is obtained with a light beam with a radius as close as possible to the Airy disk radius.

With reference to FIGURE 2, a spatial filter 36 is placed after the holographic plate to selectively pass only light with OAM and spin. An example of such a filter is shown in FIGURE 5. The 0th order spot 32 always appears in a predictable spot, and thus can be blocked. As shown, the filter 36 allows light with OAM to pass. Note that the filter 36 also blocks the circles that occur below and to the right of the bright spot 32. Since OAM of the system is conserved, this light has OAM that is equal and opposite to the OAM of the light that the filter 36 allows to pass. It would be counterproductive to let all of the light pass, because the net OAM transferred to the target molecule would be zero. Thus, the filter 36 only allows light having OAM of one polarity to pass.

With continuing reference to FIGURE 2, the diffracted beams carrying OAM are collected using concave mirrors 38 and focused to the region of interest with a fast microscope objective lens 40. The mirrors 38 may not be necessary if coherent light were being used. A faster lens (having a high f-number) is desirable to satisfy the condition of a beam waist as close as possible to the size of the Airy disk. In alternate embodiments, the lens 40 may be replaced or supplemented with an alternative light guide or fibre optics.

CLAIMS:

1. A magnetic resonance spectroscopy assembly including

- a magnet to generate a steady magnetic field
- an RF transmit/receive antenna to transmit an RF excitation field into an examination region and acquire magnetic resonance signals from the examination region
- a magnetic resonance spectrometer coupled to the RF transmit/receive antenna to collect magnetic resonance spectroscopy data from the magnetic resonance signals and
- an interventional instrument carrying an optical module to generate photonic radiation endowed with orbital optical momentum (OAM).

2. A magnetic resonance spectroscopy assembly as claimed in Claim 1, wherein the optical module combines the functions of (i) generation of photonic radiation endowed with orbital momentum and (ii) optical imaging of an field of view around the interventional instrument's distal end.

3. A magnetic resonance spectroscopy assembly as claimed in Claim 2, wherein the optical module includes a rotatable reflector, in particular a rotatable prism between an OAM-orientation and an imaging orientation, the optical module generating OAM endowed photonic radiation with the prism in its OAM-orientation and the optical module imaging its field of view.

4. A magnetic resonance spectroscopy assembly as claimed in Claim 1, wherein the magnet is integrated in the interventional instrument.

5. A magnetic resonance spectroscopy assembly as claimed in Claim 1, wherein a RF receive/transmit coil is integrated in the interventional instrument and the RF receive/transmit coil is coupled to the magnetic resonance spectrometer.

6. A magnetic resonance spectroscopy assembly as claimed in Claim 1, comprising a surface RF receive/transmit coil or coil array which is coupled to the magnetic

resonance spectrometer.

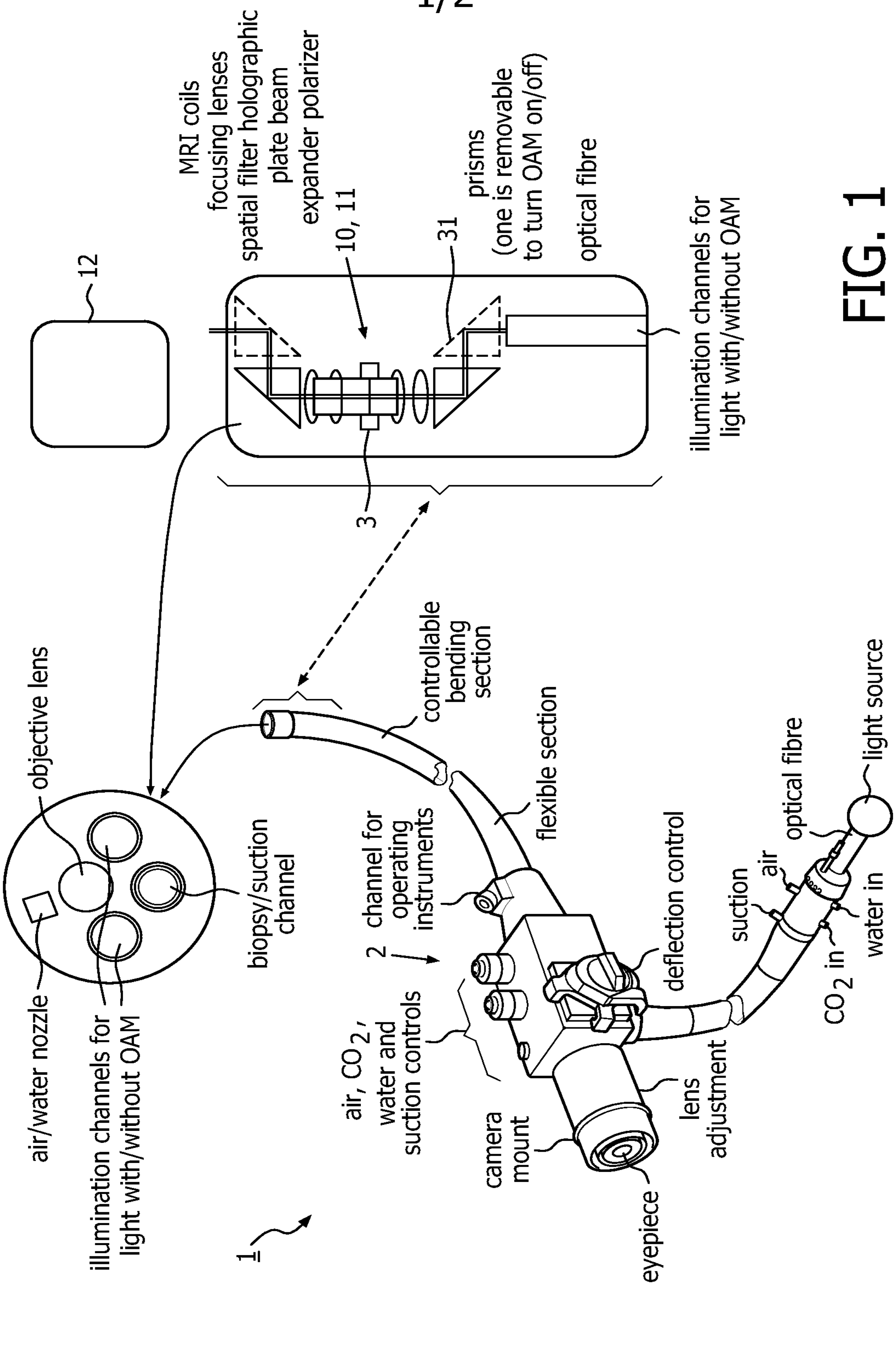
12
MRI coils
focusing lenses
spatial filter holographic
plate beam
expander polarizer
10, 11
31
prisms
(one is removable
to turn OAM on/off)
optical fibre
illumination channels for
light with/without OAM
3
objective lens
air/water nozzle
illumination channels for
light with/without OAM
biopsy/suction
channel
controllable
bending
section
flexible section
2 channel for
operating
instruments
deflection control
air, CO_2,
water and
suction controls
camera
mount
lens
adjustment
eyepiece
suction
air
optical fibre
light source
water in
CO_2 in
1

FIG. 1

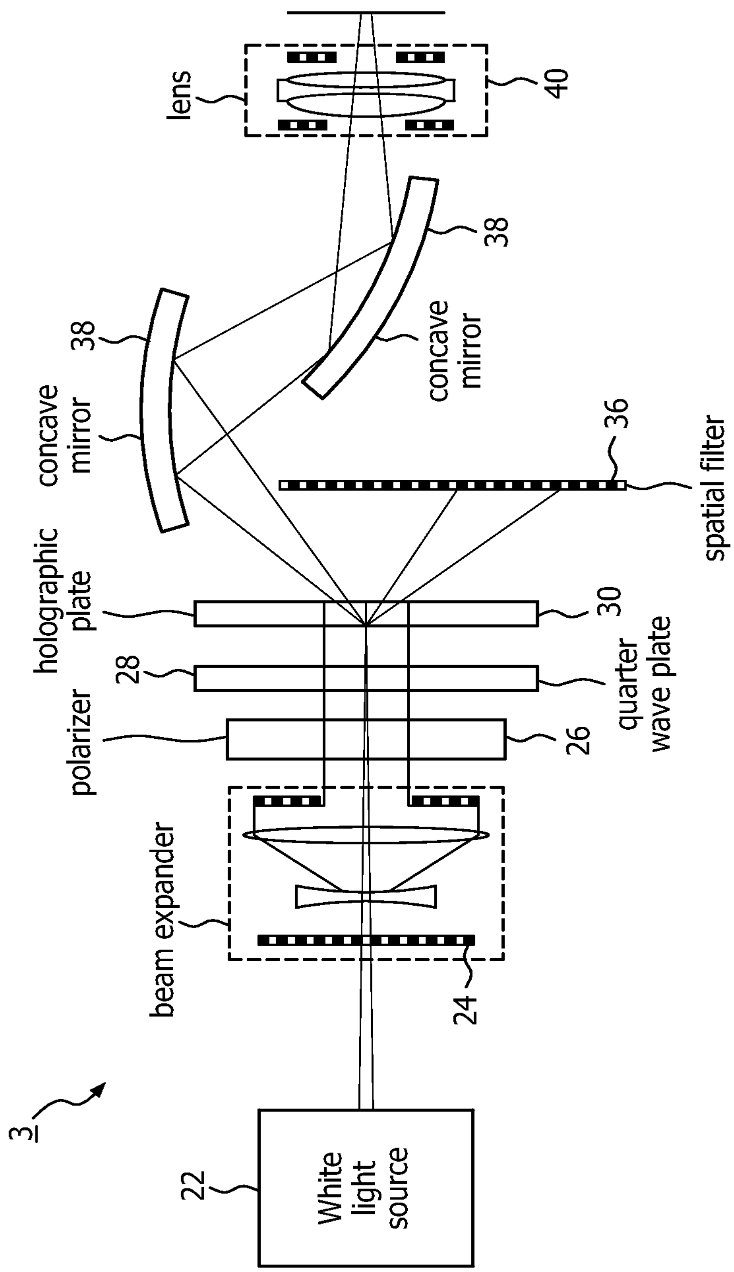
White light source
22
3
beam expander
24
polarizer
26
28
quarter wave plate
holographic plate
30
spatial filter
36
concave mirror
38
38
concave mirror
lens
40

FIG. 2

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(54) Title: ORBITAL ANGULAR MOMENTUM

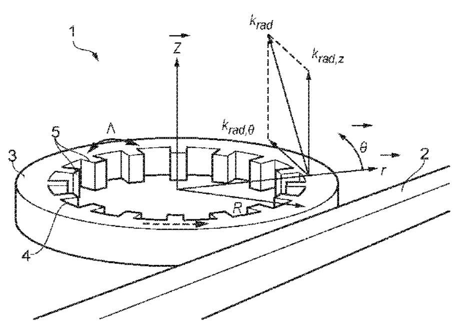

FIG. 1(a)

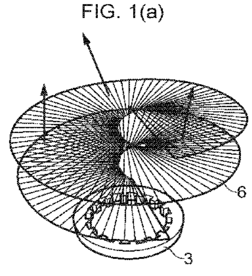

FIG. 1(b)

(57) Abstract: The invention relates to methods, devices, systems and uses of such systems for the generation and detection of electromagnetic fields carrying orbital angular momentum. An electromagnetic wave placed in a resonator having a closed-loop waveguide supporting a guided wave propagating at resonance with angular order, p, and with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements. The angular grating selectively couples the guided wave mode to a free space radiation mode having an OAM quantity, l, and out-of-plane wave vector component, krad,z, and wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied: l= p– mq where: m is the diffraction order of the angular grating, m = 1, 2, 3,...,.

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Orbital Angular Momentum

FIELD OF THE INVENTION

The present invention relates to the generation and detection of electromagnetic fields carrying orbital angular momentum. In particular, the invention relates to methods, devices, systems and uses of such systems for the generation and detection of electromagnetic fields carrying orbital angular momentum.

BACKGROUND OF THE INVENTION

An electromagnetic field, and indeed a single photon, carries energy and momentum. The momentum may comprise two components. Linear momentum is responsible for the observable radiation pressure, whilst angular momentum is the rotation of the wave around its own axis as it propagates forward and is observable as a radiation torque. The angular momentum also comprises two components, namely spin angular momentum and orbital angular momentum (OAM). For a paraxial beam spin angular momentum is associated with polarization, whilst OAM is associated with the spatial field distribution.

Of particular interest is the origin independent internal OAM, which can be associated with a helical wavefront shape. In these helical modes the electromagnetic field has a helical wavefront shape with a central vortex such that the beam phase varies in a corkscrew-like manner in the beam propagation direction.

The OAM carried in such a field enables it to trap and rotate colloid particles and living cells as a so called “optical spanner” for use in biophysics, micromechanics or microfluidics. OAM also has the potential to be used in super-high optical data storage, imaging and metrology, or in free-space communications. More generally OAM has great potential for new and wide-ranging applications in both classic and quantum optics.

Current techniques for generating light carrying OAM using bulk optics, including computer generated holograms, spiral phase plates, q-plates and dove prisms, have limitations in terms of efficiency, cost, flexibility and scalability. These methods do not lend themselves to integration which is essential for widespread and large scale utilization in future applications.

SUMMARY OF THE INVENTION

A first aspect of the invention provides a method of generating electromagnetic radiation carrying orbital angular momentum (OAM). comprising placing an electromagnetic wave in a resonator having a closed-loop waveguide supporting a guided wave propagating at resonance with angular order, p, and with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating selectively couples the guided wave mode to a free space radiation mode having an OAM quantity, l, and out-of-plane wave vector component, $k_{rad\,z}$, and wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied:

$$l = p - m\,q$$

where:

m is the diffraction order of the angular grating, m = 1, 2, 3,...,.

A series of resonances will be formed at wavelengths that are an integer ($p=1,2,3,\ldots$) fraction of the length of the closed-loop. Alternatively at a particular resonance the closed-loop waveguide contains an integer number (p) periods of the electromagnetic wave in a full roundtrip in the resonator (or 2π azimuth angle). p is known as the azimuth angular order of the particular resonance. The total phase shift of the electromagnetic wave when propagating around the closed-loop waveguide is therefore $p\times2\pi$.

The angular grating is defined as a modulation of the waveguide material's geometry or dielectric constant in the azimuth angle direction. The angular grating may be a second order angular Bragg grating. An example of such a grating is shown in figure 1(a). In a typical embodiment the grating elements may be equally spaced in the angular direction, meaning that the phase shift of the electromagnetic wave between each grating element is constant.

The free space radiation mode is a beam of electromagnetic wave that has a propagation direction away from the closed-loop resonator. This beam will have a phase shift in the azimuth angular direction of $l\times2\pi$, and its out-of-plane wave vector, $k_{rad,z}$, points away from the resonator. An electromagnetic wave beam having a phase shift $l\times2\pi$ in the azimuth angular direction carries OAM, the quantity of which is characterised by the value of l.

The possible values of m is dependent upon the material refractive indices and structure of the waveguide and its surrounding media. In a typical embodiment m may take the value of 1 (unity).

The resonator may include a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements such that the free space radiation mode has a plurality of OAM quantities, l. It therefore becomes possible to generate EM radiation having a plurality of l values for a given wavelength.

The guided wave mode has an angular wave vector, k_{guide}, and the free space radiation mode has a wave vector, k_{rad}, with angular component, $k_{rad,\theta}$, and out-of-plane component, $k_{rad,z}$. The wave matching condition $l = p - m\,q$ can therefore be translated to:

$$k_{rad,\theta} = k_{guide} - mq / R = k_{guide} - m2\pi / \Lambda$$

where:

R is the effective radius of the angular grating where it interacts with the guided wave,

$k_{guide} = p / R$, and

Λ is the period of the angular grating at R.

In the case that the closed-loop waveguide resonator itself, or the guided wave in such a resonator, is substantially in a plane, the electromagnetic radiation carrying OAM may be a beam having a beam axis substantially perpendicular to the plane of the guided wave. When m=1, the electromagnetic radiation carrying nonzero OAM when $l \neq 0$ or $p \neq q$ has a helical wave-front.

The emitted electromagnetic radiation may have a helical wave-front inclined at an angle, φ, to the guided wave plane normal.

The electromagnetic wave may be coupled into the closed-loop waveguide from a nearby input waveguide, preferably by evanescent coupling. The efficiency of the evanescent coupling may be maximised by providing the coupling ratio between the resonator and the input waveguide at the critical coupling point.

The electromagnetic wave may also be generated inside the closed-loop waveguide itself by an emission mechanism such as stimulated emission.

The electromagnetic wave in the closed-loop waveguide may be substantially TE polarized, or s-polarized, in which its electric field vector lies substantially in the plane of the guided wave resonance mode.

The method may further comprise controlling the amount of OAM, l, carried by the emitted beam.

The value of l may be controlled by means of tuning the wavelength of the electromagnetic wave so that its wavelength aligns with one or more of the resonance modes of the resonator, corresponding to one or multiple p values. Because the number of grating elements, q, is fixed in any pre-fabricated structure, changing the wavelength of the electromagnetic wave will change the value of p, which will in turn change the value of l. Therefore the tuning step may be used to control the OAM quantum number, l, of the electromagnetic radiation carrying OAM.

The method may further comprise tuning the resonance modes of the resonator, whilst maintaining the wavelength of the input electromagnetic wave substantially constant, wherein tuning the resonance modes of the resonator includes changing a refractive index and/or a dimension of the resonator such that the input wavelength aligns with one or more of the resonance modes, p, of the resonator. Thereby the value of l can be changed.

The method may further comprise tuning the wavelength of the electromagnetic wave, or the resonance of the resonator, so that l has a positive or a negative value.

The method may further comprise having electromagnetic waves that contain multiple wavelengths, each wavelength tuned to correspond with a resonance, p, of the resonator, so that multiple values of the OAM quantity l exist in the emitted beam simultaneously.

The method may further comprise having electromagnetic waves that propagate in the same closed-loop waveguide resonator in different directions, so that multiple values of the OAM quantity l exist in the emitted beam. In one example wherein the resonator is substantially in a plane, two electromagnetic waves propagate in the clock-wise and/or anti-clockwise directions of the resonator may result in the emitted beam having positive and/or negative l values.

The closed-loop waveguide may be a ring or a disc, or may be substantially spherical.

The method may be used to generate light carrying orbital angular momentum (OAM), wherein the resonator is an optical resonator and the electromagnetic wave is from a light source.

A second aspect of the invention provides a method of detecting or manipulating electromagnetic radiation carrying orbital angular momentum (OAM), the method comprising receiving incoming electromagnetic radiation carrying OAM at a resonator having a closed-loop waveguide with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating selectively couples the incoming incident electromagnetic radiation having OAM quantity, l, and out-of-plane wave vector component $k_{rad\ z}$, from a free space mode to a guided wave mode propagating in the closed-loop waveguide at resonance with angular order, p. wherein significant coupling into the resonator occurs only when the following wave matching condition is satisfied:

$$l = p - mq$$

where m is a diffraction order of the grating, m=1, 2, 3,...,.

The resonator may include a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements such that a plurality of OAM quantities, l, in the incoming incident radiation are each selectively coupled to a guided wave mode by the respective grating.

The method may further comprise coupling the guided wave from the closed-loop waveguide to a detector thereby detecting the incident electromagnetic radiation carrying OAM.

The step of coupling the electromagnetic wave from the closed-loop waveguide to the detector may be via an output waveguide, wherein the output waveguide is preferably evanescently coupled to the closed-loop waveguide.

The incident electromagnetic radiation carrying OAM may be a beam having a beam axis substantially perpendicular to the plane of the guided wave.

The incident electromagnetic radiation when carrying non-zero OAM such that $p \neq q$ or $l \neq 0$ may have a helical mode.

The closed-loop waveguide may be a ring or a disc, or may be substantially spherical.

The method may further comprise tuning the resonance modes of the resonator by changing a refractive index and/or a dimension of the resonator such that the incoming electromagnetic radiation of substantially constant wavelength is aligned with one or more of the resonance modes of the resonator whereby to selectively detect electromagnetic radiation carrying specific OAM quantum numbers, l.

The method may be used to detect light carrying orbital angular momentum (OAM), wherein the resonator is an optical resonator and the detector is a photo-detector.

A third aspect of the invention provides a device for generating and/or detecting and/or manipulating electromagnetic radiation carrying orbital angular momentum (OAM), the device comprising a resonator including a closed-loop waveguide for supporting a guided wave propagating at resonance with angular order, p, and with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating is arranged to selectively couple the guided wave mode to a free space radiation mode having an OAM quantity l and out-of-plane component, $k_{rad\ z}$, and wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied:

$$l = p - m\, q$$

where m is a diffraction order of the resonator, m =1, 2, 3,...,.

The resonator may include a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements, and wherein each angular grating is arranged to selectively couple a guided wave mode to a free space radiation mode having a different respective OAM quantity, l.

The device may be capable of supporting a plurality of guided waves at resonance with angular order, p_1, p_2, .. p_n. The angular grating may be arranged to selectively couple the plurality of guided wave modes, p_1, p_2,... p_n simultaneously to respective free space radiation modes having an OAM quantity l_1, l_2,.. l_n. and out-of-plane component, $k_{rad\ z1}$, $k_{rad\ z2}$,.. $k_{rad\ zn}$. when the following wave matching condition(s) are satisfied:

$$l_n = p_n - m_n\, q$$

where m_n is a diffraction order of the angular grating, m_n=1, 2, 3,...,.

The device may therefore be arranged to radiate an emitted beam with an OAM quantity of l_1 substantially different from an incident beam OAM quantity l_2.

The device may further comprise an input/output waveguide for coupling an electromagnetic wave to/from the closed-loop waveguide, preferably by evanescent coupling.

The closed-loop waveguide may be a ring or a disc, or may be substantially spherical.

The resonator may be incorporated in an integrated circuit (IC).

The IC may include an array of the resonators.

The device may be micro sized, wherein R is less than 100 μm, preferably less than 50 μm, preferably less than 20 μm, preferably less than 10 μm.

The device may be adapted for generating light carrying OAM, wherein the resonator is an optical resonator and may further comprise a laser source coupled to the optical resonator.

The laser source may be tunable.

The device may be adapted for generating electromagnetic radiation carrying OAM, and may further comprise a polarization controller for coupling a TE polarized, or s-polarized, electromagnetic wave into the closed-loop waveguide, in which the electric field vector of the electromagnetic wave lies substantially in the plane of the guided wave.

The device may be adapted for detecting light carrying OAM, wherein the resonator is an optical resonator and the device may further comprise a photo-detector coupled to the optical resonator.

A further aspect of the invention provides an optical tweezer system including a device according to the invention for generating light carrying OAM.

A further aspect of the invention provides use of the optical tweezer system to hold and/or move an object by energizing the device to generate light carrying OAM.

A further aspect of the invention provides a communications system including at devices according to the invention for generating electromagnetic radiation carrying OAM and for detecting the electromagnetic radiation carrying OAM.

In the communications system the electromagnetic radiation carrying OAM may be used to encode quantum information in a quantum communications channel or may be used in a quantum key distribution system.

The communications system may further comprise a plurality of the devices for generating/detecting electromagnetic radiation carrying OAM.

The communications system may further comprise at least one optical interconnect between the devices.

The communications system may further comprise an optical bandpass filter and/or a optical multiplexer.

A further aspect of the invention provides a micro-fluidic system including at least one device according to the invention, wherein the device is adapted to rotate microspheres or microparticles within the micro-fluidic system when the device(s) are energized to generate electromagnetic radiation carrying OAM.

A further aspect of the invention provides use of the microfluidic system for sorting different microspheres or microparticles according to type.

A further aspect of the invention provides use of the microfluidic system as a micropump for displacing microspheres or microparticles through the system.

A further aspect of the invention provides use of a device according to the invention having an array of the resonators, for beam steering.

A further aspect of the invention provides use of a device according to the invention having an array of the resonators for coherent or incoherent combining of multiple OAM states generated by the resonators.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 (a) illustrates schematically a micro-ring optical resonator having a closed-loop waveguide patterned with an angular grating, and a linear waveguide for evanescently coupling tunable input laser light into the closed-loop waveguide;

Figure 1 (b) illustrates schematically the helical wave-front of the radiated wave generated by coupling a guided wave to the angular grating;

Figures 2 (a) and (b) illustrate a scanning electron microscope image of the optical resonator showing the elements of the grating patterned along the inside wall of the micro-ring cavity;

Figure 3 (a) illustrates an experimental setup for detecting radiation carrying OAM generated by the optical resonator embodied in a silicon-on-insulator photonic integrated circuit;

Figure 3 (b) illustrates a measured radiation spectrum obtained from the experimental setup shown in Figure 3 (a) and showing peaks corresponding to the topological charge (quantum states) , l, of the radiation carrying OAM;

Figure 3 (c) illustrates interference patterns captured by the infra red camera in the experimental setup shown in Figure 3 (a) when the wavelength of the tunable laser is adjusted to multiple resonances of the optical resonator to show the interference patterns at the different OAM topological charges;

Figure 4 illustrates an application of the invention in an optical interconnect using an array of OAM sources and detectors; and

Figure 5 illustrates another application of the invention in a microfluidic device for sorting microparticles.

DETAILED DESCRIPTION OF EMBODIMENT(S)

Figure 1 (a) illustrates an optical resonator 1 including an input straight (linear) waveguide 2 and a closed-loop ring waveguide 3. An angular grating 4 is patterned within the ring waveguide 3. The angular grating is used to selectively couple a guided wave propagating in the ring waveguide with an in-plane angular wave vector to a free space radiation mode with a wave vector pointing at an angle from the waveguide plane.

The ring waveguide 3 is an example of a substantially planar waveguide structure that provides strong confinement of light that propagates around the ring by way of total internal reflection. At one or more resonant wavelengths of the ring waveguide 3 constructive interference occurs which develops the intensity of the guided wave propagating in the waveguide as it executes multiple circuits of the ring. Light is coupled into the ring waveguide 3 evanescently from the input waveguide 2. Efficient coupling from the input waveguide to the ring waveguide 3 is achieved at the critical coupling point where maximum power is transferred from the input waveguide 3 into the ring. If the ring waveguide also has a high Quality factor then a highly efficient optical system can be devised.

The ring waveguide 3 is perturbed by the angular grating 4 patterned along the inside wall of the ring cavity. The radius of the ring is R, and the period of the angular grating at R is Λ. Thus the number of the angular grating elements, q, is an integer given by $q = 2\pi R / \Lambda$. The angular grating is a second order grating in which the waveguide 3 is perturbed with a period close to the wavelength of the guided wave. The incoming guided wave is scattered by each and every grating element 5 acting as a phased radiation source, so that a waveguide mode with an in-plane wave vector is coupled to a free space radiation mode with a wave vector pointing away from the waveguide plane normal, in which constructive interference occurs.

Vertical emission (in the z direction normal to the waveguide plane) is achieved when the grating period, Λ, coincides with the wavelength of the guided wave, so that all grating elements 5 radiate in-phase. When the radiation from the consecutive grating elements are not in phase, the radiated light 6 is oblique as the wave-front is skewed to fulfil the Bragg condition. Since the waveguide 3 carrying the grating 4 is a ring, the wave-front of the diffracted field skews in the angular direction, θ, and transforms to a helix, as shown in Figure 1 (b). As mentioned previously, a helical wave-front is associated with OAM.

The mode coupling mechanism in the angular grating 4 is directly derived by coupled mode theory (CMT) in cylindrical coordinates to show that significant mode coupling only takes place between a guided mode and a radiation mode when the following angular phase matching condition is satisfied:

$$l = p - m\,q$$

which translates into

$$k_{rad,\theta} = = k_{guide} - mq / R = k_{guide} - m2\pi / \Lambda$$

where:

R is the effective radius of the angular grating where it interacts with the guided wave

k_{guide} is the (in-plane) projection of the wave vector of the guided wave in the angular (tangential) direction at radius R

$k_{rad,\theta}$ is the projection of the wave vector, k_{rad}, of the free space radiation mode in the angular (tangential) direction at radius R, and

m is the diffraction order of the resonator, $m = 1, 2, 3,...,$.

The field in the ring resonator needs to fulfil the self-consistent resonance condition:

$$2\pi R k_{guide} = 2p\pi$$

where p is the angular order of the guided wave in the resonator, $p=\pm1, \pm2,$. etc

Therefore a quantized projection of the wave vector in the angular direction for the radiation mode is provided:

$$k_{rad,\theta} = (p-q) / R = l / R$$

where l is an integer, and $l=p-q$.

The radiation mode wave vector has no angular component, i.e. $k_{rad,\theta} = 0$ or $l=0$ when $p=q$, while it contains nonzero angular component when $p \neq q$. Therefore, the radiation mode contains the angular transverse phase factor $exp(-ik_{rad,\theta}R\theta)=exp(-il\theta)$, indicating an OAM of $l\hbar$ per photon, where $\hbar$ is the reduced Planck constant. l, known as the OAM quantum number or topological charge, is determined by the difference between the guided wave angular order p and the number of angular grating elements, q.

The guided waves in the ring resonator are essentially angular propagating waves carrying $p\hbar$ OAM per photon. The physical meaning of the equation, $l=p-q$, is that the angular grating 4 diffracts the guided wave by changing the OAM by an amount of $q\hbar$. For a fabricated device, q is a constant while p is different at different resonances. Therefore variable OAM quantum numbers, l, can be generated by simply tuning the injected laser wavelength to various resonance, or alternatively tuning the micro-ring resonances, by changing refractive index of the waveguide, with a fixed input wavelength.

Figures 2 (a) and (b) illustrate a scanning electron microscopy (SEM) image of an optical ring resonator fabricated on a silicon-on-insulator (SOI) photonic integrated circuit (PIC) 20. Both the input straight waveguide 2 and the ring waveguide 3 are 500-nm wide and 220-nm thick. The gap between the ring and the straight waveguide is 200nm, and the straight waveguides are tilted 7° from the normal of the chip facets to reduce the Fabry-Perot effects induced by optical reflection from the facets. The structures are defined using electron-beam lithography followed by inductively coupled plasma etching. Following the etching, a 300-nm-thick silicon dioxide layer is deposited onto the wafer to encapsulate the waveguides. The radius of the ring and the pattern of the angular grating 4 were designed in such a way that the resonance wavelength associated with zero quantum number OAM ($l=0$) is around 1550nm.

A plurality of different sized micro-ring resonators were fabricated on the same chip 20. Exemplary micro-ring resonators have radius of 3.9 μm and 7.5 μm, with 36 and 72 angular grating elements, respectively. This gives rise to a value for the angular order, p, of the guided wave that is typically large. For example, in a 10 μm radius SOI micro-ring resonator, p is about 140 at 1550nm. For SOI material, $m = 1$ around the wavelength of 1550nm.

In principle, a plurality of modes may be involved as long as their angular wave vectors are matched for some integer m. However, the practical value for m may be limited by the used material system due to the limitations imposed by the refractive index of the waveguide material as will be explained below.

The free space radiation has wave vector $k_{rad} = 2\pi / \lambda$, where λ is the free space wavelength. The angular component of the free space wave vector, $k_{rad,\theta}$, must therefore satisfy:

$$|k_{rad,\theta}| < 2\pi / \lambda$$

Also, the guided wave vector, $k_{guide} = n_{eff}\ (2\pi / \lambda)$, where n_{eff} is the effective refractive index of the waveguide material.

Based upon the above described angular grating wave matching condition:

$$k_{rad,\theta} = k_{guide} - m2\pi / \Lambda$$

reveals that for a wavelength λ of around 1550nm, with Λ at around 450nm and n_{eff} around 3.5, m is in the order of 0.8 to 1.6. Since m is an integer the only possible value for m is 1.

The grating elements 5 are in the shape of 'nano-teeth' protruding from the inner wall of the ring.

An experimental arrangement based on a Mach–Zehnder interferometric configuration, shown in Figure 3 (a), was used to study the phase structure of the radiation beam. The output of a high precision tunable laser 7 was split into two branches using a fibre coupler 8. The laser 7 outputs a near Gaussian paraxial beam with cylindrical symmetry. In one branch 9a the laser power was coupled into one port 2a of the PIC 20 straight waveguide 2 using a tapered fibre lens tip, with suitable power levels controlled by a variable optical attenuator (VOA) 10. A fibre-optic polarization controller 11 was used to launch light in the quasi-TE mode in the waveguide 3 (E-field in waveguide plane). With a planar waveguide, launch at TE polarisation is required as TM mode will not emit vertically out of the waveguide plane. In order to monitor the polarization, a polarizer 12 followed by an optical power meter 13 is arranged at the output port 2b of the waveguide 2. When the laser wavelength coincides with a resonance of the micro-ring 3, the radiation beam 6 is emitted, and then collimated by an objective lens 14.

In the other branch 9b, the power level was replicated by another VOA 15 and polarization controller 16, and the laser power coming out of a flat-end fibre 17 is directed to a collimator 18 in order to produce an expanded and collimated Gaussian reference beam 19. The two beams are combined at a beam splitter 21 and projected onto an infrared camera 22.

Figure 3 (b) shows the radiation spectra for the fabricated SOI device 20, measured by replacing the infrared camera 22 with an optical power meter (not shown). The doublets in the spectra result from eigen-mode splitting caused by coupling between the otherwise degenerate clockwise and counter-clockwise travelling-wave modes in the ring 3. The coupling is due to back-reflection of the grating elements 5, which could be minimised with refinement of the grating design.

Figure 3 (c) shows photographs of interference patterns associated with a left-hand and right-hand circularly polarised reference beam, with the different resonant wavelengths for the 3.9 μm radius device 20. Of these the middle one shows the special case of $l=0$, while the others show $l=-4$ *to* $+4$. In real time the spiral patterns can be observed to rotate when the phase of the Gaussian reference beam is changed continuously, confirming that the wave-front of the light radiated from fabricated device 20 is indeed helical with $l=p-q$.

Theoretically, radiated beams with any OAM quantum numbers l can be generated from the device 20. However, the observable OAM is limited by the tuning range of the tunable laser 7, which in the setup shown in Figure 3 (a) was 1460-1570 nm. Higher quantum numbers of OAM can be observed from larger devices because of their smaller free spectral range. For example, with a ring radius of 7.5 μm, the spiral fringe patterns associated with $l=-3$ *to* $+3$ were observed, as expected, on the shorter and longer wavelength side, respectively.

The integrated OAM emitters have therefore successfully been realized in CMOS-compatible SOI PICs.

Compared to previous techniques, the invention enables multiple OAM values to be selectively generated, and rapid switching among them can be easily achieved, as the silicon micro-rings 3 have already been shown to tune at frequencies up to 10 GHz. With larger ring resonators tuning in the THz region is achievable.

The radiated beams 6 always possess integer quantized OAM, while the non-integer value OAM beam (with wavelengths between micro-ring resonances) is always rejected. The device 20 can be scaled to generate radiation beams carrying OAM with very large quantum numbers by carefully choosing the structure parameters.

In the above arrangement a micro-ring 3 optical resonator is used in the device 20. However, it will be appreciated that other optical resonators may be used such as a micro-disc, or spherical resonator. What is important is the waveguide forms a closed loop.

A micro-disc cavity can be made from a planar waveguide by etching a circular sidewall that penetrates the waveguide core layer. This structure provides strong confinement of light in the so-called whispering gallery mode (WGM) which travels along the circumference of the micro-disc by way of total internal reflection at the sidewall. In the fundamental mode with a micro-disc of high Quality factor the only significant propagation term in the WGM is the wave-vector in the angular direction. By patterning an angular grating in the sidewall of the micro-disc cavity, similar to that described above for the micro-ring, selective coupling between the guided WGM and a free space radiation mode carrying quantized OAM states can be realised. Alternatively, other grating designs could be implemented, such as patterning on the top of the microdisc.

A micro-sphere resonator is a non-planar waveguide that can support a plurality of bound guided planar waves in different respective planes. A micro-sphere may open the possibility to provide a plurality of different angular gratings patterned in the inside wall of the spherical cavity for tuning the micro-sphere at different resonances.

Light may be coupled into the micro-disc or micro-sphere using a linear waveguide as described previously. With the micro-sphere a plurality of input waveguides may be provided aligned with each angular grating. It is not necessary that the input waveguide need be provided adjacent the resonator in the plane of the micro-ring or micro-disc. Alternatively, the input waveguide may be arranged above or below the plane the micro-ring or micro-disc. Evanescent coupling approaching or at the critical coupling point is well understood and will not be elaborated here so as to avoid obscuring the clarity of the invention.

The micro-ring device 20 described above is operated as an optical resonator with a laser light source. However, it will be appreciated that the invention is not particularly limited to optical resonators and the principles of the invention apply throughout the electromagnetic spectrum, e.g. in the radio frequency, or THz regions.

The angular grating patterned in the resonator can take a variety of forms and is not limited to the ‘nano teeth’ described for exemplary the micro-ring structure. The grating may take any tooth like or crenulated form, or may be include a series of rods, for example.

For on-chip applications a variety of different substrate materials may be used as an alternative to the silicon-on insulator arrangement described above. For example, the substrate material may be include any one or more of: compound semiconductors (GaAs/AlGaAs, InGaAsP/InP, etc), polymers, silicon oxynitride (SiON) / silicon dioxide, silicon dioxide (doped)/silicon dioxide, AlGaN/InGaN/GaN, lithium niobate, diamond thin films, etc. as will be appreciated by those skilled in the art. As mentioned previously the material selection has implications for the diffraction order, m, of the wave matching condition of the angular grating.

It is possible to excite several guided wave modes at the same time in the device. The outgoing beam will therefore be a frequency division multiplexed (FDM) OAM beam, with different frequencies carrying different OAM. Such a beam can be decoded using simple optical bandpass filters to separate different OAM.

In addition to tuning the emitted radiation carrying OAM by simply tuning the input laser source, this may also be realised by tuning the micro-ring refractive index or ring diameter R when the input light frequency is fixed, achieving the same control over the output beam OAM. This tunes the resonance modes of the resonator such that the input wavelength aligns with one or more of the resonance modes of the resonator.

By the principle of reciprocity, an emitter of an out-going beam with a certain OAM will also couple the same incoming beam back into the resonator. Hence the same device 20 can be used as an OAM-selective receiver. The evanescently coupled straight waveguide 2 can then operate as an output waveguide. The angular grating performs exactly the same selective coupling between the incoming incident free space electromagnetic radiation carrying OAM and a guided wave propagating in the resonator as for the OAM generator described above.

By coupling the output waveguide to a photo-detector it becomes possible to detect one or more OAM states of the incident radiation.

This opens up a very wide range of applications for the technology, a few of which will be briefly described below and are not intended as an exhaustive list of potential applications. Due to the extremely compact size of the OAM emitter/receive device (may be less than 10μm in diameter), one dimensional or two dimensions arrays of the devices may be provided, which are not currently possible with existing technology that tends to be approximately 3 orders of magnitude greater in dimension. A particularly beneficial aspect of the OAM emitter/receiver device is that it can provide very fast reconfigurability at speeds of nano-second or faster.

Optical tweezer systems are known which can impart angular momentum to a trapped particle, resulting in spin in the particle. Such spin can be controlled by the sign and amount of OAM carried by the beam. This may result in the change of physical signatures of these particles (e.g., its luminescence spectrum, its magnetic properties if the particle is charged). In such an optical tweezer system the size and cost of the system could be reduced significantly using a device according to the invention. New types of optical tweezer systems could also be envisaged as the radiation emission source could be integrated closer to a sample due to its very small size.

In the field of quantum communications the light carrying OAM may be used to encode the quantum information, for instance in any quantum communication channel where quantum superposition states, entangled states or any other quantum states are communicated between multiple parties. OAM quantum communications channels can be realised between two chips, each containing the same integrated OAM PIC, or an array of OAM emitters/receivers on a chip.

A compact OAM source and detector realised by a device according to the invention could lead to a reduction in the size of a system and the development of handheld quantum key distribution devices.

For optical interconnect technology there is the potential to increase the capacity of the communication system using an array of OAM sources and detectors (due to unlimited OAM states) each provided by a device according to the invention, as shown in Figure 4.

The OAM device may also be configured as a storage device for the OAM quantum state carried by the incident radiation beam, with the Q-factor of the resonator cavity deciding the decay rate / lifetime of the stored state. The same angular grating, which serves as the input coupling mechanism, will couple the light out of the guided wave back into the beam, shortening the cavity photon lifetime.

It is possible to fabricate angular gratings that can be electrically (through electro-optical effect) or optically (through photo-refractive effect or Kerr effect, for example) controlled, so that the grating only exists during writing (input coupling) and reading (output coupling), while it is erased during the storage period to increase the cavity Q-factor.

It is possible for a high intensity guided wave mode to generated photons of different frequencies using nonlinear optical processes (such as spontaneous four wave mixing - FWM) – the high Q factor of the resonator cavity enables high efficiency in nonlinear optical processes. The generated photons will be emitted into two different OAM beams. These two OAM states should be entangled and can be spatially separated using optical bandpass filters.

Arrays of OAM emission sources could be used to generate optical vortices so as to form controllable and reconfigurable drivers for micro-fluidic and nano-particle manipulation machines. For example, Figure 5 illustrates a system for rotating microspheres by switching on an array of OAM sources below the microparticles. The source organizes fluid-borne colloidal particles into rapidly circulating rings, thereby generating fluid flows with pinpoint control and no moving parts. The vortex created acts to pump the particles through the device. The device can be configured using different OAM states to sort particles. This has applications in sensing, chemical analysis, quantum science etc., and enables label-free cell sorting “lab on a chip” technology.

Although the invention has been described above with reference to one or more preferred embodiments, it will be appreciated that various changes or modifications may be made without departing from the scope of the invention as defined in the appended claims.

Claims

1. A method of generating electromagnetic radiation carrying orbital angular momentum (OAM), the method comprising placing an electromagnetic wave in a resonator having a closed-loop waveguide supporting a guided wave propagating at resonance with angular order, p, and with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating selectively couples the guided wave mode to a free space radiation mode having an OAM quantity, l, and out-of-plane wave vector component, $k_{rad,z}$, and wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied:

$$l = p - m\,q$$

where:

m is the diffraction order of the angular grating, m = 1, 2, 3,...,.

2. A method according to claim 1, wherein the resonator includes a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements such that the free space radiation mode has a plurality of OAM quantities, l.

3. A method according to claim 1 or claim 2, wherein the guided wave mode has an angular wave vector, k_{guide}, and the free space radiation mode has a wave vector, k_{rad}, with angular component, $k_{rad,\theta}$, and out-of-plane component, $k_{rad,z}$, and wherein the wave matching condition translates to:

$$k_{rad,\theta} = k_{guide} - mq / R = k_{guide} - m2\pi / \Lambda$$

where:

R is the effective radius of the angular grating where it interacts with the guided wave,

$k_{guide} = p / R$, and

Λ is the period of the angular grating at R.

4. A method according to any preceding claim, wherein the electromagnetic radiation carrying OAM is a beam having a beam axis substantially perpendicular to the plane of the guided wave.

5. A method according to any preceding claim, wherein the electromagnetic radiation carrying OAM has a helical mode with nonzero OAM when $p \neq q$.

6. A method according to claim 5, wherein the electromagnetic radiation has a helical wave-front inclined at an angle, φ, to the guided wave plane normal.

7. A method according to any preceding claim, wherein the electromagnetic wave is coupled into the closed-loop waveguide from an input waveguide, preferably by evanescent coupling.

8. A method according to claim 7, wherein the efficiency of the evanescent coupling is maximised by providing the coupling ratio between the resonator and the input waveguide at the critical coupling point.

9. A method according to claim 7 or claim 8, wherein the input electromagnetic wave is coupled into one or both propagation directions in the closed-loop waveguide resonator.

10. A method according to any of claims 7 to 9, wherein the input electromagnetic wave is substantially TE polarized, or s-polarized, in which its electric field vector lies substantially in the plane of the guided wave.

11. A method according to any preceding claim, further comprising tuning the wavelength of the input electromagnetic wave so that its wavelength aligns with one or more of the resonance modes of the resonator.

12. A method according to claim 11, wherein the tuning step is used to control the OAM quantum number, l, of the electromagnetic radiation carrying OAM.

13. A method according to any of claims 1 to 10, further comprising tuning the resonance modes of the resonator, whilst maintaining the wavelength of the

input electromagnetic wave substantially constant, wherein tuning the resonance modes of the resonator includes changing a refractive index and/or a dimension of the resonator such that the input wavelength aligns with one or more of the resonance modes of the resonator.

14. A method according to any preceding claim, wherein the closed-loop waveguide is a ring or a disc, or is substantially spherical.

15. A method according to any preceding claim used to generate light carrying orbital angular momentum (OAM), wherein the resonator is an optical resonator and the electromagnetic wave is from a light source.

16. A method of detecting or manipulating electromagnetic radiation carrying orbital angular momentum (OAM), the method comprising receiving incoming electromagnetic radiation carrying OAM at a resonator having a closed-loop waveguide with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating selectively couples the incoming incident electromagnetic radiation having an OAM quantity, l, and out-of plane wave vector component, $k_{rad\ z}$, from a free space mode to a guided wave mode propagating in the closed-loop waveguide at resonance with angular order, p, the method further comprising detecting or manipulating the guided wave, wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied:

$$l = p - m\,q$$

where:

m is the diffraction order of the angular grating, m=1, 2, 3,...,.

17. A method according to claim 16, wherein the resonator includes a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements such that a plurality of OAM quantities, l, in the incoming incident radiation are each selectively coupled to a guided wave mode by the respective grating.

18. A method according to claim 16 or claim 17, wherein the guided wave mode has an angular wave vector, k_{guide}, and the free space radiation mode has a wave vector, k_{rad}, with angular component, $k_{rad,\theta}$, and out-of-plane component, $k_{rad,z}$, and wherein the wave matching condition translates to:

$$k_{rad,\theta} = k_{guide} - mq / R = k_{guide} - m2\pi / \Lambda$$

where:

R is the effective radius of the angular grating where it interacts with the guided wave,

$k_{guide} = p / R$, and

Λ is the period of the angular grating at R.

19. A method according to any of claims 16 to 18, further comprising coupling the guided wave from the closed-loop waveguide to a detector thereby detecting the incident electromagnetic radiation carrying OAM.

20. A method according to claim 19, wherein the step of coupling the electromagnetic wave from the closed-loop waveguide to the detector is via an output waveguide, wherein the output waveguide is preferably evanescently coupled to the closed-loop waveguide.

21. A method according to any of claims 16 to 20, wherein the incident electromagnetic radiation carrying OAM is a beam having a beam axis substantially perpendicular to the plane of the guided wave.

22. A method according to any of claims 16 to 21, wherein the incident electromagnetic radiation carrying OAM has a helical mode with nonzero OAM such that $p \neq q$.

23. A method according to claim 22, wherein the incident electromagnetic radiation has a helical wave-front inclined at an angle, φ, to the guided wave plane normal.

24. A method according to any of claims 16 to 23, wherein the closed-loop waveguide is a ring or a disc, or is substantially spherical.

25. A method according to any of claims 16 to 24, further comprising tuning the resonance modes of the resonator by changing a refractive index and/or a dimension of the resonator such that the incoming electromagnetic radiation of substantially constant wavelength is aligned with one or more of the resonance modes of the resonator whereby to selectively detect electromagnetic radiation carrying specific OAM quantum numbers, l.

26. A method according to any of claims 16 to 25 used to detect light carrying orbital angular momentum (OAM), wherein the resonator is an optical resonator and the detector is a photo-detector.

27. A device for generating and/or detecting and/or manipulating electromagnetic radiation carrying orbital angular momentum (OAM), the device comprising a resonator including a closed-loop waveguide for supporting a guided wave propagating at resonance with angular order, p, and with an angular grating patterned in the closed-loop waveguide, the angular grating having a integer number, q, of grating elements, wherein the angular grating is arranged to selectively couple the guided wave mode to a free space radiation mode having an OAM quantity, l, and out-of-plane wave vector component, $k_{rad\ z}$, and wherein significant coupling to the grating occurs only when the following wave matching condition is satisfied:

$$l = p - m\,q$$

where:

m is the diffraction order of the resonator, m=1, 2, 3,...,.

28. A device according to claim 27, wherein the resonator includes a plurality of the angular gratings patterned in the closed-loop waveguide, each angular grating having a different integer number, q, of grating elements, and wherein each angular grating is arranged to selectively couple a guided wave mode to a free space radiation mode having a different respective OAM quantity, l.

29. A device according to claim 27 or claim 28, wherein the guided wave mode has an angular wave vector, k_{guide}, and the free space radiation mode has a wave vector, k_{rad}, with angular component, $k_{rad,\theta}$, and out-of-plane component, $k_{rad,z}$, and wherein the wave matching condition translates to:

$$k_{rad,\theta} = k_{guide} - mq / R = k_{guide} - m2\pi / \Lambda$$

where:

R is the effective radius of the angular grating where it interacts with the guided wave,

$k_{guide} = p / R$, and

Λ is the period of the angular grating at R.

30. A device according to claim 29, wherein R is less than 100 μm, preferably less than 50 μm, preferably less than 20 μm, preferably less than 10 μm.

31. A device according to any of claims 27 to 30, further comprising an input/output waveguide for coupling an electromagnetic wave to/from the closed-loop waveguide, preferably by evanescent coupling.

32. A device according to any of claims 27 to 31, wherein the closed-loop waveguide is a ring or a disc, or is substantially spherical.

33. A device according to any of claims 27 to 32, wherein the resonator is incorporated in an integrated circuit (IC).

34. A device according to claim 33, wherein the IC includes an array of the resonators.

35. A device according to any of claims 27 to 33 for generating light carrying OAM, wherein the resonator is an optical resonator and further comprising a laser source coupled to the optical resonator.

36. A device according to claim 35, wherein the laser source is tunable.

37. A device according to any of claims 27 to 36 for generating electromagnetic radiation carrying OAM, further comprising a polarization controller for coupling a TE polarized, or s-polarized, electromagnetic wave into the closed-loop waveguide, in which the electric field vector of the electromagnetic wave lies substantially in the plane of the guided wave.

38. A device according to any of claims 27 to 34 for detecting light carrying OAM, wherein the resonator is an optical resonator and further comprising a photo-detector coupled to the optical resonator.

39. An optical tweezer system including a device according to any of claims 27 to 34 for generating light carrying OAM.

40. Use of an optical tweezer system according to claim 39 to hold and/or move an object by energizing the device to generate light carrying OAM.

41. A communications system including at device according to any of claims 27 to 34 for generating electromagnetic radiation carrying OAM and a further device according to any of claims 25 to 31 for detecting the electromagnetic radiation carrying OAM.

42. A communications system according to claim 41, wherein the electromagnetic radiation carrying OAM is used to encode quantum information in a quantum communications channel or is used in a quantum key distribution system.

43. A communications system according to claim 41 or claim 42, further comprising a plurality of the devices for generating/detecting electromagnetic radiation carrying OAM.

44. A communications system according to any of claims 41 to 43, further comprising at least one optical interconnect between the devices.

45. A communications system according to claim 44, further comprising an optical bandpass filter and/or a optical multiplexer.

46. A micro-fluidic system including at least one device according to any of claims 27 to 34, wherein the device is adapted to rotate microspheres or

microparticles within the micro-fluidic system when the device(s) are energized to generate electromagnetic radiation carrying OAM.

47. Use of a microfluidic system according to claim 46 for sorting different microspheres or microparticles according to type.

48. Use of a microfluidic system according to claim 46 as a micropump for displacing microspheres or microparticles through the system.

49. Use of a device according to any of claims 27 to 34 and having an array of the resonators, for beam steering.

50. Use of a device according to any of claims 27 to 34 and having an array of the resonators for coherent or incoherent combining of multiple OAM states generated by the resonators.

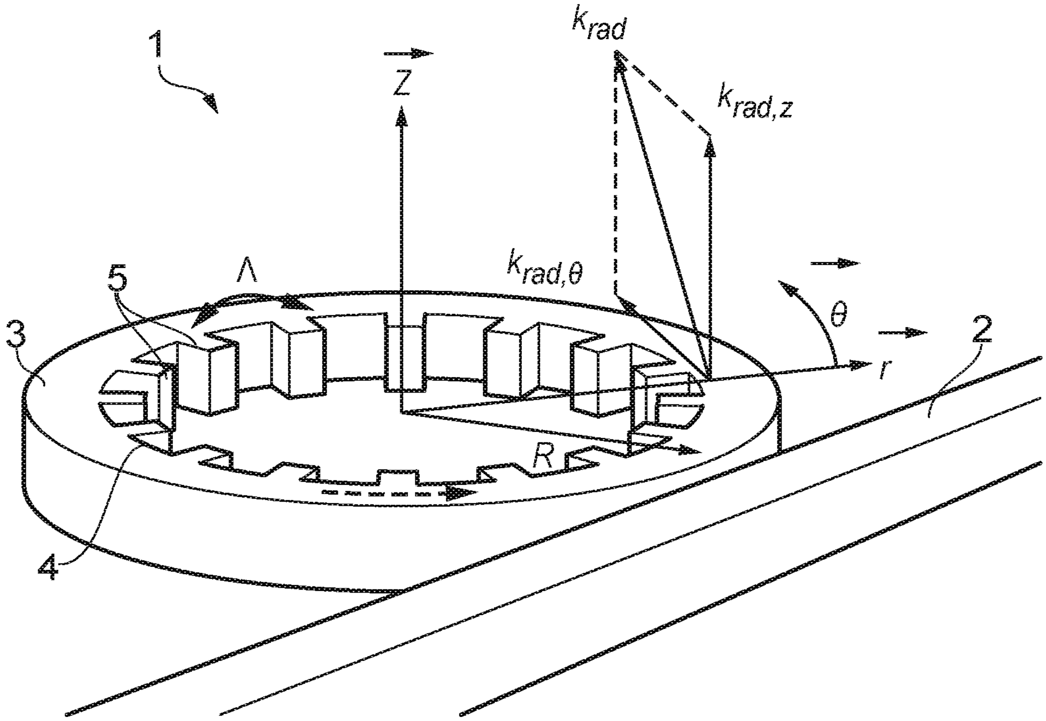


FIG. 1(a)

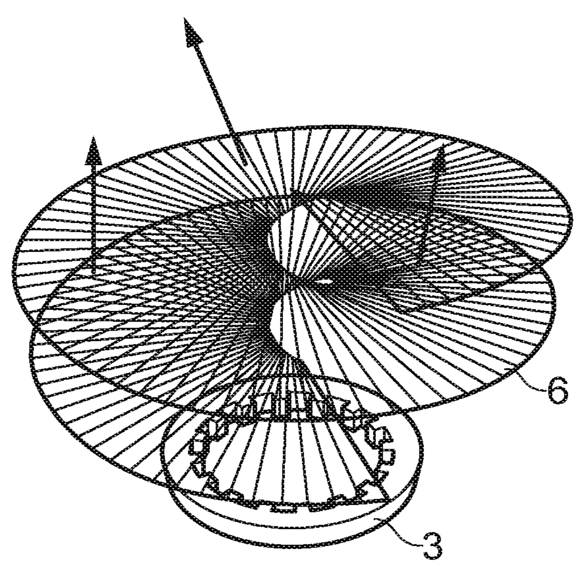


FIG. 1(b)

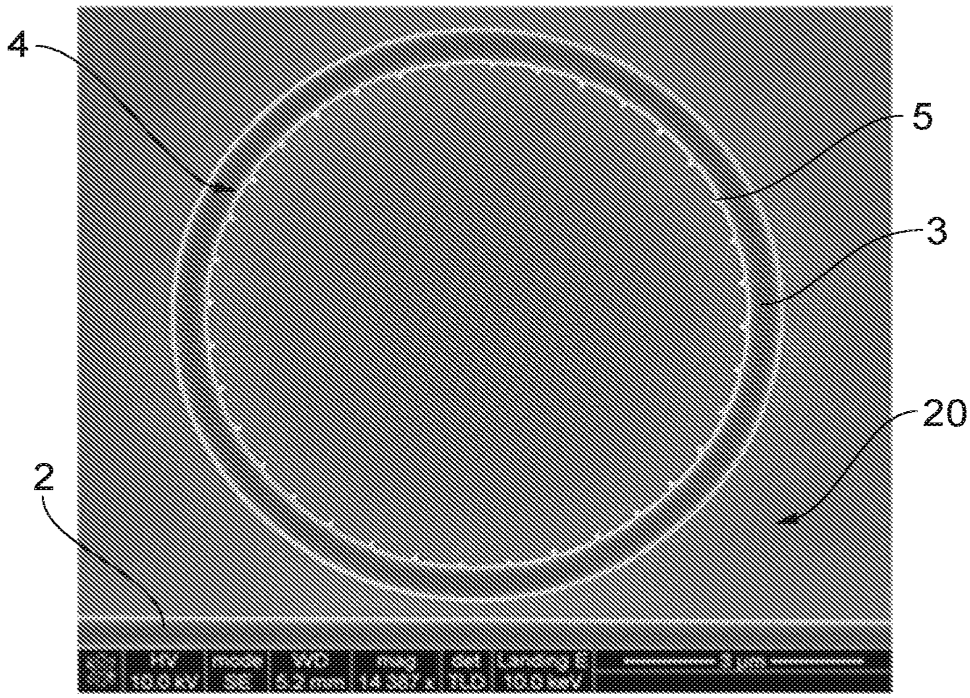


FIG. 2(a)

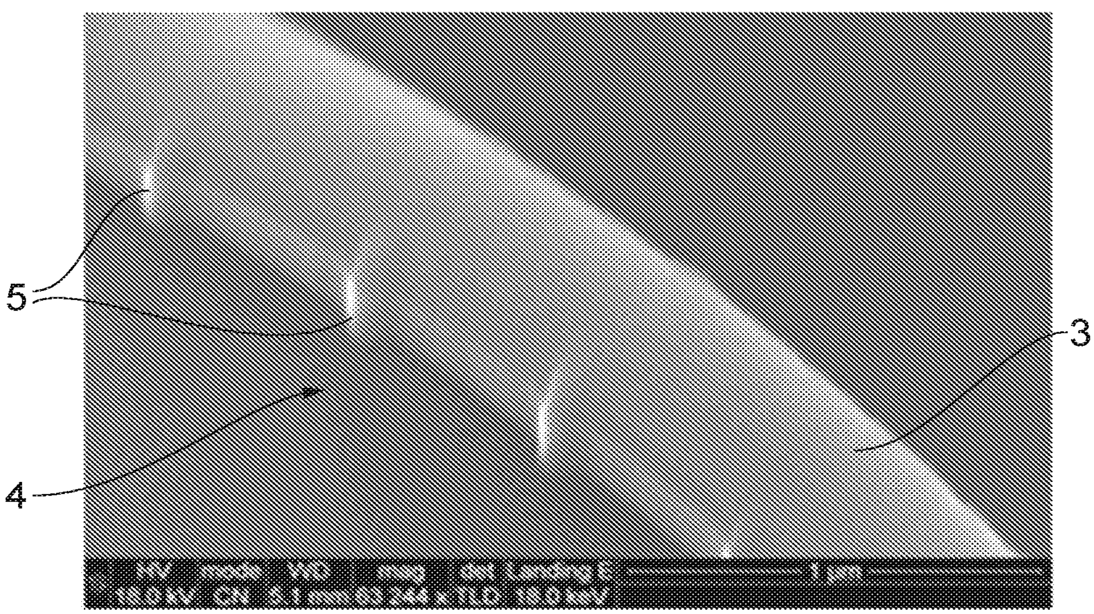


FIG. 2(b)

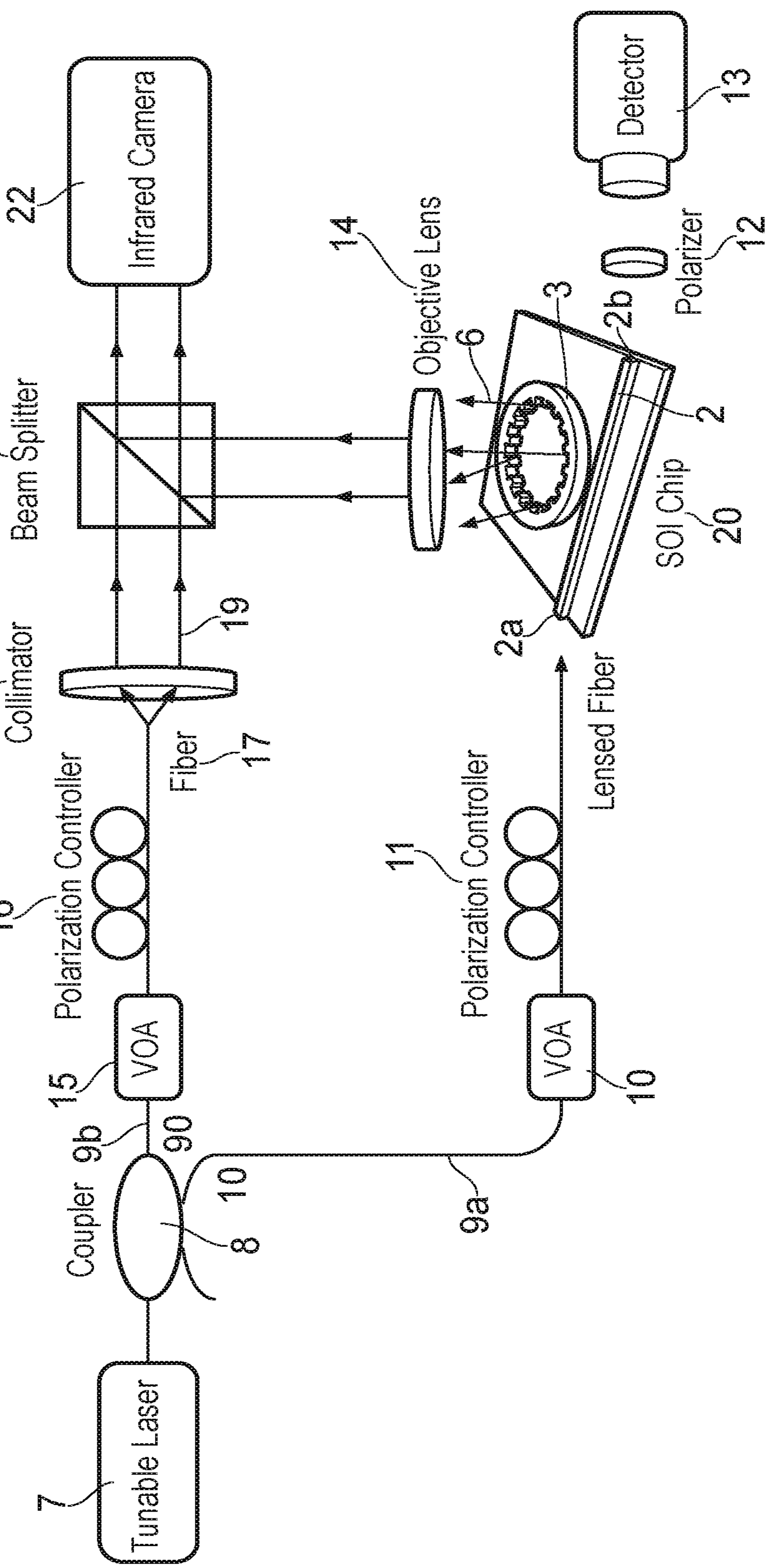
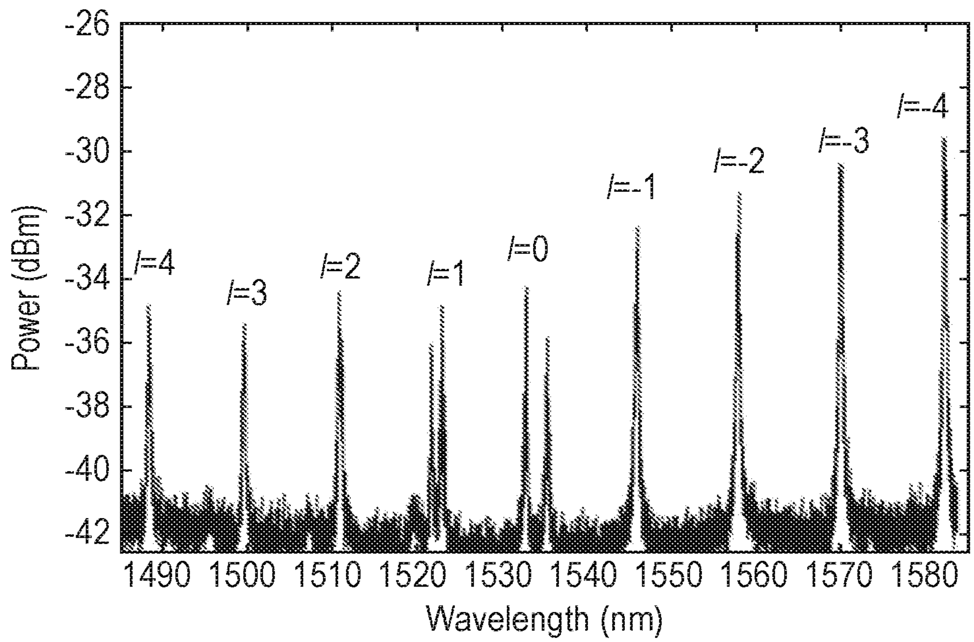
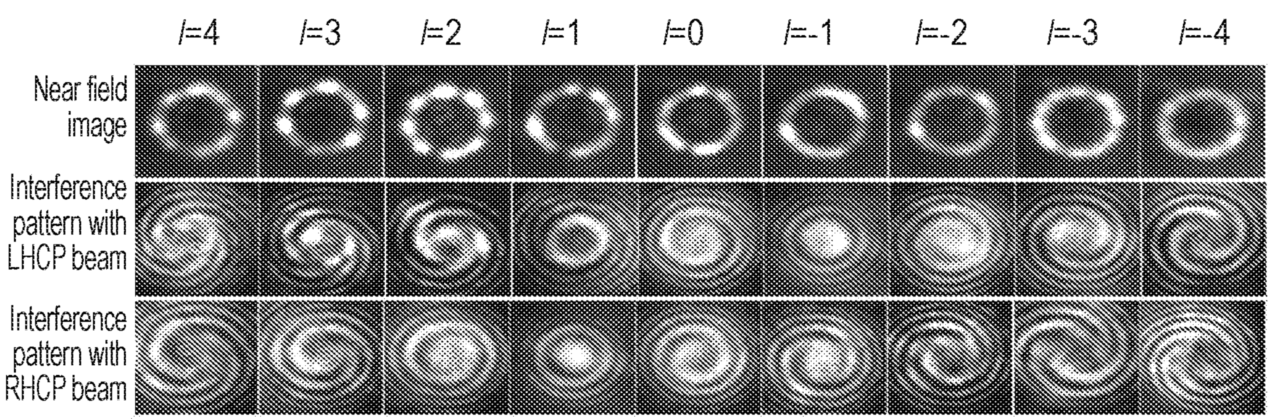

Tunable Laser
7
Coupler
8
9b
90
10
9a
VOA
15
VOA
10
Polarization Controller
16
Polarization Controller
11
Fiber
17
Lensed Fiber
Collimator
18
19
Beam Splitter
21
Infrared Camera
22
Objective Lens
14
6
3
2b
2
2a
SOI Chip
20
Polarizer
12
Detector
13

FIG. 3(a)



-26
-28
-30
-32
-34
-36
-38
-40
-42
Power (dBm)
l=4
l=3
l=2
l=1
l=0
l=-1
l=-2
l=-3
l=-4
1490 1500 1510 1520 1530 1540 1550 1560 1570 1580
Wavelength (nm)

FIG. 3(b)



l=4 l=3 l=2 l=1 l=0 l=-1 l=-2 l=-3 l=-4
Near field image
Interference pattern with LHCP beam
Interference pattern with RHCP beam

FIG. 3(c)

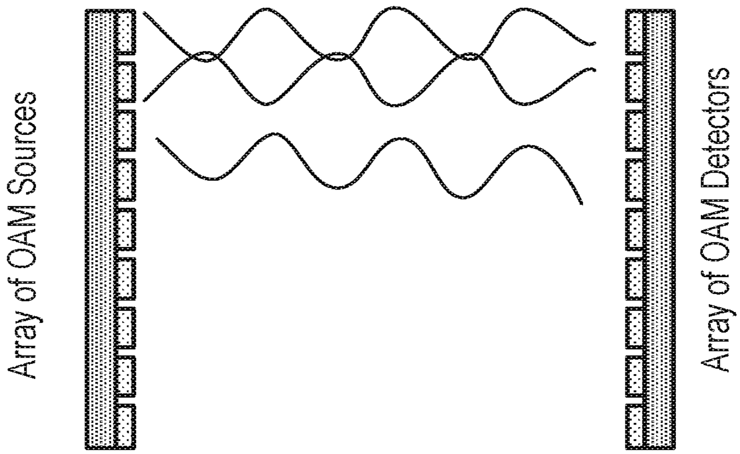

Array of OAM Sources
Array of OAM Detectors

FIG. 4

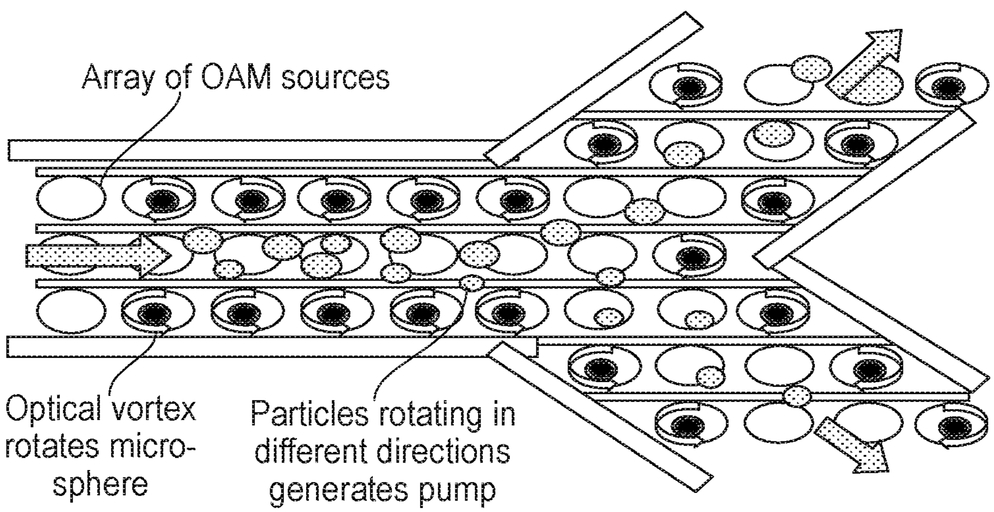

Array of OAM sources
Optical vortex rotates micro-sphere
Particles rotating in different directions generates pump

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/051414

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/12 G02B6/124
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Y. F. YU ET AL: "Pure angular momentum generator using a ring resonator", OPTICS EXPRESS, vol. 18, no. 21, 11 October 2010 (2010-10-11), page 21651, XP055074379, ISSN: 1094-4087, DOI: 10.1364/OE.18.021651	1-12,14, 15, 27-37, 39,40, 46-50
Y	the whole document	13, 16-26, 38,41-45

Y	US 2012/063484 A1 (GODDARD LYNFORD L [US] ET AL) 15 March 2012 (2012-03-15) abstract paragraph [0030]; claims 56-58	13,25

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[X] Further documents are listed in the continuation of Box C.

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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cohen, Adam

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/051414

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GIBSON G ET AL: "Free-space information transfer using light beams carrying orbital angular momentum", OPTICS EXPRESS, OSA (OPTICAL SOCIETY OF AMERICA), WASHINGTON DC, (US), vol. 12, no. 22, 1 November 2004 (2004-11-01), pages 5448-5456, XP002500773, ISSN: 1094-4087, DOI: 10.1364/OPEX.12.005448 the whole document -----	16-26, 38,41-45
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INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/051414

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	JIANGBO ZHU ET AL: "Theoretical model for angular grating-based integrated optical vortex beam emitters", OPTICS LETTERS, vol. 38, no. 8, 15 April 2013 (2013-04-15), page 1343, XP055074371, ISSN: 0146-9592, DOI: 10.1364/OL.38.001343 the whole document -----	1,27

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2013/051414

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012063484 A1	15-03-2012	NONE	

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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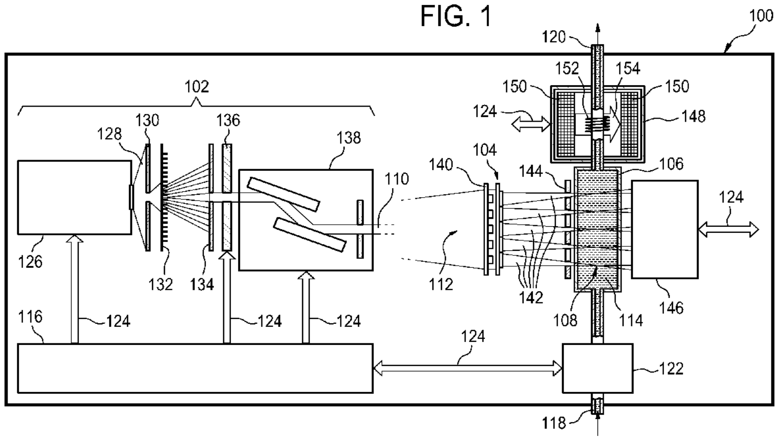
(54) **Title**: FLUID HYPERPOLARIZER.

FIG. 1



(57) **Abstract**: The invention provides for a fluid hyperpolarizer (100) for hyperpolarizing a fluid (114). The fluid hyperpolarizer comprises a narrow band X-ray source (102) for producing a narrow band X-ray beam (110, 112). The fluid hyperpolarizer further comprise at least one spiral zone plate (104) operable for imparting orbital angular momentum to the narrow band X-ray beam and operable for focusing the narrow band X-ray beam into a focus volume (108). The fluid hyperpolarizer comprises a hyperpolarization chamber (106) for receiving the fluid. The focus volume is within the hyperpolarization chamber.

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Fluid hyperpolarizer

TECHNICAL FIELD

The invention relates to the hyperpolarization of atoms, in particular to the use of X-rays with orbital angular momentum for the hyperpolarization.

BACKGROUND OF THE INVENTION

A static magnetic field is used by Magnetic Resonance Imaging (MRI) scanners to align the nuclear spins of atoms as part of the procedure for producing images within the body of a patient or subject. This large static magnetic field is referred to as the B_0 field.

Magnetic resonance imaging systems or scanners typically are used to image the concentrations or properties of protons, or hydrogen atoms, in a subject. Magnetic resonance imaging systems are especially useful for imaging the soft tissues of a subject. Contrast agents are often used to enhance imaging.

The journal article Goldman et al., "Molecular imaging using hyperpolarized ^{13}C", The British Journal of Radiology, 76 (2003), S118-127 reviews the use of ^{13}C as a hyperpolarized contrast agent for medical imaging.

SUMMARY OF THE INVENTION

The invention provides for a fluid hyperpolarizer, a nuclear magnetic resonance spectrometer, and a magnetic resonance imaging system in the independent claims. Embodiments are given in the dependent claims.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a apparatus, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more computer readable medium(s) having computer executable code embodied thereon.

Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A ‘computer-readable storage medium’ as used herein encompasses any tangible storage medium which may store instructions which are executable by a processor of a computing device. The computer-readable storage medium may be referred to as a computer-readable non-transitory storage medium. The computer-readable storage medium may also be referred to as a tangible computer readable medium. In some embodiments, a computer-readable storage medium may also be able to store data which is able to be accessed by the processor of the computing device. Examples of computer-readable storage media include, but are not limited to: a floppy disk, a magnetic hard disk drive, a solid state hard disk, flash memory, a USB thumb drive, Random Access Memory (RAM), Read Only Memory (ROM), an optical disk, a magneto-optical disk, and the register file of the processor. Examples of optical disks include Compact Disks (CD) and Digital Versatile Disks (DVD), for example CD-ROM, CD-RW, CD-R, DVD-ROM, DVD-RW, or DVD-R disks. The term computer readable-storage medium also refers to various types of recording media capable of being accessed by the computer device via a network or communication link. For example a data may be retrieved over a modem, over the internet, or over a local area network. Computer executable code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

A computer readable signal medium may include a propagated data signal with computer executable code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

‘Computer memory’ or ‘memory’ is an example of a computer-readable storage medium. Computer memory is any memory which is directly accessible to a processor. ‘Computer storage’ or ‘storage’ is a further example of a computer-readable storage medium. Computer storage is any non-volatile computer-readable storage medium. In some embodiments computer storage may also be computer memory or vice versa.

A ‘processor’ as used herein encompasses an electronic component which is able to execute a program or machine executable instruction or computer executable code.

References to the computing device comprising “a processor” should be interpreted as possibly containing more than one processor or processing core. The processor may for instance be a multi-core processor. A processor may also refer to a collection of processors within a single computer system or distributed amongst multiple computer systems. The term computing device should also be interpreted to possibly refer to a collection or network of computing devices each comprising a processor or processors. The computer executable code may be executed by multiple processors that may be within the same computing device or which may even be distributed across multiple computing devices.

Computer executable code may comprise machine executable instructions or a program which causes a processor to perform an aspect of the present invention. Computer executable code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages and compiled into machine executable instructions. In some instances the computer executable code may be in the form of a high level language or in a pre-compiled form and be used in conjunction with an interpreter which generates the machine executable instructions on the fly.

The computer executable code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

A ‘user interface’ as used herein is an interface which allows a user or operator to interact with a computer or computer system. A ‘user interface’ may also be referred to as a ‘human interface device.’ A user interface may provide information or data to the operator and/or receive information or data from the operator. A user interface may enable input from an operator to be received by the computer and may provide output to the user from the computer. In other words, the user interface may allow an operator to control or manipulate a computer and the interface may allow the computer indicate the effects of the operator's control or manipulation. The display of data or information on a display or a graphical user interface is an example of providing information to an operator. The receiving of data through a keyboard, mouse, trackball, touchpad, pointing stick, graphics tablet, joystick, gamepad, webcam, headset, gear sticks, steering wheel, pedals, wired glove, dance pad, remote control, and accelerometer are all examples of user interface components which enable the receiving of information or data from an operator.

A ‘hardware interface’ as used herein encompasses an interface which enables the processor of a computer system to interact with and/or control an external computing device and/or apparatus. A hardware interface may allow a processor to send control signals or instructions to an external computing device and/or apparatus. A hardware interface may also enable a processor to exchange data with an external computing device and/or apparatus. Examples of a hardware interface include, but are not limited to: a universal serial bus, IEEE 1394 port, parallel port, IEEE 1284 port, serial port, RS-232 port, IEEE-488 port, Bluetooth connection, Wireless local area network connection, TCP/IP connection, Ethernet connection, control voltage interface, MIDI interface, analog input interface, and digital input interface.

A ‘display’ or ‘display device’ as used herein encompasses an output device or a user interface adapted for displaying images or data. A display may output visual, audio, and or tactile data. Examples of a display include, but are not limited to: a computer monitor, a television screen, a touch screen, tactile electronic display, Braille screen, Cathode ray tube (CRT), Storage tube, Bistable display, Electronic paper, Vector display, Flat panel display, Vacuum fluorescent display (VF), Light-emitting diode (LED) displays, Electroluminescent display (ELD), Plasma display panels (PDP), Liquid crystal display (LCD), Organic light-emitting diode displays (OLED), a projector, and Head-mounted display.

Magnetic Resonance (MR) data is defined herein as being the recorded measurements of radio frequency signals emitted by atomic spins by the antenna of a Magnetic resonance apparatus during a magnetic resonance imaging scan. A ‘Magnetic Resonance Imaging (MRI) image’ or ‘magnetic resonance image’ is defined herein as being the reconstructed two or three dimensional visualization of anatomic data contained within the magnetic resonance imaging data. This visualization can be performed using a computer.

Nuclear Magnetic Resonance spectra data is defined herein as being the recorded measurements of radio frequency signals emitted by atomic spins by the antenna of a Nuclear Magnetic Resonance spectrometer during a magnetic resonance experiment scan which contains information which is descriptive of multiple resonance peaks.

In one aspect the invention provides for a fluid hyperpolarizer for hyperpolarizing a fluid. Hyperpolarizing as used herein encompasses aligning the spins of nuclei in a predetermined direction. The fluid hyperpolarizer comprises a narrow band X-ray source for producing a narrow band X-ray beam. A narrow band X-ray beam as used herein encompasses a beam of X-rays or energetic photons which have a restricted bandwidth. For instance the bandwidth of the X-ray beam may be 1 keV or less. An example of an X-ray source which is not narrow band would be a conventional X-ray tube which produces a full spectrum of X-rays through the Bremsstrahlung process. A narrow band X-ray source may be constructed for instance by taking a conventional X-ray tube or X-ray source and using a device which only allows X-rays in a certain energy range to pass.

The fluid hyperpolarizer further comprises at least one spiral zone plate operable for imparting orbital angular momentum to the narrow band X-ray beam. The spiral zone plate is further operable for focusing the narrow band X-ray beam into a focus volume. That is to say that the individual photons which comprise the narrow band X-ray beam are filtered such that the overall narrow band X-ray beam has a net orbital angular momentum. In general the orbital angular momentum can be described by a mode number. The higher the mode number the more effective the process may be. The fluid hyperpolarizer further comprises a hyperpolarization chamber for receiving the fluid. The focus volume is within the hyperpolarization chamber. This embodiment may have the benefit that any fluid within the hyperpolarization chamber will be hyperpolarized when a portion of the fluid is within the focus volume.

The above mentioned fluid hyperpolarizer could be implemented in a variety of ways. For instance a container or cuvette could be positioned into the hyperpolarization chamber and all or a portion of the fluid may be hyperpolarized. In other embodiments the hyperpolarization chamber may be supplied with an inlet and outlet so that a fluid may be continuously hyperpolarized.

In various embodiments there may be a single spiral zone plate or there may be an array of spiral zone plates or an array of spiral zone plate structures on one plate. This may then create multiple focus volumes that could be used to hyperpolarize the fluid in more than one location. As such the focus volume in the claim could refer to multiple focus volumes.

In some embodiments the narrow band X-ray source produces a narrow band of X-ray beams with an energy approximately 10 keV to 25 keV. In other embodiments the energy of the narrow band X-ray source can be between 10 keV and 35 keV and in some cases even as high as 40 keV. In general the higher the energy of the X-rays the more effective the hyperpolarization process will be. However, there is a limit on how high the upper energy can practically be because of the construction of the spiral zone plates. For instance a spiral zone plate may be constructed using a combination of a phase zone plate and a Fresnel zone plate. These may be two individual plates or the pattern may be combined into a single plate. At higher energy X-rays it is more difficult to construct a phase zone plate or a Fresnel zone plate which functions properly. Zone plates may be for instance constructed using a metal or other X-ray absorbing material on a substrate such as ceramic, glass, sapphire, silicon, or silicon nitrate (Si3N4). At higher energy thicker and thicker layers of metal are necessary to block the X-rays.

In another embodiment the spiral zone plate is a zone plate combining a phase zone plate and a Fresnel zone plate. In some embodiments this may be a combination of two separate plates or it may be a pattern which is a combination of the two.

In another embodiment the narrow band X-ray source comprises an X-ray tube operable for generating a broad spectrum X-ray beam. This for instance may also include an X-ray source generated by a Linac source. The narrow band X-ray source further comprises a monochromator operable for producing the narrow band X-ray beam using the broad spectrum X-ray beam.

In another embodiment the hyperpolarization chamber further comprises an X-ray intensity sensor for measuring an intensity level of the narrow band X-ray beam. The fluid hyperpolarizer further comprises a control unit operable for adjusting the intensity of the X-ray beam. This embodiment may be beneficial because the amount of hyperpolarization created by the X-ray beam may be better controlled.

In an alternate embodiment the controller may be used to adjust a fluid flow rate or a fluid exposure duration. For instance the amount of hyperpolarization can be controlled not just by controlling the X-ray intensity but also controlling how long the fluid or portion of the fluid is within the focus volume.

In another embodiment the fluid hyperpolarizer further comprises a fluid inlet and a fluid outlet. The fluid inlet is operable for supplying fluid to the hyperpolarization chamber. The fluid outlet is operable for draining fluid from the hyperpolarization chamber. This embodiment may be beneficial because a fluid may be continuously hyperpolarized by the fluid hyperpolarizer. The hyperpolarization chamber may be designed so that the fluid flows through the focus volume or volumes. This of course may enable continuous hyperpolarization. The fluid hyperpolarizer may also have a flow sensor for controlling the fluid flow through the polarization chamber. This may enable the embodiment of using a controller to adjust or control the fluid flow rate or the fluid exposure duration.

In another embodiment the hyperpolarization chamber comprises a nuclear polarization detector for measuring the hyperpolarization of the fluid at the fluid outlet. The nuclear polarization detector may for instance incorporate a magnet and a coil for measuring an NMR signal from the fluid. This embodiment may be beneficial because the amount of hyperpolarization can be better controlled. For instance a process or other control system may use the measurement of the hyperpolarization of the fluid to control the intensity of the X-ray beams and/or the fluid flow rate to make the hyperpolarization more uniform.

In another embodiment the X-ray optics surrounding the spiral zone plate or plates incorporates a central stop array and an order sorting aperture for better controlling the focus of the narrow band X-ray beam into the focus volume.

In another aspect the invention provides for a nuclear magnetic resonance spectrometer for acquiring nuclear magnetic resonance data from an analysis volume. The nuclear magnetic resonance spectrometer comprises a fluid hyperpolarizer according to an embodiment of the invention. The analysis volume as used herein encompasses a region of a magnetic field generated by a magnet of the nuclear magnetic resonance spectrometer which is of sufficient strength and uniformity for producing a region from which a magnetic resonance spectra data is able to be acquired. The nuclear magnetic resonance spectrometer further comprises a sample chamber at least partially within the analysis volume. The nuclear magnetic resonance spectrometer further comprises a conduit for connecting the fluid outlet to the sample chamber. The conduit is operable for supplying the sample chamber with the fluid. Various embodiments may comprise a controller for acquiring the nuclear magnetic resonance spectral data and/or controlling the operation of the spectrometer.

In another embodiment the nuclear magnetic resonance spectrometer further comprises a blood pump system operable for pumping blood from a subject and supplying at least one blood component to the fluid inlet. This embodiment may be very beneficial because it may enable the blood component to be analyzed automatically. A blood pump as used herein may encompass a simple pump or it may also contain components which are used to process and/or filter the blood. For instance the blood pump may include a device for diluting the blood, it may also comprise a centrifuge, membrane or other means for separating the blood component out.

In another embodiment the blood pump system is further operable for returning the blood to the subject. In this case the blood pump system may function similarly to those pumps used for kidney dialysis and/or extracting plasma from the blood of a subject.

In another embodiment the sample chamber further comprises a sample outlet. The blood pump system is operable for returning the at least one blood component to the blood using the sample outlet before returning the blood to the subject.

In another aspect the invention provides for a magnetic resonance imaging system operable for acquiring magnetic resonance data from an imaging volume. The magnetic resonance imaging system further comprises a fluid hyperpolarizer according to an embodiment of the invention. The magnetic resonance imaging system further comprises a dispenser operable for receiving the fluid from the fluid hyperpolarizer. The dispenser is operable for injecting the fluid into a subject located at least partially within the imaging volume. The dispenser and the fluid hyperpolarizer may be incorporated into a single unit in some embodiments. The hyperpolarized fluid is generated from the fluid. This embodiment may be beneficial because the fluid hyperpolarizer creates the hyperpolarized fluid immediately before use. This may increase the effectiveness of using the hyperpolarized fluid for magnetic resonance imaging.

In another embodiment the magnetic resonance imaging system further comprises a memory for storing machine executable instructions. The magnetic resonance imaging system further comprises a processor for controlling the medical apparatus. Execution of the instructions causes the processor to generate the hyperpolarized fluid using the fluid hyperpolarizer. Execution of the instructions further causes the processor to control the dispenser to inject the subject with the hyperpolarized fluid. Execution of the instructions further causes the processor to acquire the magnetic resonance data. This embodiment may be beneficial because the magnetic resonance imaging system can automatically generate a hyperpolarized fluid and inject it into a subject. These steps caused by the processor may also be used to form the steps for a method or for machine executable instructions on a computer-readable storage medium. As such the invention may also provide for a method and a computer program product.

In another embodiment the magnetic resonance imaging system comprises a magnet operable to generate a main magnetic field. The hyperpolarization chamber is located within the main magnetic field. This embodiment may be beneficial because the hyperpolarized fluid may be generated within the magnetic field. This may eliminate the loss of hyperpolarization when the hyperpolarized fluid is brought into the magnetic field.

In another embodiment the narrow band X-ray beam has a trajectory through the focus volume. The main magnetic field has a direction. That is to say that the field lines of the main magnetic field have a direction. The trajectory is parallel to the trajectory. This embodiment may be beneficial because the nuclei are polarized and have their polarization aligned with the main magnetic field.

In another embodiment the narrow band X-ray source is located outside of the main magnetic field. For instance the X-ray source may be a bit remote from the magnet of the magnetic resonance imaging system and X-rays may travel through a tube with a vacuum or gas that does not absorb the X-rays very well. Removing the X-ray source from the vicinity of the magnet may be beneficial because X-rays are typically generated using an electron beam. Moving the electron beam further away from the magnetic field may provide for a lower cost method of providing the X-ray source. For instance a conventional MRI system may be retrofitted with the fluid hyperpolarizer as opposed to constructing a custom magnet for magnetic resonance imaging system that has a region of low magnetic field where the X-ray source can be located.

It is understood that one or more of the aforementioned embodiments of the invention may be combined as long as the combined embodiments are not mutually exclusive.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following preferred embodiments of the invention will be described, by way of example only, and with reference to the drawings in which:

Fig. 1 illustrates a fluid hyperpolarizer according to an embodiment of the invention;

Fig. 2 illustrates the typical X-ray flux spectrum from an X-ray tube.

Fig. 3 illustrates a spiral zone plate;

Fig. 4 shows a further view of the spiral zone plate of Fig. 3;

Fig. 5 illustrates a spiral zone plate;

Fig. 6 illustrates a nuclear magnetic resonance spectrometer according to an embodiment of the invention;

Fig. 7 illustrates a nuclear magnetic resonance spectrometer according to a further embodiment of the invention; and

Fig. 8 illustrates a magnetic resonance imaging system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Like numbered elements in these figures are either equivalent elements or perform the same function. Elements which have been discussed previously will not necessarily be discussed in later figures if the function is equivalent.

Embodiments of the invention may provide for inducing nuclear hyperpolarization in liquids using X-rays endowed with Orbital Angular Momentum (OAM). The embodiments described here may provides details on: (1) the generation and preparation of X-ray beams endowed with various amounts of OAM, (2) the manipulation of an OAM X-ray beam relative to a liquid sample in order to achieve optimal nuclear polarization, and (3) proposed device designs configured to induced nuclear polarization using OAM X-rays in specific liquid targets like water and saline solutions, or in blood, which may be removed from the body and possibly re-injected into the vasculature after being hyperpolarized and potentially mixed with additional substances.

After the inducement of nuclear hyperpolarization in a liquid sample, the nuclear magnetic resonance (NMR) signal of the sample can be interrogated using conventional NMR imaging (MRI) or magnetic resonance spectroscopy (MRS) methods and equipment. Depending on the choice of liquid sample and embodiment of the hyperpolarization device, including how it is integrated or interfaced with the NMR measurement system, the subsequent MRI or MRS measurement may enable unique medical diagnostic procedures to be conducted that would otherwise not be possible. Examples of medical procedures enabled by this invention are: detection and assessment of cancerous tissue, detection and assessment of vascular disorders like atherosclerosis, and detection and assessment of a wide range of metabolic disorders.

Detection and assessment of cancerous tissue can be enabled using this invention by hyperpolarizing a saline solution of 13C-labeled Pyruvate, which is injected into a patient who subsequently undergoes an MRS procedure inside a conventional MRI scanner. The resulting MRS measurement will reveal the distribution of the 13C-labeled Pyruvate, as well as the key metabolic by-products of Pyruvate, Lactate and Alanine. The ratios of Pyruvate, Lactate and Alanine in the tissue under investigation will allow detection and assessment of malignant tumours.

Detection and assessment of vascular disorders like atherosclerosis can be performed can be enabled using this invention by hyperpolarizing a solution of 13C-enriched water-soluble compound (bis-1,1-(hydroxymethyl)-1-13C-cyclopropane-D8), which is injected into a patient who subsequently undergoes an MR Angiogram (MRA) procedure inside a conventional MRI scanner. The MRA will reveal the distribution of hyperpolarized saline inside the patient's vasculature and thereby reveal the geometry of the interior of the patient's blood vessels.

Finally, there is large spectrum of metabolic disorders that are potentially detectable using MRS. This invention will enable detection and assessment of these disorders by directing a sample of blood or other body fluid into a hyperpolarization device and subsequently directing the hyperpolarized fluid sample into the MRS measurement equipment. The fluid may or may not be reintroduced back into the patient (similar to how a dialysis machine removes blood, then interacts with it before re-injecting it into the patient). Metabolic disorders and the associated target molecules that may be measured with a hyperpolarized MRS method or apparatus according to the invention may be found in the journal article "MR spectroscopy of metabolic disorders" Neuroimaging Clin N Am. (2006), Vol.16(1), pages 87-116 by KM Cecil.

Embodiments of the invention may overcomes the limitations of existing methods by enabling hyperpolarized liquid samples to be generated at the point of use inside or nearby a conventional MRI scanner. For example, liquid samples can be hyperpolarized as they are being injected into a patient or blood samples can be hyperpolarized as they are being removed from the patient. This hyperpolarization method is also non-destructive and allows blood and other substances (e.g. cells, proteins) to be hyperpolarized without disrupting their natural state. The ability to generate states of high degrees of polarization allows the subsequent MRI/MRS measurement to detect substances that are present in extremely low concentrations, which would be invisible to conventional MRI/MRS measurements.

The enhancement of the nuclear magnetic polarization (hyperpolarization) of fluids at room temperature with ~10keV X-rays beams endowed with OAM of charge 40 has been experimentally tested.

Embodiment of the invention may be designed to induced large nuclear polarization (in excess of 10%) using OAM X-rays in flowing liquid targets (e.g. water, saline solutions or blood, which may be removed from the body and possibly re-injected into the vasculature after being hyperpolarized and potentially mixed with additional substances.

Fig. 1 illustrates a fluid hyperpolarizer 100 according to an embodiment of the invention. The fluid hyperpolarizer 100 comprises a narrow band X-ray source 102. The fluid hyperpolarizer 100 further comprises a spiral zone plate 104. The fluid hyperpolarizer 100 is shown as further comprising a hyperpolarization chamber 106. Within the hyperpolarization chamber there are a number of focus volumes 108. The narrow band X-ray source 102 generates a narrow band X-ray beam 110. The narrow band X-ray beam 110 is shown in an expanded view 112. The narrow band X-ray beam goes through a spiral zone plate 104. In this example there are multiple spiral zone structures on the plate. The spiral zone plate 104 imparts an orbital angular momentum to the X-ray beams and focuses them to the focus volumes 108. There is a fluid 114 within the hyperpolarization chamber 106. Fig. 1 also shows an optional controller 116. The controller 116 may be used to control various components of the fluid hyperpolarizer 100. For example in this embodiment there is an optional fluid inlet 118 and fluid outlet 120 which enables fluid to enter and exit the hyperpolarization chamber 106 continuously. A hyperpolarized fluid may therefore be generated continuously or on demand. The controller 116 may be used to control the operation and function of the fluid controller 122. The controller 116 and the fluid controller 122 are shown as having a connection to the controller 124. Connections for other components with the controller 116 are also labeled 124.

An example of the construction of the narrow band X-ray source 102 is also shown. The narrow band X-ray source is shown as comprising an X-ray tube 126. The X-ray tube 126 is operable for producing a broad spectrum X-ray beam 128. The broad spectrum X-ray beam 128 then goes through a spatial filter 103. After traveling through the spatial filter 130 the X-ray beam is then passed through a transversal coherence filter 132. The transversal coherence filter 132 may for instance may be rectangular-shape channels through a plate. The X-ray beam then further passes through another spatial filter 134. The combination of the two spatial filters 130, 134 and the transversal coherence filter 132 provide X-rays that are traveling relatively parallel to each other and may then be fed into an X-ray monochromator 138. Between the spatial filter 134 and the X-ray monochromator 138 there is an electronic shutter 136 for stopping or blocking the broadband X-ray beam 128. At the exit of the X-ray monochromator 138 the broad spectrum X-ray beam 128 has been transformed into the narrow band X-ray beam 110. The narrow band X-ray beam 110 has a restricted bandwidth and the photons travel relatively parallel to one another. It can be seen that the controller 116 may also be used for controlling the operation and function of the components of the narrow band X-ray source 102.

Next the narrow band X-ray beam 112 passes through an array of stops. There is a stop for each of the spiral zone plates 104. At the exit of each of the spiral zone plates 104 there is X-ray beams with orbital angular momentum 142. Before passing into the hyperpolarization chamber 106 the X-ray beams 142 are again passed through an order sorting aperture 144. The spiral zone plate 104 focuses the X-rays using a combination of a fork hologram with a Fresnel-type lens. The order sorting aperture 144 blocks higher orders from the spiral zone plate 104.

In the embodiment shown in Fig. 1 there is shown an optional X-ray intensity meter 146. The X-ray intensity meter is operable and is connected 124 for communicating with the controller 116. The X-ray intensity meter 146 uses a sensor or sensors for detecting the intensity of X-ray energy coming through the hyperpolarization chamber 106. This may be useful for maintaining a constant level of hyperpolarization. The placement of the X-ray intensity meter 146 may be in different locations. For instance the beam may be sampled at some point prior to it entering the hyperpolarization chamber 106. Before the fluid 114 reaches the outlet 120 in this embodiment there is an optional nuclear polarization device 148. The nuclear polarization device 148 is operable for measuring hyperpolarization of the fluid 114. The nuclear polarization device 148 for example may be a small or simple NMR spectrometer. For example the nuclear polarization device 148 is connected with the controller 116. The fluid 114 flows through a duct on its way to the outlet 120 which is surrounded by an NMR coil 152. This is within the magnetic field generated by the magnets 150. The arrow 154 shows the direction of the magnetic field generated by the magnets 150. This is also the same direction in which the fluid 114 is polarized.

In the context of Fig.1, a method and device for imparting high levels of nuclear magnetic polarization at room temperature if flowing fluids is describe. The fluid flow injected in the hyperpolarization chamber 106 is controlled and monitored with a standard fluid flow controller 122.

While in the hyperpolarization chamber 106 the targeted fluid is irradiated with an array of ~25keV X-ray beams, each endowed with OAM of a fixed charge (e.g. OAM = 40) and optically focused to a beam with a beam waist of ~ 0.5μm .. 4μm, for a depth of focus ranging from ~10μm to 400μm (as a function of the optical elements and OAM charge). The interaction of the OAM with the molecules within the fluid establish the alignment of the molecular momenta to the direction of the OAM vector, and consequently – through hyperfine interaction – lead to the alignment along the same direction of the nuclear magnetic momenta of the nuclei.

The nuclear polarization is proportional to the intensity of the beam, the square of the OAM value, reverse proportional to the square of the wavelength of the photons within the beam and reverse proportional to the beam waist of the beam.

A step function of the intensity of the beam determines an exponentially saturated increase of the nuclear polarization in time with a linear time parameter dependent of the molecular specificity.

For a single X-ray beam endowed with OAM, the polarized volume included within the boundaries of the “depth of focus” region is in the range of $10^5 \mu m^3$. The “time constant” T_H measured for 19-crown-ether at 12.8keV X-rays endowed with an OAM=40, and a photon flux of ~10^9 photons/s has been found in the range of seconds.

It has been devised – from practical reasons - that a “useful” flow of hyperpolarized fluid to be used for medical applications is in the range of 2µl/s

Embodiment of the invention may provide for a method and an apparatus capable of delivering a hyperpolarized fluid flow in excess of $2x10^9 \mu m^3/s$. Actions which may help the hyperpolarization be more efficient include:

1. use ~25keV X-ray beams (a gain of ~ 6 folds compare to the ~ 10keV used in the experiments)
2. use higher OAM values (e.g. OAM 200, a gain of 25)
3. use multiple beams (e.g. 50, a gain of 50)
4. increase the bandwidth of the X-ray energy beam, therefore increase the photon flux (~ by a factor of 10).

Taking such action could improve the “gain” of the device as 6 X 25 X 50 X 10 = 75,000, factor which shall allow the polarization of 75 x 103 x 105 $\mu m^3/s = 7.5 \times 10^9 \mu m^3/s$ = 7.5µl/s, which shall be sufficient for a large number of medical applications.

Fig. 2 illustrates the X-ray flux from a typical X-ray tube. The x-axis is the energy 200 in keV and the y-axis is the X-ray flux 202 in arbitrary units. In this plot is shown the X-ray emission for silver target 204 and an indium alloy target 206. On the plot the location of the silver K_α line for silver is labeled 210. The K_α line 208 for indium 206 is also labeled. It can be seen that the emission of the two K_α lines 208, 210 is roughly a factor of 10 higher than the surrounding Bremsstrahlung emission at the adjacent energies. It may therefore be beneficial in some embodiments to adjust the X-ray monochromator to use the X-rays at the K_α lines to increase the intensity of the narrow beam X-ray beam.

For example, a microfocus X-ray tube operated at ~ 40kV, with an anode with a K_α resonant emission at around 25keV. The flux corresponding to the resonant K_α level emission is ~10 time higher than the Bremsstrahlung emission at adjacent energies. This is illustrated in Fig. 2.

The transversal coherence of the source may be controlled with the transversal coherence source filter and spatial filters (pin holes).

The longitudinal/temporal coherence of the X-ray beam is controlled by a monochromator made with two Si <111> crystals, oriented at angles appropriate for the selection of the 25keV beam.

The bandwidth of the signal is a parameter of the system and can be controlled/modified with the monochromator in conjunction with the spatial filters dimensions

The X-ray beam flux and energy may be controlled with the X-ray tube power (anode voltage, beam current), and optical train parameters (pin holes sizes, monochromator angles), in a close loop with the "Intensity measurement device", which is placed as the termination of the optical train.

An elements used for the generation of X-ray beams with OAM the purpose are the diffractive optical elements call "Spiral Zone Plates", which combine a phase zone plate with focusing Fresnel zone plates. Figs. 3 and 4 depicts some geometrical details of the spiral zone plate used for imparting an OAM = 40 to an ~ 10 keV X-ray beam.

Figs. 3 and 4 show scanning electron microscope images of a spiral zone plate 300 with an orbital angular momentum charge 40. The spiral zone plate has 300 μm diameter objects with 40 nm outermost zone with half period. The spiral zone plate 300 is a combination of a phase zone plate with a focusing Fresnel zone plate. The spiral zone plate 300 shown in Figs. 3 and 4 are used for imparting an orbital angular momentum of 40 to a 10 kev X-ray beam.

In order to generate multiple beams endowed with OAM, the pattern of a single spiral zone plate can be in multiple locations on a 2D plane, with a separation of ~ 50μm between adjacent elements.

Fig. 5 shows an example of an array 500 of spiral zone plates 502. The spiral zone plate array 500 comprises 52 spiral zone plates 502. Each has an orbital angular momentum charge of 10. The individual spiral zone plate patterns are indented to be representative and are not accurate in this Fig.

The optical train for these diffractive elements call for isomorphic arrays of "central stop" elements, (with the function of attenuating of the zero order X-ray beams) and "order sorting aperture" elements (with the function of attenuation the higher order diffraction beams, generated by the spiral zone plates)

A sample holder device or hyperpolarization chamber may for instance be a fluid cuvette with thin walls (0.2mm) and low X-ray attenuation, with a thickness higher than the “depth of focus” (~ 1.5mm) and an exposed surface larger than the projection of the OAM beam array at the focal plane (for the 52 elements array, an exposed surface of a circle with a 3 mm diameter).

The fluid is injected within this cuvette with a “flow control device”, which is controlled in a feedback loop with the “NMR polarization measuring device”

To further improve the repeatability of the hyperpolarization of the fluid, a miniature NMR polarization measuring device may be used. The micro NMR device, may be capable of creating a Larmor magnetic field (with an electromagnet, at low fields of ~ 50mT) and parallel to the orientation of the hyperpolarization vector (parallel to the OAM vector and the direction of the propagation of the X-ray beams). The RF transmit and receive coils are winded around the fluid outlet. The NMR pulse sequence interrogates the fluid with small flip angles, such that the hyperpolarized state is not significantly modified during the measurements. The time between the measurements is controllable. The measurement results are used for controlling the optical parameters of the hyperpolarizer (X-ray beam power, energy, bandwidth, coherence) within an algorithm that optimizes the cost functions for the nuclear degree of polarization and polarization timing. The specificity of the hyperpolarized molecule, dilution and temperature are also taken into account.

Applications of the invention include medical procedures enabled by this invention are: detection and assessment of cancerous tissue, detection and assessment of vascular disorders like atherosclerosis, and detection and assessment of a wide range of metabolic disorders.

Fig. 6 illustrates a nuclear magnetic resonance spectrometer 600 according to an embodiment of the invention. The nuclear magnetic resonance spectrometer 600 comprises a fluid hyperpolarizer 100. The fluid hyperpolarizer has an inlet 118 and an outlet 120. There is a conduit 601 connecting the outlet 120 to a sample chamber 602. The spectrometer 600 further comprises a magnet 604 for generating a magnetic field. This magnetic field forms an analysis volume 606 from which nuclear magnetic resonance data may be acquired. Surrounding the sample chamber 602 is a nuclear magnetic resonance coil 608 for acquiring the data. Components such as power supplies and radio-frequency systems are well understood in the art and are not illustrated in this Fig. The nuclear magnetic resonance spectrometer 600 is shown as being optionally connected to a hardware interface 612 of a computer system 610. In some embodiments the nuclear magnetic resonance spectrometer 600 may comprise a computer 610 or other control or control system. The hardware interface is connected to a processor 614. The hardware interface enables the processor 614 to control the operation and function of the nuclear magnetic resonance spectrometer 600. The computer system is shown as further having a computer interface 616, computer storage 618 and a computer memory 620 connected to the processor 614. The computer storage 622 is shown as containing nuclear magnetic resonance spectra data 622 acquired from the nuclear magnetic resonance spectrometer 600. The computer storage 618 is further shown as containing a nuclear magnetic resonance spectra 624. The nuclear magnetic resonance spectra 624 was reconstructed from the nuclear magnetic resonance spectra data 622. The computer storage 620 is shown as containing a control module 626. The control module 626 contains computer executable code which enables the processor 614 to control the operation and function of the nuclear magnetic resonance spectrometer 600. This may include such things as operating the fluid hyperpolarizer and also for acquiring the nuclear magnetic resonance spectra data. The computer memory 620 is further shown as containing a reconstruction module 628. The reconstruction module contains computer executable code which enables the processor 614 to reconstruct the nuclear magnetic resonance spectra 624 from the nuclear magnetic resonance spectra data 622.

Fig. 7 illustrates a nuclear magnetic resonance spectrometer 600' according to a further embodiment of the invention. The nuclear magnetic resonance spectrometer 600' comprises a nuclear magnetic resonance spectrometer 600 that is connected to a blood pump 700. The blood pump 700 has a sample inlet 702 for receiving blood or a blood product and a sample outlet 704 which is optionally there to return the blood or blood product to a subject 706. Blood is pumped through the inlet 702 into the blood pump 700. The blood pump may either provide blood directly to the spectrometer 600 or it may process and/or separate the blood. For instance the blood may be thinned and/or a blood component may be removed from the blood. In any event at least one blood component is pumped from the blood pump 700 to the spectrometer 600. The nuclear magnetic resonance spectral data is acquired and the blood product is optionally returned to the blood pump 700. The blood or blood component may also be optionally returned to the subject 706. The spectrometer 600' is shown as being controlled by a computer system 610 which is equivalent in function to the computer system shown in Fig 6. The control module 626 also contains code for controlling the operation and function of the blood pump 700.

Fig. 8 illustrates a magnetic resonance imaging system 800 according to an embodiment of the invention. The magnetic resonance imaging system 800 is shown as comprising a magnet 804. The magnet 804 is a cylindrical type superconducting magnet with a bore 806 through the center of it. The magnet 804 has a liquid helium cooled cryostat with superconducting coils. It is also possible to use permanent or resistive magnets. The use of different types of magnets is also possible for instance it is also possible to use both a split cylindrical magnet and a so called open magnet. A split cylindrical magnet is similar to a standard cylindrical magnet, except that the cryostat has been split into two sections to allow access to the iso-plane of the magnet, such magnets may for instance be used in conjunction with charged particle beam therapy. An open magnet has two magnet sections, one above the other with a space in-between that is large enough to receive a subject: the arrangement of the two sections area similar to that of a Helmholtz coil. Open magnets are popular, because the subject is less confined. Inside the cryostat of the cylindrical magnet there is a collection of superconducting coils. Within the bore of the cylindrical magnet there is an imaging zone 802 where the magnetic field is strong and uniform enough to perform magnetic resonance imaging.

Also within the bore of the magnet is a magnetic field gradient coil 810 which is used for acquisition of magnetic resonance data to spatially encode magnetic spins within the imaging zone 802 of the magnet. The magnetic field gradient coil 810 is connected to a magnetic field gradient coil power supply 812. The magnetic field gradient coil is representative. Typically magnetic field gradient coils contain three separate sets of coils for spatially encoding in three orthogonal spatial directions. A magnetic field gradient power supply 812 supplies current to the magnetic field gradient coils. The current supplied to the magnetic field coils is controlled as a function of time and may be ramped and/or pulsed.

Adjacent the imaging zone 804 is a radio-frequency coil 814. The radio-frequency coil 814 is connected to a radio-frequency transceiver 816. Also within the bore of the magnet 804 is a subject 706 that is reposing on a subject support 808 and is partially within the imaging zone 802.

Adjacent to the imaging zone 802 is a radio-frequency coil 814 for manipulating the orientations of magnetic spins within the imaging zone 802 and for receiving radio transmissions from spins also within the imaging zone 802. The radio-frequency coil 814 may contain multiple coil elements. The radio-frequency coil 814 may also be referred to as a channel or an antenna. The radio-frequency coil is connected to a radio frequency transceiver 816. The radio-frequency coil 814 and radio frequency transceiver 816 may be replaced by separate transmit and receive coils and a separate transmitter and receiver. It is understood that the radio-frequency coil 814 and the radio-frequency transceiver 816 are representative. The radio-frequency coil 814 is intended to also represent a dedicated transmit antenna and a dedicated receive antenna. Likewise the transceiver 816 may also represent a separate transmitter and a separate receiver.

The magnetic resonance imaging system 800 is shown as further comprising a fluid hyperpolarizer 100. The fluid hyperpolarizer 100 is shown as supplying a dispenser 818 with hyperpolarized fluid. The dispenser 818 is operable for dispensing the hyperpolarized fluid to the subject 706 using a dispensing tube 820.

The magnetic field gradient coil power supply 812, the radio-frequency transceiver 816, fluid hyperpolarizer 100, and the dispenser 818 are connected to the hardware interface 612 of a computer system 610. The computer system 610 is equivalent to that as shown in Figs. 6 and 7.

The computer storage 618 is shown as containing a pulse sequence 822. The pulse sequence 822 either comprises instructions used for controlling the magnetic resonance imaging system 800 to acquire magnetic resonance data 824 or a time sequence of commands which may be converted into instructions for controlling the magnetic resonance imaging system to acquire magnetic resonance data. The computer storage 618 is further shown as containing magnetic resonance data 824 that was acquired from the magnetic resonance imaging system using the pulse sequence 822. The computer storage 618 is further shown as containing a magnetic resonance image 826 reconstructed from the magnetic resonance data 824.

The computer memory 620 is shown as containing a control module 830. The control module contains computer executable code which enables the processor 614 to control the operation and function of the magnetic resonance imaging system 800. For instance the control module 830 may enable the processor 614 to use the pulse sequence 822 to acquire the magnetic resonance data 824. The pulse sequence 822 may also contain commands or instructions which can be converted into commands for controlling the operation of the fluid hyperpolarizer and the dispenser 818. In this way the hyperpolarized fluid can be dispensed in a way which is optimal for the acquisition of the magnetic resonance data 824. The computer memory 620 is further shown as containing an image reconstruction module 832. The reconstruction module 832 contains computer executable code which enables the processor 614 to reconstruct the magnetic resonance image 826 from the magnetic resonance data 824.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE NUMERALS

100	fluid hyperpolarizer
102	narrow band X-ray source
104	spiral zone plate
106	hyperpolarization chamber
108	focus volume
110	narrow band X-ray beam
112	expanded view of narrow band X-ray beam
114	fluid
116	controller
118	fluid inlet
120	fluid outlet
122	flow controller
124	connection to controller
126	X-ray tube
128	broad spectrum X-ray beam
130	spatial filter
132	transversal coherence filter
134	spatial filter
136	electronic shutter
138	X-ray monochromator
140	central stop array
142	X-ray beams with orbital angular momentum
144	order sorting aperture
146	X-ray intensity meter
148	nuclear polarization device
150	magnet
152	NMR coils
154	direction of polarization
200	energy in keV
202	X-ray flux in arbitrary units
204	silver
206	Indium allow
208	silver K_α line

210	Indium alloy K_α line
300	spiral zone plate
500	spiral zone plate array
502	spiral zone plate
600	nuclear magnetic resonance spectrometer
600’	nuclear magnetic resonance spectrometer
601	conduit
602	sample chamber
604	magnet
606	analysis volume
608	NMR coil
610	computer
612	hardware interface
614	processor
616	user interface
618	storage
620	memory
622	nuclear magnetic resonance spectra data
624	nuclear magnetic resonance spectra
626	control module
628	reconstruction module
700	blood pump
702	sample inlet
704	sample outlet
706	subject
800	magnetic resonance imaging system
802	imaging volume
804	magnet
806	bore of magnet
808	subject support
810	magnetic field gradient coil
812	magnetic field gradient coil power supply
814	radio frequency coil
816	radio frequency transceiver

818	dispenser
820	dispenser tube
822	pulse sequence
824	magnetic resonance data
826	magnetic resonance image
830	control module
832	image reconstruction module

CLAIMS:

1. A fluid hyperpolarizer (100) for hyperpolarizing a fluid (114), wherein the fluid hyperpolarizer comprises:

- a narrow band X-ray source (102) for producing a narrow band X-ray beam (110, 112),
- at least one spiral zone plate (104) operable for imparting orbital angular momentum to the narrow band X-ray beam and operable for focusing the narrow band X-ray beam into a focus volume (108), and
- a hyperpolarization chamber (106) for receiving the fluid, wherein the focus volume is within the hyperpolarization chamber.

2. The fluid hyperpolarizer of claim 1, wherein the spiral zone plate is a zone plate combining a phase zone plate and a Fresnel zone plate.

3. The fluid hyperpolarizer of claim 1 or 2, wherein the narrow band X-ray source comprises:

- an X-ray tube (126) operable for generating a broad spectrum X-ray beam (138);
- a monochromator (138) operable for producing the narrow band X-ray beam using the broad spectrum X-ray beam.

4. The fluid hyperpolarizer of any one of the preceding claims, wherein the hyperpolarization chamber further comprises an X-ray intensity sensor (146) for measuring an intensity level of the narrow band X-ray beam, wherein the fluid hyperpolarizer further comprises a control unit (116) operable for adjusting the intensity of the X-ray beam.

5. The fluid hyperpolarizer of any one of the preceding claims, wherein the fluid hyperpolarizer further comprises a fluid inlet (118) and a fluid outlet (120), wherein the fluid inlet is operable for supplying fluid to the hyperpolarization chamber, and wherein the fluid outlet is operable for draining fluid from the hyperpolarization chamber.

6. The fluid hyperpolarizer of claim 5, wherein the hyperpolarization chamber further comprises a nuclear polarization detector (148) for measuring the hyperpolarization of the fluid at the fluid outlet.

7. A nuclear magnetic resonance spectrometer (600, 600') for acquiring nuclear magnetic resonance spectra data (622) from an analysis volume (606), wherein the nuclear magnetic resonance spectrometer comprises:

- a fluid hyperpolarizer (100) according to claim 5 or 6;
- a sample chamber (602) at least partially within the analysis volume; and
- a conduit (601) for connecting the fluid outlet to the sample chamber, wherein the conduit is operable for supplying the sample chamber with the fluid.

8. The nuclear magnetic resonance spectrometer of claim 7, wherein the nuclear magnetic resonance spectrometer comprises a blood pump system (700) operable for pumping blood from a subject (706) and supplying at least one blood component to the fluid inlet.

9. The nuclear magnetic resonance spectrometer of claim 8, wherein the blood pump system is further operable for returning the blood to the subject.

10. The nuclear magnetic resonance spectrometer of claim 9, wherein the sample chamber further comprises a sample outlet (704), wherein the blood pump system is operable for returning the at least one blood component to the blood using the sample outlet before returning the blood to the subject.

11. A magnetic resonance imaging system (800) operable for acquiring magnetic resonance data from an imaging volume, wherein the magnetic resonance imaging system comprises:

- a fluid hyperpolarizer (100) according to claim 5 or 6, wherein the hyperpolarizer is operable for producing a hyperpolarized fluid; and
- a dispenser (818) operable for receiving the fluid from the fluid hyperpolarizer, wherein the dispenser is operable for injecting the fluid into a subject (706) located at least partially within the imaging volume.

12. The magnetic resonance imaging system of claim 11, wherein the magnetic resonance imaging system further comprises:

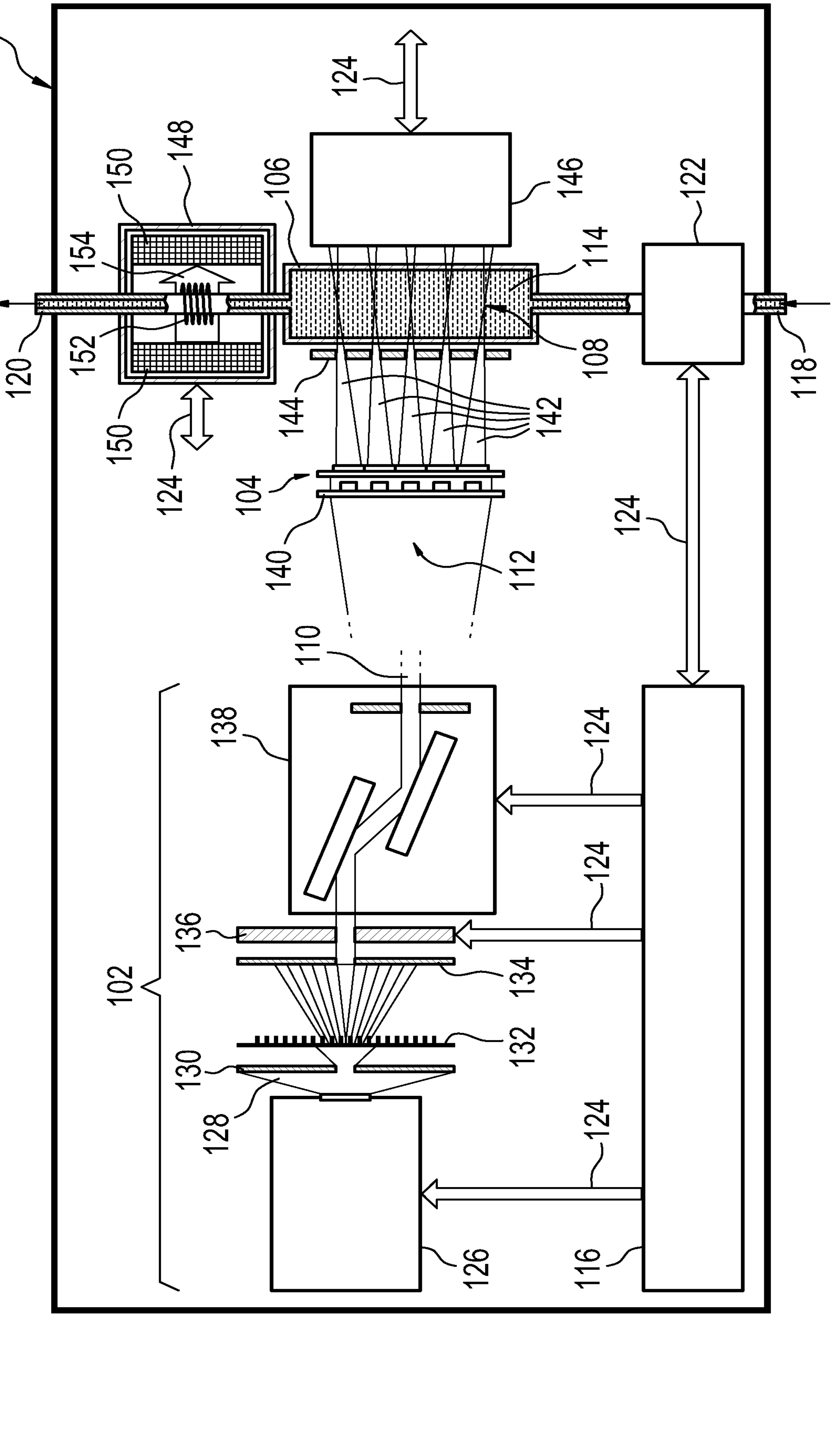
- a memory (620) for storing machine executable instructions (830, 832); and
- processor (614) for controlling the medical apparatus, wherein execution of the instructions causes the processor to:
  - generate the hyperpolarized fluid using the fluid hyperpolarizer;
  - control the dispenser to inject the subject with the hyperpolarized fluid; and
  - acquire the magnetic resonance data.

13. The magnetic resonance imaging system of claim 12, wherein the magnetic resonance imaging system comprises a magnet (804) operable for generating a main magnetic field, wherein the hyperpolarization chamber is located within the main magnetic field.

14. The magnetic resonance imaging system of claim 11, 12, or 13, wherein the narrow band X-ray beam has a trajectory through the focus volume, wherein the main magnetic field has a direction, and wherein the trajectory is parallel to the trajectory.

15. The magnetic resonance imaging system of claim 13 or 14, wherein the narrow band X-ray source is located outside of the main magnetic field.

FIG. 1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150
124
144
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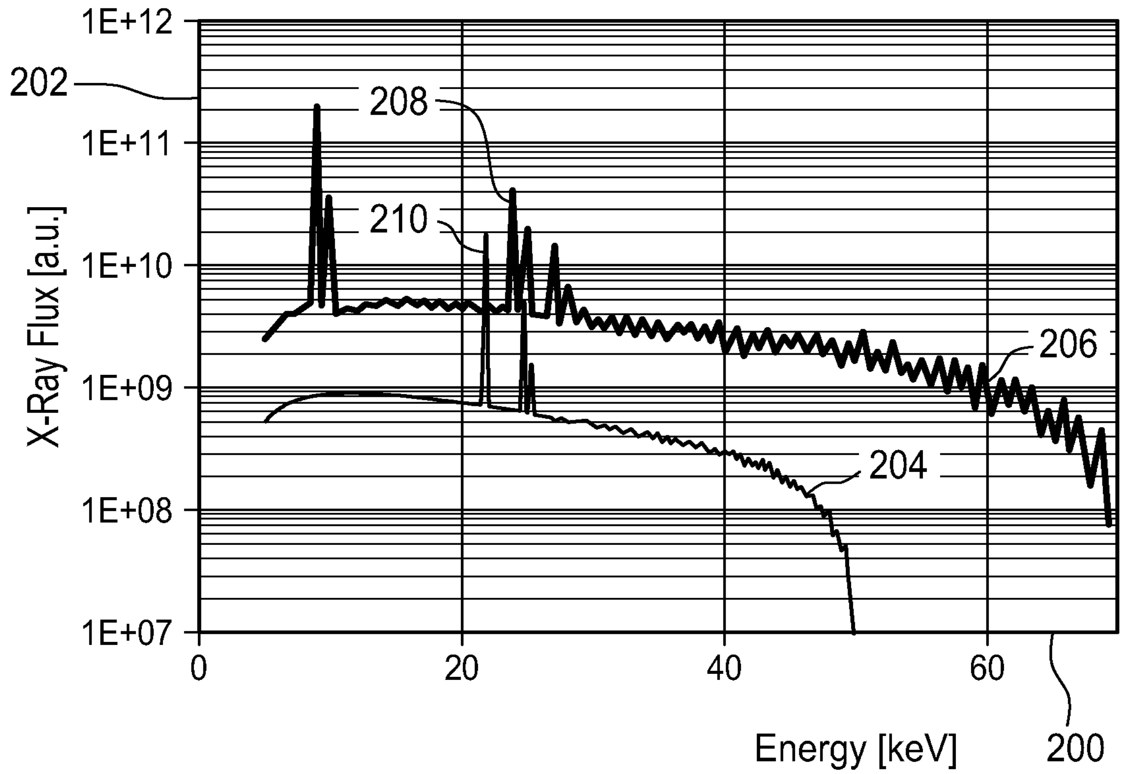
128
124
126
116

FIG. 2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1E+11
1E+10
1E+09
1E+08
1E+07
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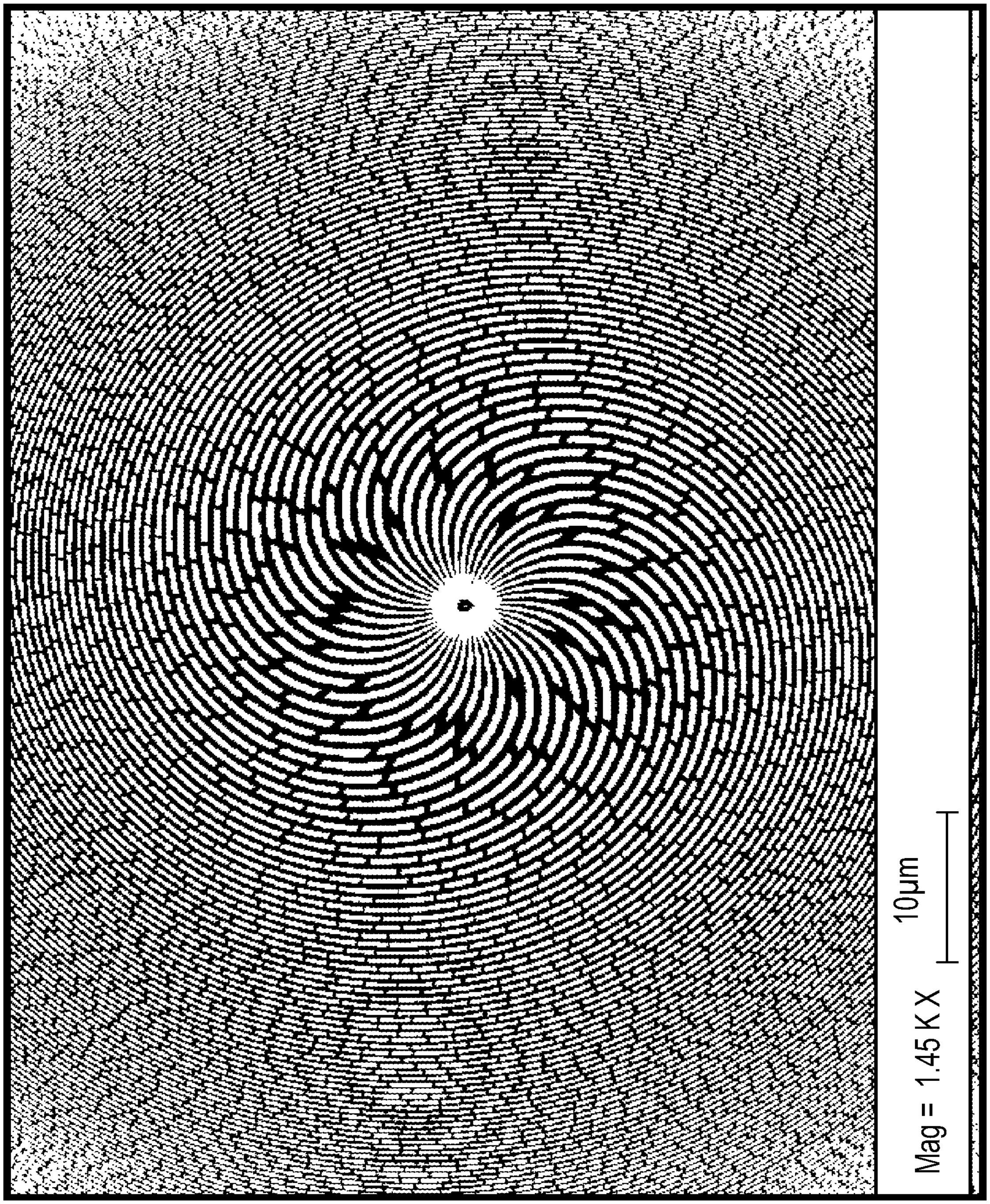
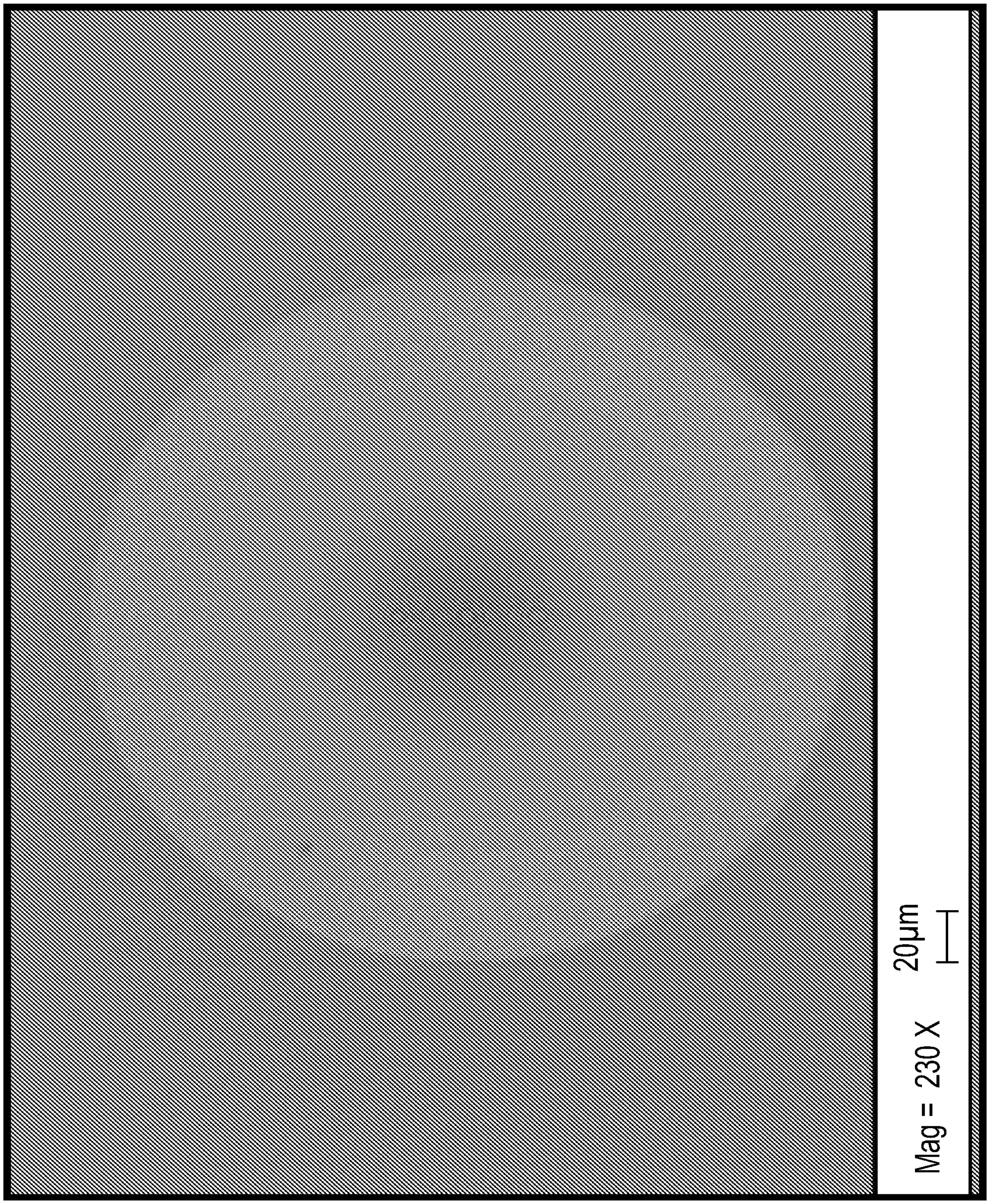
204
0
20
40
60
Energy [keV]
200



300

FIG. 3



300

FIG. 4

FIG. 5

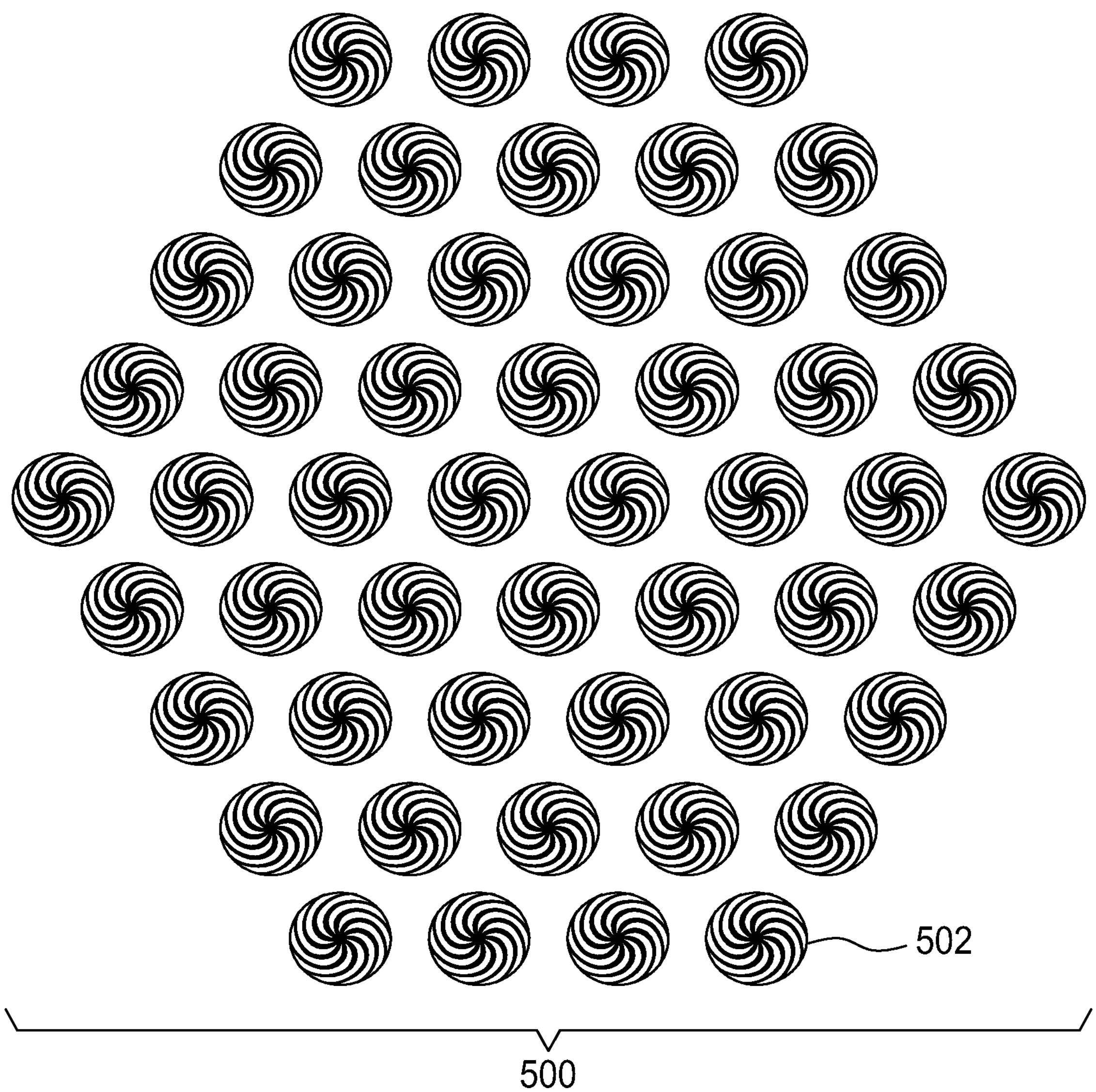
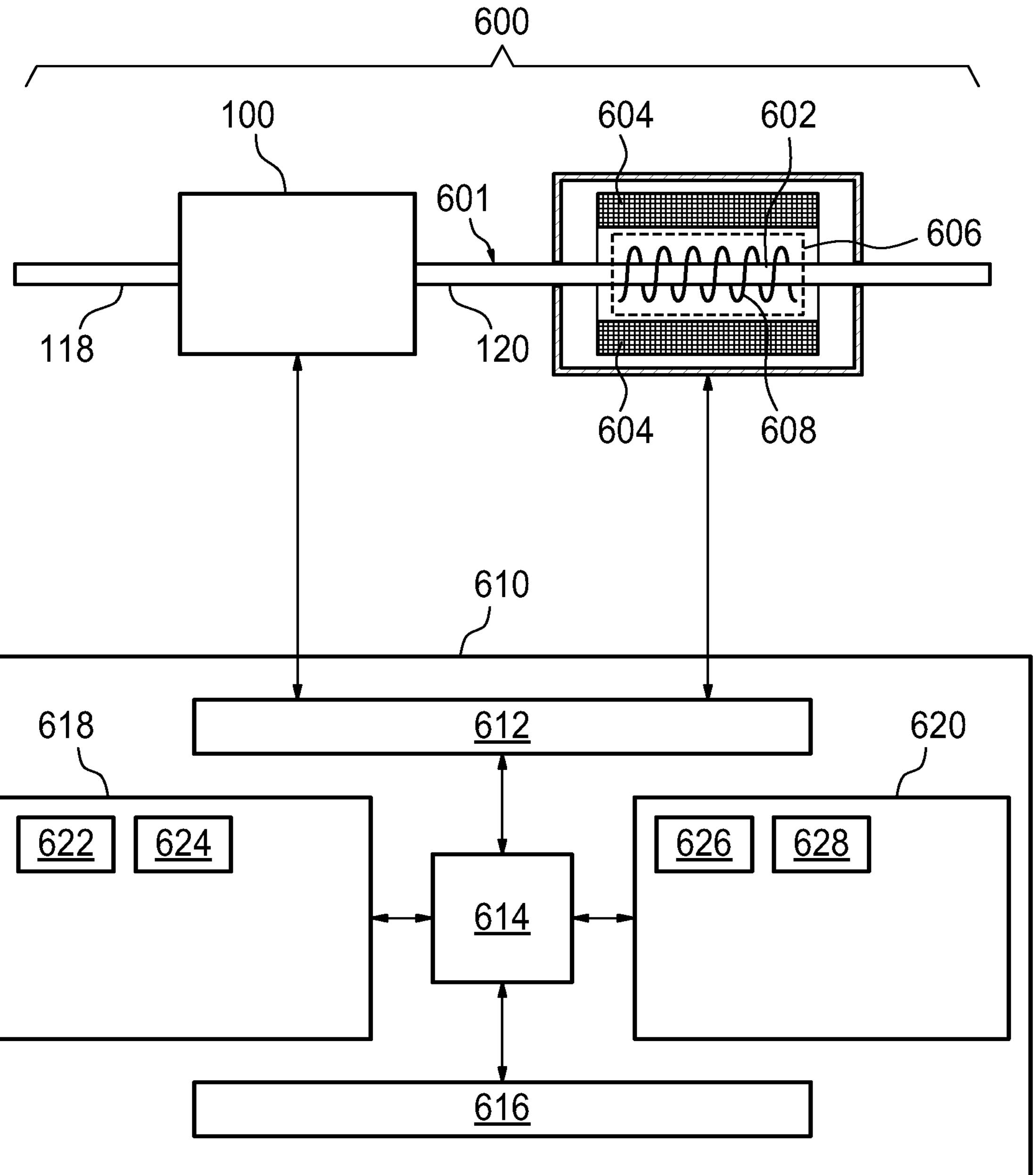


FIG. 6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100
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608
610
612
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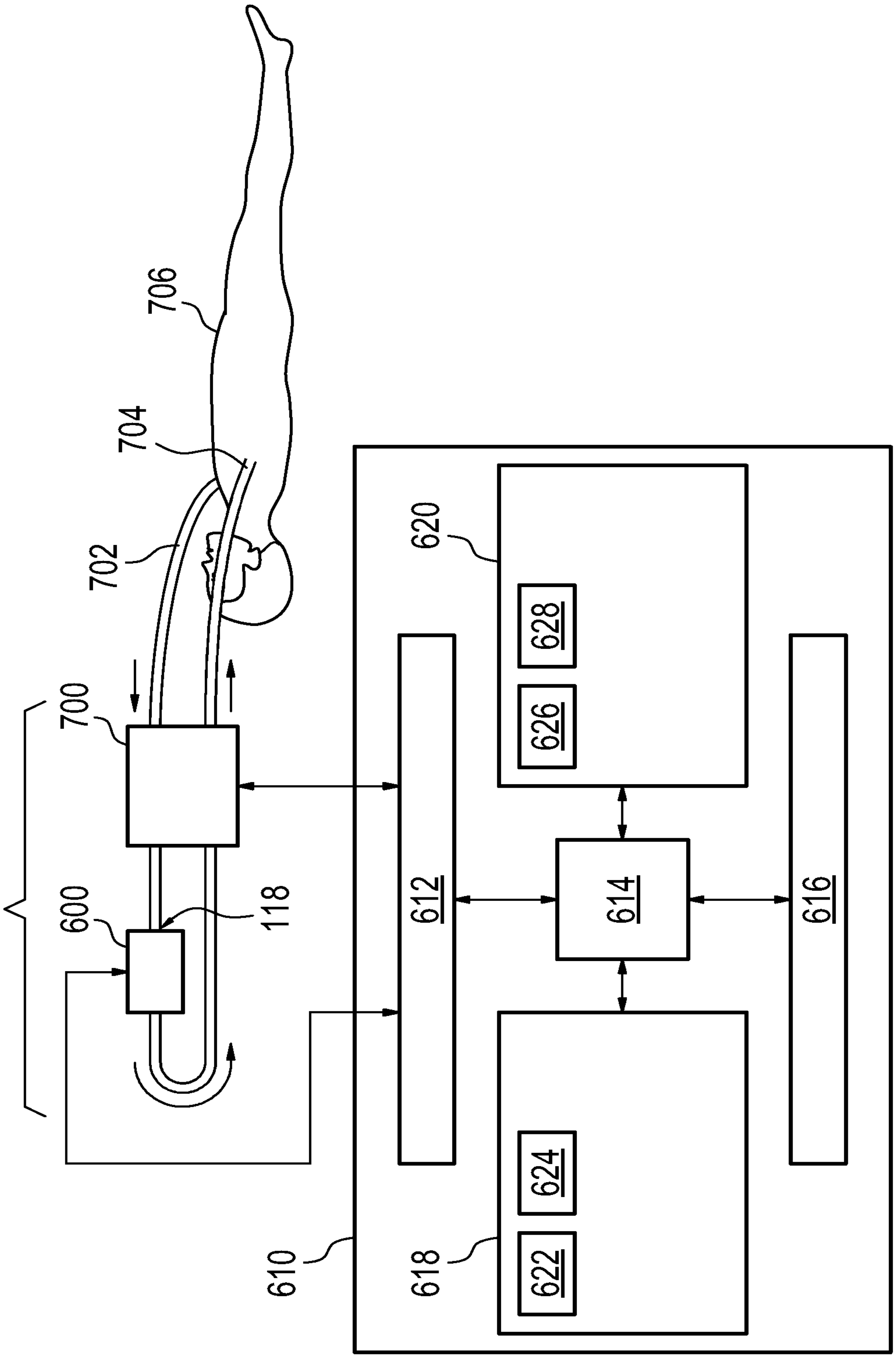
616

FIG. 7


600'
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118
702
704
706
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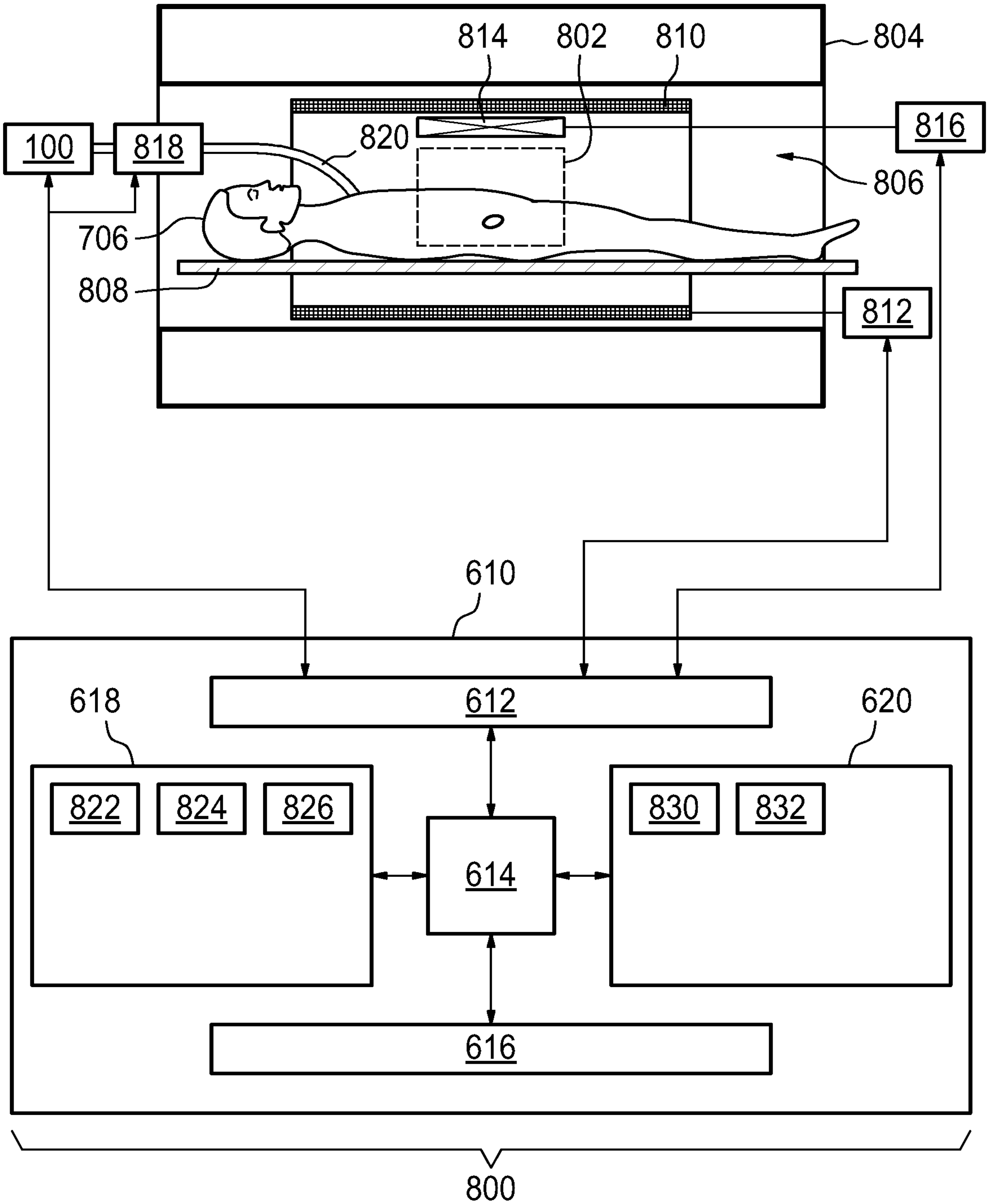
626
628

FIG. 8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802
810
804
100
818
820
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806
706
808
812
610
612
618
620
822
824
826
830
832
614
616
800

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(54) **Title**: SYSTEM AND METHOD FOR PERFORMING MICROSCOPY WITH LIGHT EXHIBITING AN ORBITAL ANGULAR MOMENTUM

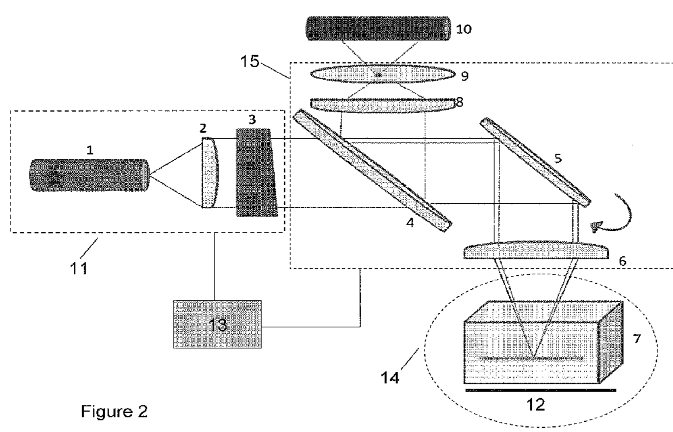

Figure 2

(57) **Abstract**: A microscopy system is provided comprising a light source for generating a first light beam, a sample area for accommodating a sample to be examined, a detector for detecting a second light beam generated by the sample in response to the first light beam and an optical assembly for focusing the first light beam on the sample area and for focusing the second light beam on the detector. The light source is arranged for generating the first light beam with an orbital angular momentum. The system may comprise a sample with one or more helical structures, for example collagen molecular structures. The scattering process will be more efficient when the characteristics of the first light beam match the characteristics of the molecular structures in the sample. By changing the orbital angular momentum of the first light beam, the pitch and the handedness of its wave front may be adjusted in order to match these characteristics of the sample.

WO 2011/028109 A1

Title: System and method for performing microscopy with light exhibiting an orbital angular momentum.

Field of the invention

The invention relates to a system and a method for performing microscopy, and more particularly to a microscopy system comprising a light source for generating a first light beam, a sample area for accommodating a sample, a detector for detecting a second light beam generated by the sample in response to the first light beam and an optical assembly for focusing the first light beam on the sample area and for focusing the second light beam on the detector.

Background of the invention

About 25% to 35% of the protein content in a human body consists of the protein collagen. Collagen fibres are made of bundles of long collagen protein molecules. They can be found inside and outside of biological cells and provide structure to cells. The collagen molecule or tropocollagen is about 300 nm long and 1.5 nm in diameter and comprises three polypeptide strands with a left-handed helix. Together these three helices form a right-handed coiled coil or a triple helix stabilized by numerous hydrogen bonds. Collagen structures may have different three-dimensional structures and are identified by their so-called type number. Different collagen types may be found in different parts in the human body or in different phases of biological processes. For example, type I collagen can be found in skin, tendon, vascular, ligature, organs, and/or bones, while type IV collagen is found in the bases of the cell basement membranes.

Collagen may change its helical structure from one type to another type, for example during the process of scarring, wound healing or the formation of bones. The structure of collagen may therefore be studied for diagnostic purposes, especially in the area of dermatology, ophthalmology and oncology.

The structure of molecules may be studied with a microscopy technique in which an excitation light beam is scattered by a sample and the scattered light is detected. Besides linear scattering, also non-linear scattering processes may be used, such as the second harmonic generation process, in which the wavelength of the scattered light is half a wavelength of the excitation light. In general, the scattered light will be detected and measured during a sampling time and on the bases of these measurements an image of the sample may be constructed. The efficiency of the scattering process may be defined as the ratio of the intensity of the scattered light beam and the intensity of the excitation light beam.

However, the scattering process may not be very efficient, and therefore the contrast of the images may be low and/or the sampling times may be long.

Summary of the invention

The objective of this invention is to improve the efficiency of the scattering process in a sample. To achieve this objective, a microscopy system is provided comprising a light source arranged for generating a first light beam, a sample area arranged for accommodating a sample, a detector arranged for detecting a second light beam generated by the sample in response to the first light beam and an optical assembly arranged for focusing the first light beam on the sample area and arranged for focusing the second light beam on the detector, characterized in that the light source is arranged for generating the first light beam with an orbital angular momentum.

The light source, the sample area, the detector and the optical assembly may be arranged or placed on a frame.

It appears that, in case of a sample with molecular helical structure, the light generation processes in response to the first light beam are more efficient when the molecules of the sample receive a first light beam with an orbital angular momentum. The contrast of the images improves and the sampling time decreases. As will be explained further below, according to a further embodiment the characteristics of the first light beam preferably match more or less the characteristics of the molecules of the sample. According to another further embodiment, elucidated further below, the second light beam is generated by scattering of the first light beam in the sample.

Another advantage of providing a first light beam with an orbital angular momentum may be that it enables the study of the characteristics of the sample, for example the pitch, the handedness and the direction of a helical structure in the sample.

In a further embodiment of the microscopy system the orbital angular momentum may be in the range of 1-100 $\hbar$ per photon.

In a further embodiment of the microscopy system according to the invention, the microscopy system comprises said sample to be examined, the sample comprising at least one molecular helical structure. In an embodiment, the microscopy system further comprises a sample holder arranged in the sample area, wherein the sample holder is holding said sample. The sample holder may be arranged or placed on the frame.

Since the wave front of a light beam with an orbital angular momentum has a helical structure, it may be advantageous to use a first light beam with an orbital angular momentum to excite one or more molecules with a helical structure, since their characteristics may be matched relatively easy.

According to the invention, in another embodiment, the detector is arranged for selectively detecting a wavelength of the second light beam, being equal to half a wavelength of the first light beam or being equal to the wavelength of the first light beam.

The scattering process may be a linear or a non-linear process, for example second harmonic generation. In a linear scattering process the wavelength of the second light beam equals the wavelength of the first light beam. In a second harmonic generation process, the wave length of the second light beam equals half the wavelength of the first beam. Therefore it may be advantageous to provide a detector that selectively detects light with these wavelengths.

In a further embodiment, the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm, and/or the detector is arranged for selectively detecting the second light beam with wavelengths in the range of 700 – 1000 nm and/or of

350-500 nm. Light with a wavelength in the range of 700 – 1000 nm provides deep penetration of biological tissue. According to the invention, especially collagen can be examined very well with wavelengths in the range of 700 – 1000 nm for the first light beam. A wavelength of about 800 nm for the first light beam appears very advantageous for amongst others collagen.

In another embodiment of the microscopy system according to the invention, the microscopy system further comprises an orbital angular momentum adjuster for adjusting the orbital angular momentum of the first light beam, and/or a propagation direction adjuster for adjusting a mean propagation direction of the first light beam with respect to the sample area. Since the light generation processes in sample in response to the first light beam appear to be more efficient when the characteristics of the first light beam match the characteristics of the molecules of the sample, it is advantageous to be able to change the characteristics of the first light beam depending on the sample to be examined..

In a further embodiment, the detector is arranged for providing a detection signal in response to the detection of the second light beam. Preferably this detection signal is representative for the second light beam. Additionally, the microscopy system further comprises a control unit arranged for receiving the detection signal and controlling the orbital angular momentum adjuster in response to the detection signal and/or controlling the propagation direction adjuster in response to the detection signal. The advantage of such a control unit may be that it enables looking for the optimal characteristics of the first light beam with respect to the efficiency of the second light beam generating process. This process may be executed automatically when the control unit comprises a computer or manually, when a human acts as control unit.

In both cases, the control unit, according to a further embodiment, is arranged for adjusting in response to the detection signal: the orbital angular momentum of the first light beam to the pitch of the helical structure of the sample; and/or the handedness of the first light beam to the handedness or the opposite handedness of the helical structure of the sample. In an embodiment the control unit is arranged for adjusting in response to the detection signal the mean propagation direction of the first light beam to the direction of the helix axis of the helical structure of the sample.

In an embodiment, the detector is arranged for providing a detection signal, representative of a light intensity of the detected second light beam.

In an embodiment the control unit is arranged to vary one of three characteristics of the first light beam, the three characteristics being: the pitch of its wave front, the handedness of its wave front, and the mean propagation direction, on the basis of the detection signal, by controlling the orbital angular momentum adjuster or by controlling the propagation direction adjuster. In an embodiment, the control unit is arranged to receive said detection signal and to control the orbital angular momentum adjuster and/or by controlling the propagation direction adjuster in response to the detection signal, such that detection signal achieves a predetermined criterion. In an embodiment, said predetermined criterion corresponds to a maximum light intensity of the detected second light beam. In an embodiment, the control unit is arranged to determine a matching value for said one characteristic, wherein the matching value is a value of said one characteristic at which the detection signal achieves said predetermined criterion.

The control unit may vary one of three characteristics of the first light beam (i.e. the pitch or the handedness of its wave front or the mean propagation direction of the first light beam) by controlling the orbital angular momentum adjuster and/or by controlling the propagation direction adjuster. On the basis of the detection signals during the variation of this one characteristic, the control unit may determine that the detection signal has achieved a predetermined criterion, for example that a maximum intensity of light is detected at a certain value for said characteristic.

At this certain value (referred to as a matching value), said characteristic of the first light beam matches the corresponding characteristic of the sample (i.e. the pitch of wave front of the first light beam corresponds to the pitch of the helical structure of the sample, the handedness of the wave front of the first light beam corresponds to the handedness or the opposite of the handedness of the helical structure of the sample or the mean propagation direction of the first light beam corresponds to the direction of the helix axis of the helical structure of the sample). When the characteristics of the first light beam matches the corresponding characteristics of the helical structure of the sample, the detector will detect a maximum light intensity (as is explained below). As a consequence, information about the characteristics of the helical structure of the sample is obtained, because the characteristics of the helical structure of the sample may follow from the matching values.

Thus, when the characteristics of the first light beam do not completely match the characteristics of the helical structure of the sample, the intensity of the light detected on the detector will be lower than in the case that the characteristics of the first light beam match the characteristics of the helical structure of the sample.

This effect may be advantageously used to find the matching value for one or more characteristics. The matching value of a characteristic of the first light beam provides information about the sample, i.e. about the value of the corresponding characteristic of helical structure of the sample. In another embodiment of the microscopy system according to the invention, the detector comprising one of more filters for selectively detecting a part of the second light beam, wherein the part of the second light beam comprises an orbital angular momentum within a predefined orbital angular momentum range and/or wavelength within a predefined wavelength range. In a further embodiment the predefined orbital angular momentum range may be in the range of 1-100 $\hbar$ per photon and/or the predefined wavelength range in the range of 700 – 1000 nm. The advantage of such a detector may be that it prevents spurious light to be detected that, for example, is generated by molecular structures or light generation processes that are not to be studied. This light may have a different orbital angular momentum and/or wavelength than the light generated by the molecular structures or processes to be studied.

The light source may comprise, in another embodiment of the microscopy system according to the invention, a light generator for generating a light beam and a mode converter for filtering the light beam to generate a first light beam with an orbital angular momentum. The advantage of such a light source is that it enables adjusting the characteristics of the first light beam by changing the operation of the mode converter.

In another embodiment, the sample comprises biological tissue, especially collagen. Details of the structure of collagen – as well as other biological tissue – might provide important information for research, therapy or diagnostic purposes. Up to now biological tissue having a molecular helical structure was difficult to examine.

According to another aspect of the invention, methods are provided for performing microscopy with a system according to embodiments as described above. According to one of the methods according to the invention, one or more characteristics of the first light beam are adjusted in order to match one of more characteristics of the sample, comprising at least one of molecular helical structure. The characteristics of the first light beam may comprise the orbital angular momentum of the first light beam, the handedness of the first light beam, and the mean propagation direction of the first light beam. The characteristics of the sample may comprise the pitch of the helical structure, the handedness of the helical structure and the direction of a helix axis of the helical structure.

In another embodiment of the invention, a use of a light beam exhibiting an orbital angular momentum is provided for performing microscopy on a sample comprising a at least one or a plurality of molecular helical structures. In a further embodiment, the sample comprises biological tissue, especially biological tissue of a mammal like a human. Collagen can be examined very well with the microscopy system according to the invention and/or method according to the invention.

Brief description of the drawings

Further advantageous embodiments of the microscopy system and the method for performing microscopy according to the invention are described in the claims and in the following description with reference to the drawing, in which:

Figure 1 shows a helical structure; and

Figure 2 shows an embodiment of a microscopy system according to the invention;

Figure 3 shows an embodiment of a microscopy system arranged to use a light beam exhibiting an orbital angular momentum light.

Detailed description of the invention

In Figure 1, a helical structure has been depicted. The helical structure may be characterized by its direction, indicated by arrow a and its pitch, indicated by distance b. Helical structures have an orientation or handedness, indicated by arrow c and a helix is either left-handed or right-handed. Figure 1 shows a right-handed helix.

When a light beam is said to have an orbital angular momentum, the wave front of the electromagnetic radiation has a helical structure. The orbital angular momentum is expressed in a multiple of $\hbar$ per photon. The pitch of the helical wave front for a beam with orbital angular momentum of $l = 1\ \hbar$ (left-handed) or $l = -1\ \hbar$ (right-handed) equals the wavelength of the light. For larger values of the orbital angular momentum l the pitch is decreased proportionally.

A light beam can be scattered in a material both by linear scattering and by non-linear scattering. In a linear scattering process, the wavelength of the scattered light beam equals the wavelength of the excitation light beam. In a second harmonic generation process, a non-linear scattering process, the wavelength of the scattered light beam equals half the wavelength of the excitation light beam. Other non-linear scattering processes may also occur, when an excitation light beam is scattered in a sample.

In Figure 2, an embodiment of a microscopy system according to the invention is shown. Light source 11 is arranged for generating a first light beam or excitation light beam which exhibits an orbital angular momentum. Light source 11 may comprise a light generator 1 for generating a light beam and a mode converter 3 for filtering the light beam to generate a first light beam with an orbital angular moment. The mode convertor may be a spiral phase plate, a (holographic) grating with a dislocation or a spatial phase modulator, for example a pixelated LCD screen with spatially variant phase. These types of mode convertors are well known in the art. The light generator 1 may be a laser, for example an ultra-fast laser source with a pulse width of 100 fs or smaller and a wavelength in the range of 700-1000 nm.

Furthermore, the light source 11 may comprise a beam cleaning device 2 comprising lenses and/or pinholes in order to create a collimated first light beam with a beam waist adjusted to the entrance pupil of lens 6.

The optical assembly 15 for focusing the first light beam on the sample area 14 containing a sample 7 and for focusing a second light beam on the detector comprises lenses 4,5,6, 8 and 9. It also possible that a separate lens or a separate set of lenses is arranged to focus the first light beam on the sample and a different lens or a different set of lenses is arranged to focus the second light beam on the detector. The optical assembly 15 may also comprise pinholes.

The microscopy system according to the invention may be a scanning microscopy system or a confocal microscopy system or a confocal scanning microscopy system.

In a confocal (scanning) microscopy system, the detector is a point detector and the optical assembly is arranged for focusing the second light beam on the point detector.

The microscopy system according to the invention may also be a second harmonic generation microscopy system. In that case, the second harmonic light that is generated in the sample is used to study the sample.

In this document, all features may be applicable for both a confocal (scanning) microscopy system and a second harmonic generation microscopy system, unless it is stated differently.

The detector detects the light intensity of the second light beam that is focused on the detector. The detector may provide a detection signal, being representative of the detected light intensity.

As shown in figure 2, the sample area might be provided with a sample holder 12 holding the sample 7.

In Figure 2 a dichroic mirror 4 is provided, which separates the excitation light from the second harmonic generated scattered light. A scanning mirror 5 may be provided to scan the sample with the first light beam and to de-scan the second light beam.

In case of linear scattering it may be desirable to separate the light path of the first light beam and the light path of the second light beam, since the two light beams will have the same wavelength. The optical assembly will then have a different configuration than is shown in Figure 2.

Detector 10 may be a standard detector know in art of the scanning optical microscopy and may be provided with one of more filters for selectively detecting a part of the second light beam. In this manner only light will be detected which has an orbital angular momentum within a predefined orbital angular momentum range and/or a wavelength within a predefined wavelength range. This will decrease the detection of spurious light coming from other sources than the scattering process in the sample. The filter for filtering out light having an orbital angular momentum outside a predefined range may comprise of the same elements as the mode converter.

The microscopy system may comprise an orbital angular momentum adjuster for adjusting the orbital angular momentum of the first light beam. The orbital angular momentum of the first light beam or excitation light beam may be adjusted in various ways. For example, the mode converter may comprise an adjuster which acts on the working of the mode converter, for example on the working of the pixelated LCD screen with spatially variant phase. It also possible to provide an extra mode convertor in the light path of the first light beam.

The microscopy system may comprise a propagation direction adjuster for adjusting a mean propagation direction of the first light beam with respect to the sample area. This adjuster can act on various elements of the microscopy system. It may, for example, change the direction of light which is sent out by the light source. It may also change the position of the lenses in the optical arrangement and/or the sample holder and thereby change the position of the sample with respect to the first light beam.

In another embodiment, the microscopy system may comprise a control unit 13 that controls the orbital angular momentum adjuster in order to adjust the orbital angular momentum in response to a detection signal, and/or the propagation direction adjuster in order to adjust the mean propagation direction in response to the detection signal. This control unit may be an integrated circuit or computer, programmed to execute this function. It may also be a human, who receives information about the detection of the second light beam from the detector, for example on a display, and then controls one or both adjusters. In Figure 2 the control unit 13 controls the light source 11 and the optical assembly 15. However, control unit 13 may also control the sample holder 12 and/or mode convertor 3.

The microscopy system may comprise a sample with one or more helical structures, for example collagen molecules, but also other materials, for example biological tissue or tissue found in mammals, may be used. The scattering process in the microscopy system will be more efficient when the characteristics of the first light beam or excitation light beam more or less match the characteristics of the molecular structures in the sample. The characteristics of the sample may comprise the pitch of the helical structure, the handedness of the helical structure and the direction of a helix axis of the helical structure. By changing the orbital angular momentum of the first light beam, the pitch and the handedness of its wave front may be adjusted in order to match these characteristics of the sample. The mean propagation direction of the first light beam may also be adjusted to match the direction of the helix axis of the helical structure of the sample. The more these characteristics are matched, the more efficient the scattering process will take place and the more light will be detected by the detector.

When the microscopy system is a confocal (scanning) microscopy system, the detector is a point detector and the second light beam will be focussed on the point detector . In that case, the detector detects a higher light intensity of the second light beam if the second light beam comprises more light that does not possess an orbital angular momentum. It appears that light that possesses an orbital angular momentum can not be focussed on a point detector. Only when the handedness of the wave front of the first light beam corresponds to the *opposite of the handedness* of the helical structure of the sample, the second light beam may comprise light that does not possess an orbital angular momentum. In that case, a maximum light intensity may be detected by the detector.

When the microscopy system is a second harmonic generation microscopy system, the second light beam will normally not be focussed on a point detector. Therefore, light may be detected by the detector irrespective of its orbital angular momentum. Generation of the second harmonic light in the sample will be most efficient when the handedness of the wave front of the first light beam corresponds to *the handedness* of the helical structure of the sample. In that case, a maximum of light intensity of the second light beam may be detected.

Thus, with regards to a confocal (scanning) microscopy, a maximum light intensity may be detected when the handedness of the wave front of the first light beam corresponds to the *opposite of the handedness* of the helical structure of the sample. And with regards to a second harmonic generation microscopy system, a maximum light intensity may be detected when the handedness of the wave front of the first light beam corresponds to the *handedness* of the helical structure of the sample. When the handedness of the wave front of the first light beam *matches* the handedness of the helical structure of the sample, it means either that the handedness of the wave front of the first light beam corresponds to the opposite of the handedness of the helical structure of the sample or that the handedness of the wave front of the first light beam corresponds to the handedness of the helical structure of the sample.

When the characteristics of the first light beam do not completely match the characteristics of the helical structure of the sample, the detected light intensity may be less than when the characteristics of the first light beam do completely match the characteristics of the helical structure of the sample. This effect may be used to study the characteristics of the helical structure of the sample.

The control unit may vary one of three characteristics of the first light beam (i.e. the pitch or the handedness of its wave front or the mean propagation direction of the first light beam) by controlling the orbital angular momentum adjuster or by controlling the propagation direction adjuster. In the meantime, the other two characteristics of the first light beam may be kept constant. On the basis of the detection signal during the variation of this characteristic, the control unit may determine that the detection signal achieves a predetermined criterion, for example that a maximum intensity of light is detected at a certain value for said characteristic.

At this certain value (referred to a its matching value), said characteristic of the first light beam matches the corresponding characteristic of the sample (i.e. the pitch of wave front of the first light beam corresponds to the pitch of the helical structure of the sample, the handedness of the wave front of the first light beam corresponds to the handedness or the opposite of the handedness of the helical structure of the sample, or the mean propagation direction of the first light beam corresponds to the direction of the helix axis of the helical structure of the sample). The matching values provide information about the sample, i.e. about the value of the corresponding characteristics of helix structure of the sample.

The varying of one of three characteristics may be achieved by controlling the orbital momentum adjuster and/or the propagation direction adjuster such that said one characteristic of the first light beam successively has a value from a predetermined range.

The detection signal associated with each of these values may be stored by the control unit and the control unit may be arranged to select the value (referred to as matching value) at which the light intensity to which the detection signal is representative of, achieves the predetermined criterion, for example: the light intensity of the second light beam is at its maximum (this may be case when the detection signal is also at its maximum). In this way the control unit may determine a matching value for a characteristic.

The control unit may then proceed to vary another of the three characteristics of the first beam, while one or more of the previous varied characteristics may be held at their respective matching value.

The process of finding the set of matching values for one or more characteristics may be performed in different ways with different iteration steps. The process may be optimized in the relation to the sample to be studied, i.e. the process may start with the values that are expected to match the characteristics of the sample.

The one or more matching values provide information about the helical structure of the sample, with respect to the pitch and the handedness of helical structure of the sample and the direction of the helix axis of the helical structure of the sample. At their respective matching values, the pitch of the wave front of the first light beam will correspond to the pitch of the helical structure of the sample, the handedness (in the case of second generation microscopy) or the opposite of the handedness (in case of confocal (scanning) microscopy) of the wave front of the first light beam will correspond to the handedness of the helical structure of the sample and/or the mean propagation direction of the first light beam will correspond to the direction of the helix axis of the helical structure of the sample.

The microscopy system according to the invention enables the study of the characteristics of the sample. For example, the intensity of the second light beam may decrease or increase when collagen in the sample changes its structure. In another embodiment of the microscopy system according to the invention, the microscopy system may have the dimension for being placed inside a hand held scanner or inside a miniaturized photonic needle device.

Figure 3 shows an embodiment of a microscopy system according to another aspect of the invention, which is not within the scope of claims as originally filed. This microscopy system is arranged to use a light beam exhibiting an orbital angular momentum light. In this embodiment, the first light beam does not exhibit an orbital angular momentum but the second light beam does. Mode converter 3 is placed in the light path of the second light beam or scattered light beam and in front of the detector. The mode converter may act as a filter for the detector i.e. as an orbital angular momentum filter, enabling a selective detection of a part of the second light beam. Further embodiments of this embodiment may comprise the features of the microscopy system described above.

The microscopy system may be a confocal (scanning) microscopy system or a second harmonic generation microscopy system, as is explained above.

Also in the embodiment of figure 3, the light intensity detected by the detector depends on whether and/or to what extend the characteristics of the orbital angular momentum filter match the characteristics of the helical structure of the sample.

The characteristics of the orbital angular momentum filter may refer to change in orbital angular momentum of a light beam that passes through the orbital angular momentum filter or to the characteristics of the light (with respect to its orbital angular momentum) that will orbital angular momentum filter filters out.

The microscopy system may comprise an orbital angular momentum adjuster for adjusting the orbital angular momentum filter and thus for adjusting the characteristics of the orbital angular momentum filter.

The characteristics of the orbital angular momentum filter may be adjusted by a control unit which is controlling the orbital angular momentum adjuster. In a similar way as described above, the control unit may vary one or more characteristics of the orbital angular momentum filter and determine the matching values of said one or more characteristics.

One or more matching values provide information about the helical structure of the sample, for example with respect to the pitch and the handedness of the sample. Not only with respect to the figure 3 embodiments but especially also with respect to the figure 2 embodiment, it is noted that the sample can be examined in vivo as well. In case of in vitro examination, one may place the sample in a sample holder arranged in the sample area. In case of in vivo examination, one will, in general, not place the sample in a sample holder, but arrange the microscopic system such that the first light beam impinges upon the sample – which is here a part of the patient - to be examined.

The embodiments of the devices and methods described in this document may be expressed by the following clauses:

1] Microscopy system comprising:

- a light source for generating a first light beam;

- a sample area for accommodating a sample to be examined;
- a detector for detecting a second light beam generated by the sample in response to the first light beam;
- an optical assembly for focusing the first light beam on the sample area and for focusing the second light beam on the detector,

characterized in that the light source is arranged for generating the first light beam with an orbital angular momentum.

2] Microscopy system according to clause 1, further comprising a said sample to be examined, the sample comprising one or more molecular helical structures.

3] Microscopy system according to one of clauses 1-2, wherein the sample is arranged for generating the second light beam by scattering of the first light beam.

4] Microscopy system according to one of clauses 1-3, wherein the detector is arranged for selectively detecting a wavelength of the second light beam, the wavelength of the second light beam being equal to half a wavelength of the first light beam or being equal to the wavelength of the first light beam.

5] Microscopy system according to one of clauses 1-4, wherein the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm, and/or the detector is arranged for selectively detecting the second light beam comprising wavelengths in the range of 700 – 1000 nm and/or in the range of 350-500 nm.

6] Microscopy system according to one of clauses 1-5, further comprising an orbital angular momentum adjuster for adjusting the orbital angular momentum of the first light beam, and/or a propagation direction adjuster for adjusting a mean propagation direction of the first light beam with respect to the sample area.

7] Microscopy system according to clause 6, wherein the detector is arranged for providing a detection signal in response to the detection of the second light beam – the detection signal preferably being representative for the second light beam -, the system further comprising a control unit arranged for:

- receiving the detection signal; and,

- controlling the orbital angular momentum adjuster in response to the detection signal; and/or controlling the propagation direction adjuster in response to the detection signal.

8] Microscopy system according to clause 7, wherein the control unit is arranged for adjusting in response to the detection signal:

- the orbital angular momentum of the first light beam to – preferably to correspond essentially to - the pitch of the helical structure of the sample; and/or

- the handedness of the first light beam to – preferably to correspond essentially to - the handedness or the opposite of the handedness of the helical structure of the sample; and/or

- the mean propagation direction of the first light beam to – preferably to correspond essentially to - the direction of the helix axis of the helical structure of the sample.

9] Microscopy system according to one of clauses 1-8, the detector comprising one of more filters for selectively detecting a part of the second light beam, wherein the part of the second light beam:

- exhibits an orbital angular momentum within a predefined orbital angular momentum range and/or

- comprises a wavelength within a predefined wavelength range.

10] Microscopy system according to one of clauses 1-9, wherein the light source comprises:

- a light generator for generating a light beam;
- a mode converter for filtering the light beam to generate the first light beam with an orbital angular moment.

11] Microscopy system according to one of clauses 1-10, wherein the sample comprises biological tissue, preferably collagen.

12] Microscopy system according to one of the clauses 1-11, further comprising a sample holder arranged in the sample area.

12a] Microscopy system according to one of the clauses 1-12, wherein the microscopy system is a scanning microscopy system or a confocal scanning microscopy system,

12b] Microscopy system according to one of clauses1-12 and 12a, wherein the light source is a point source of light and the detector is a point detector and the optical assembly is arranged for focusing the first light beam on a point of the sample area (or the sample) and for focusing the second light beam from said point on the detector.

12c] Microscopy system according to one of the clauses 1-12 and 12a-12b wherein the detector is arranged for providing a detection signal, representative of a light intensity of the detected second light beam and the control unit is arranged to receive said detection signal

12d] Microscopy system according to clause 12c wherein wherein the control unit is arranged to vary one of the following three characteristics of the first light beam:

- the pitch of its wave front,
- the handedness of its wave front, and
- the mean propagation direction,

by controlling the orbital angular momentum adjuster or by controlling the propagation direction adjuster, preferably on the basis of the detection signal

12e] Microscopy system according to clause 12d, wherein the control unit is arranged to keep the other two characteristics of the first light beam constant.

12f] Microscopy system according to clause 12d-12e, wherein the control unit is arranged to determine a matching value for said one characteristic, wherein the matching value is a value of said one characteristic at which the detector detects a maximum light intensity of the second light beam.

12g] Microscopy system according to clause 12d-12f, wherein the control unit is arranged to keep one or more of the other two characteristics of the first light beam at their respective matching value. 12h] Microscopy system according to one of clauses12d-12g, wherein the control unit is arranged to determine a set of matching values for said three characteristics of the first light beam, wherein the set of matching values is a set of values of said three characteristics at which the detector detects a maximum light intensity of the second light beam.

13] Method for performing microscopy, comprising of steps

a) generating a first light beam;

b) focusing the first light beam on a sample;

c) focusing a second light beam on a detector, the second light beam being generated by the sample in response to the first light beam; and

d) detecting the second light beam;

characterized in that the first light beam exhibits an orbital angular momentum.

14] Method for performing microscopy according to clause 13, wherein the second light beam is generated by scattering of the first light beam.

15] Method for performing microscopy according to one of clauses 13-14, wherein a wavelength of the second light beam equals a wavelength of the first light beam or equals half the wavelength of the first light beam.

16] Method for performing microscopy according to one of clauses 13-15, wherein the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm; and/or the second light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm and/or in the range of 350-500 nm.

17] Method for performing microscopy according to one of clauses 13-16, further comprising adjusting one or more characteristics of the first light beam, the characteristics of the first light beam comprising one or more of: the orbital angular momentum of the first light beam, the handedness or the opposite of the handedness of the first light beam; and the mean propagation direction of the first light beam.

18] Method for performing microscopy according to one of clauses 13-17, wherein the sample comprises one or more molecular helical structures.

19] Method for performing microscopy according to clause 17 or 18, wherein the adjusting is performed to adjust:

- the orbital angular momentum of the first light beam to – preferably to correspond essentially to - the pitch of the helical structure of the sample; and/or

- the handedness of the first light beam to – preferably to correspond essentially to the handedness or the opposite of the handedness of the helical structure of the sample; and/or

- the mean propagation direction of the first light beam to – preferably to correspond essentially to - the direction of the helix axis of the helical structure of the sample.

20] Method for performing microscopy according to one of clauses 17-19, wherein the adjusting is performed in response to the detection of the second light beam.

21] Method for performing microscopy according to one of clauses 13-20-, wherein step d) comprises filtering and selectively detecting a part of the second light beam, wherein the part of the second light beam

- exhibits an orbital angular momentum within a predefined orbital angular momentum range and/or

- comprises a wavelength within a predefined wavelength range.

22] Method for performing microscopy according to one of clauses 13-21, wherein the sample comprises biological tissue, preferably collagen.

23] Use of a light beam exhibiting an orbital angular momentum for performing microscopy on a sample comprising one or more molecular helical structures.

24] Use of a light beam according to clause 23, wherein the sample comprises biological tissue, such as collagen.

24a] Method for performing microscopy according to one of clauses 13-24, further comprising the step of:

e) providing a detection signal, representative of a light intensity of the detected second light beam.

24b] Method for performing microscopy according to clause 24a, further comprising the step of:

f) varying one of the following three characteristics of the first light beam:

- the pitch of its wave front,
- the handedness of its wave front, and
- the mean propagation direction,

preferably on the basis of the detection signal.

24c] Method for performing microscopy according to clause 24a or 24b wherein step f) further comprises keeping the other two characteristics of the first light beam constant.

24d] Method for performing microscopy according to any of clause 24a-24c, further comprising the steps of:

g) determining a matching value for said one characteristic, wherein the matching value of said one characteristic is a value at which the detector detects a maximum light intensity of the second light beam.

24e] Method for performing microscopy according to any of clause 24c-24d, wherein step f) comprises keeping one or more of the other two characteristics of the first light beam at their respective matching value.

24f] Method for performing microscopy according to clause 24b-24e, further comprising the steps of:

h) determining a set of matching value for said three characteristics, wherein the set of matching values is a set of values of said three characteristics at which the detector detects a maximum light intensity of the second light beam.

25] Microscopy system comprising:

- a light source for generating a first light beam;
- a sample area for accommodating a sample to be examined;
- a detector for detecting a second light beam generated by the sample in response to the first light beam;
- an optical assembly for focusing the first light beam on the sample area and for focusing the second light beam on the detector, characterized in that

the detector comprises an orbital angular momentum filter for selectively detecting a part of the second light beam, wherein the part of the scattered light beam exhibits an orbital angular momentum within a predefined orbital angular momentum range, the predefined orbital angular momentum range preferably being 1-100 $\hbar$ *per photon*.

26] Microscopy system according to clause 25, further comprising a sample comprising one or more molecular helical structures.

27] Microscopy system according to one of clauses 25-26, wherein the sample is arranged for generating the second light beam by scattering of the first light beam.

28] Microscopy system according to one of clauses 25-27, wherein the detector is arranged for selectively detecting a wavelength of the second light beam, the wavelength of the second light beam being equal to half a wavelength of the first light beam or being equal to the wavelength of the first light beam.

29] Microscopy system according to one of clauses 25-28, wherein the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm; and/or the detector is arranged for selectively detecting the second light beam comprising wavelengths in the range of 700 – 1000 nm and/or in the range of 350-500 nm.

30] Microscopy system according to one of clauses 25-29, further comprising an orbital angular momentum adjuster for adjusting the orbital angular momentum filter, and/or a propagation direction adjuster for adjusting a mean propagation direction of the first light beam with respect to the sample area.

31] Microscopy system according to clause 30, wherein the detector is arranged for providing a detection signal in response to the detection of the second light beam – the detection signal preferably being representative for the second light beam -, the system further comprising a control unit arranged for:

- receiving the detection signal; and,
- controlling the orbital angular momentum adjuster in response to the detection signal; and/or controlling the propagation direction adjuster in response to the detection signal.

32] Microscopy system according to one of clauses 25-31, the detector comprising one or more filters for selectively detecting a part of the second light beam, wherein the part of the second light beam comprises a wavelength within a predefined wavelength range.

32] Microscopy system according to one of clauses 24-31, wherein the sample comprises biological tissue, such as collagen.

34] Microscopy system according to one of the clauses 25 - 33, further comprising a sample holder arranged in the sample area.

36] Method for performing microscopy, comprising of steps

a) generating a first light beam;

b) focusing the first light beam on a sample;

c) focusing a second light beam on a detector, the second light beam being generated by the sample in response to the first light beam; and

d) selectively detecting a part of the second light beam

characterized in that the part of the second light beam exhibits an orbital angular momentum within a predefined orbital angular momentum range, the predefined orbital angular momentum range preferably being 1-100 $\hbar$ per photon.

37] Method for performing microscopy according to clause 36, wherein the second light beam is generated by scattering of the first light beam.

38] Method for performing microscopy according to one of clauses 36-37, wherein a wavelength of the second light beam equals a wavelength of the first light beam or equals half the wavelength of the first light beam.

39] Method for performing microscopy according to one of clauses 36-38, wherein the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm, and/or the second light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm and/or in the range of 350-500 nm.

40] Method for performing microscopy according to one of clauses 36-39 further comprising adjusting the orbital angular momentum filter and/or a mean propagation direction of the first light beam.

41] Method for performing microscopy according to one of clauses 36-40, wherein the sample comprises one or more molecular helical structures.

42] Method for performing microscopy according to clause 40 , wherein the orbital angular momentum filter and/or a mean propagation direction of the first light beam are adjusted in response to the detection of the second light beam.

43] Method for performing microscopy according to one of clauses 36-42, wherein step d) comprises filtering and selectively detecting a part of the second light beam, wherein the part of the second light beam comprises a wavelength within a predefined wavelength range.

44] Method for performing microscopy according to one of clauses 36-43, wherein the sample comprises, biological tissue, such as collagen.

Although detailed embodiments of the present invention are disclosed herein, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting, but rather, to provide an understandable description of the invention. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. Microscopy system comprising:

- a light source for generating a first light beam;
- a sample area for accommodating a sample to be examined;
- a detector for detecting a second light beam generated by the sample in response to the first light beam; and
- an optical assembly for focusing the first light beam on the sample area and for focusing the second light beam on the detector,

characterized in that the light source is arranged for generating the first light beam with an orbital angular momentum.

2. Microscopy system according to claim 1, further comprising said sample to be examined, the sample comprising one or more molecular helical structures.

3. Microscopy system according to one of claims 1-2, further comprising a sample holder arranged in the sample area, wherein the sample holder is holding said sample.

4. Microscopy system according to one of claims 1-3, wherein the sample is arranged for generating the second light beam by scattering of the first light beam.

5. Microscopy system according to one of claims 1-4, further comprising an orbital angular momentum adjuster for adjusting the orbital angular momentum of the first light beam, and/or a propagation direction adjuster for adjusting a mean propagation direction of the first light beam with respect to the sample area.

6. Microscopy system according to claim 5,
wherein the detector is arranged for providing a detection signal in response to the detection of the second light beam,
the system further comprising a control unit arranged for:
- receiving the detection signal; and,
- controlling the orbital angular momentum adjuster in response to the detection signal; and/or controlling the propagation direction adjuster in response to the detection signal.

7. Microscopy system according to claim 6, wherein the control unit is arranged for adjusting in response to the detection signal:
- the orbital angular momentum of the first light beam to the pitch of the helical structure of the sample; and/or
- the handedness of the first light beam to the handedness or the opposite of the handedness of the helical structure of the sample.

8. Microscopy system according to claim 6 or 7, wherein the control unit is arranged for adjusting in response to the detection signal:
- the mean propagation direction of the first light beam to the direction of the helix axis of the helical structure of the sample.

9. Microscopy system according to one of claims 1-8, the detector comprising one of more filters for selectively detecting a part of the second light beam, wherein the part of the second light beam:
- exhibits an orbital angular momentum within a predefined orbital angular momentum range and/or
- comprises a wavelength within a predefined wavelength range.

10. Microscopy system according to one of claims 1-9, wherein the light source comprises:

- a light generator for generating a light beam;
- a mode converter for filtering the light beam to generate the first light beam with the orbital angular momentum.

11. Microscopy system according to one of claims 1-10, wherein the sample comprises biological tissue, such as collagen.

12. Microscopy system according to one of claims 1-11, wherein the microscopy system is a confocal microscopy system.

13. Microscopy system according to one of claims 1-12, wherein
the detector is a point detector and the optical assembly is arranged for focusing the second light beam on said point detector.

14. Microscopy system according to one of claims 1-11, wherein the microscopy system is a second harmonic generation microscopy system.

15. Microscopy system according to one of claims 1-14, wherein the detector is arranged for selectively detecting a wavelength of the second light beam, the wavelength of the second light beam being equal to half a wavelength of the first light beam or being equal to the wavelength of the first light beam.

16. Microscopy system according to one of claims 1-15, wherein
the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm, and/or

the detector is arranged for selectively detecting the second light beam with wavelengths in the range of 700 – 1000 nm and/or of 350-500 nm.

17. Microscopy system according to one of claims 1-16, wherein the detector is arranged for providing a detection signal, representative of a light intensity of the detected second light beam.

18. Microscopy system according to one of claims 6-17, wherein
the control unit is arranged to vary one, two or all of three characteristics of the first light beam, the three characteristics being:

- the pitch of its wave front,
- the handedness of its wave front, and
- the mean propagation direction,

by controlling the orbital angular momentum adjuster and/or by controlling the propagation direction adjuster.

19. Microscopy system according to claim 17 or 18, wherein
the control unit is arranged to receive said detection signal and to control the orbital angular momentum adjuster and/or the propagation direction adjuster in response to the detection signal, such that detection signal achieves a predetermined criterion.

20. Microscopy system according to claim 18-19, wherein
the control unit is arranged to determine a matching value for said one characteristic, or two matching values for said two characteristics, or three matching values for said all characteristics,
wherein each matching value is a value of the respective characteristic at which the detection signal achieves the predetermined criterion.

21. Microscopy system according to one of claims 19-20, wherein said predetermined criterion corresponds to a maximum in the detected light intensity.

22. Method for performing microscopy, comprising of steps

a) generating a first light beam;

b) focusing the first light beam on a sample;

c) focusing a second light beam on a detector, the second light beam being generated by the sample in response to the first light beam; and

d) detecting the second light beam;

characterized in that

the first light beam exhibits an orbital angular momentum.

23. Method for performing microscopy according to claim 22, wherein the second light beam is generated by scattering of the first light beam.

24. Method for performing microscopy according to one of claims 22-23, wherein a wavelength of the second light beam equals a wavelength of the first light beam or equals half the wavelength of the first light beam.

25. Method for performing microscopy according to one of claims 22-24, wherein the first light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm, and/or

the second light beam comprises electromagnetic radiation with wavelengths in the range of 700 – 1000 nm and/or in the range of 350-500 nm.

26. Method for performing microscopy according to one of claims 22-25, further comprising adjusting one or more characteristics of the first light beam, the characteristics of the first light beam comprising one or more of:

- the orbital angular momentum of the first light beam,
- the handedness of the first light beam;
- the mean propagation direction of the first light beam.

27. Method for performing microscopy according to one of claims 22-26, wherein the sample comprises one or more molecular helical structures.

28. Method for performing microscopy according to claim 26 or 27, wherein the adjusting is performed to adjust:
- the orbital angular momentum of the first light beam to the pitch of the helical structure of the sample; and/or
- the handedness of the first light beam to the handedness or the opposite of the handedness of the helical structure of the sample.

29. Method for performing microscopy according to one of claims 26-28, wherein the adjusting is performed to adjust:
- the mean propagation direction of the first light beam to the direction of the helix axis of the helical structure of the sample.

30. Method for performing microscopy according to one of claims 26-29, wherein the adjusting is performed in response to the detection of the second light beam.

31. Method for performing microscopy according to one of claims 22-30, wherein step d) comprises filtering and selectively detecting a part of the second light beam, wherein the part of the second light beam:
- exhibits an orbital angular momentum within a predefined orbital angular momentum range and/or
- comprises a wavelength within a predefined wavelength range.

32. Method for performing microscopy according to one of claims 22-31, wherein the sample comprises biological tissue, such as collagen.

33. Method for performing microscopy according to one of claims 22-32, further comprising the step of:
e) providing a detection signal, representative of a light intensity of the detected second light beam.

34. Method for performing microscopy according to one of claims 22-33, further comprising the step of:
f) varying one of three characteristics of the first light beam, the three characteristics being:

- the pitch of its wave front,
- the handedness of its wave front, and
- the mean propagation direction.

35. Method for performing microscopy according to claim 34, wherein step f) further comprises: receiving said detection signal and varying said one characteristic in response to the detection signal, such that detection signal achieves a predetermined criterion.

36. Method for performing microscopy according to claim 35, further comprising the step of: f) determining a matching value for said one characteristic,
wherein the matching value is a value of said one characteristic at which the detection signal achieves said predetermined criterion.

37. Method for performing microscopy according to claim 35 or 36, wherein
said predetermined criterion corresponds to a maximum light intensity of the detected second light beam.

38. Use of a light beam exhibiting an orbital angular momentum for performing microscopy on a sample comprising at least one molecular helical structures.

39. Use of a light beam according to claim 38, wherein the sample comprises biological tissue, such as collagen.

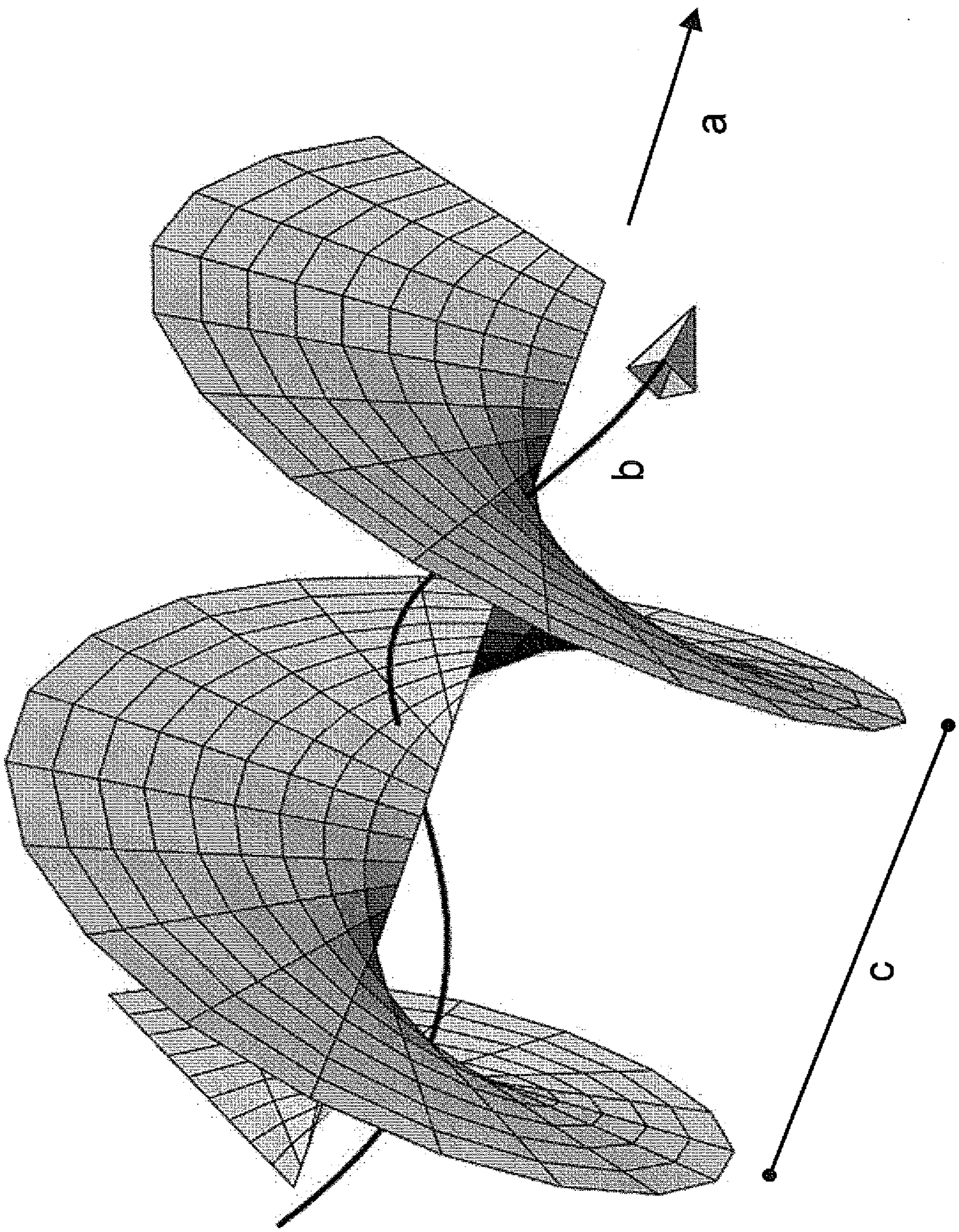

Figure 1

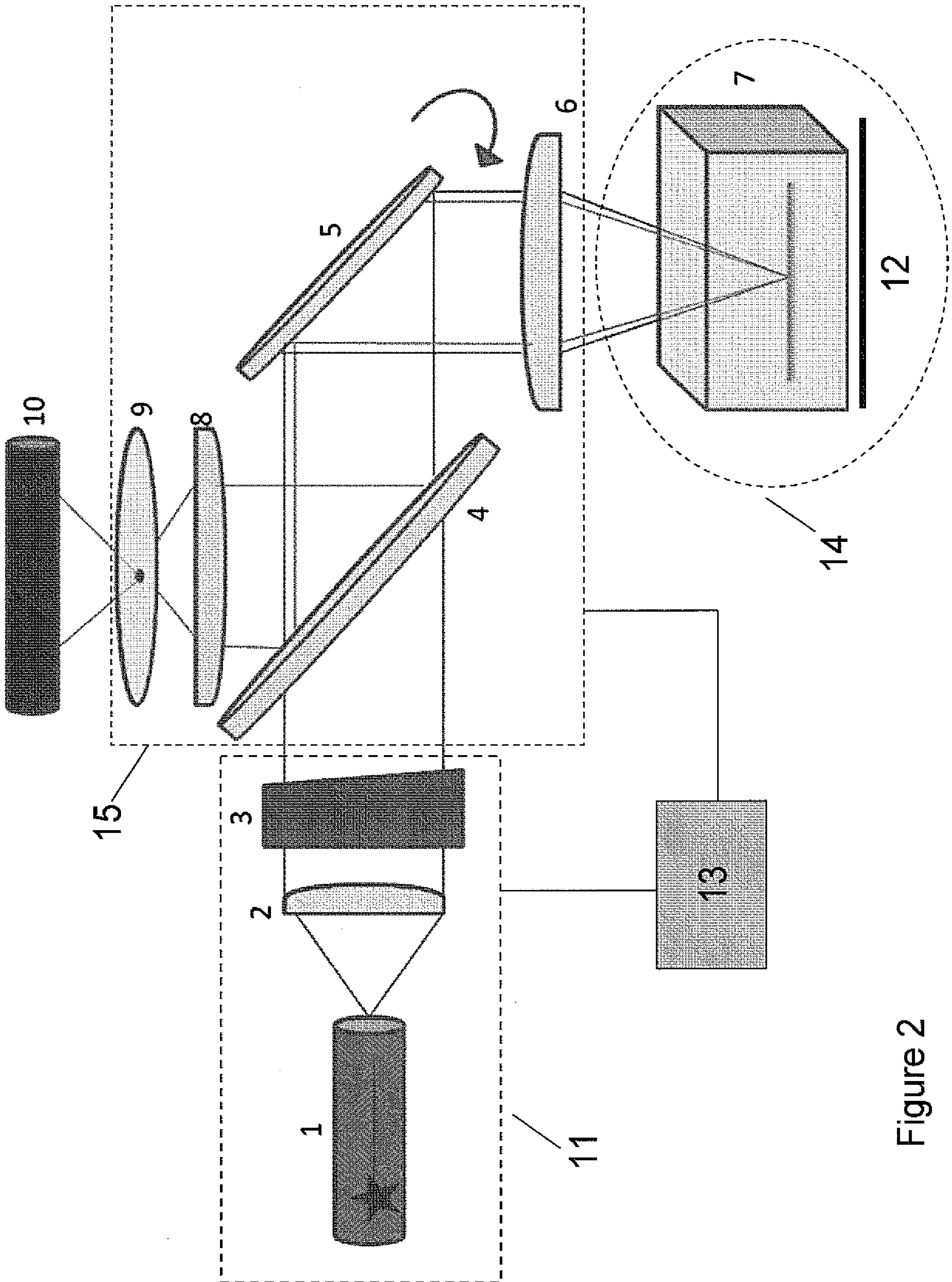

Figure 2

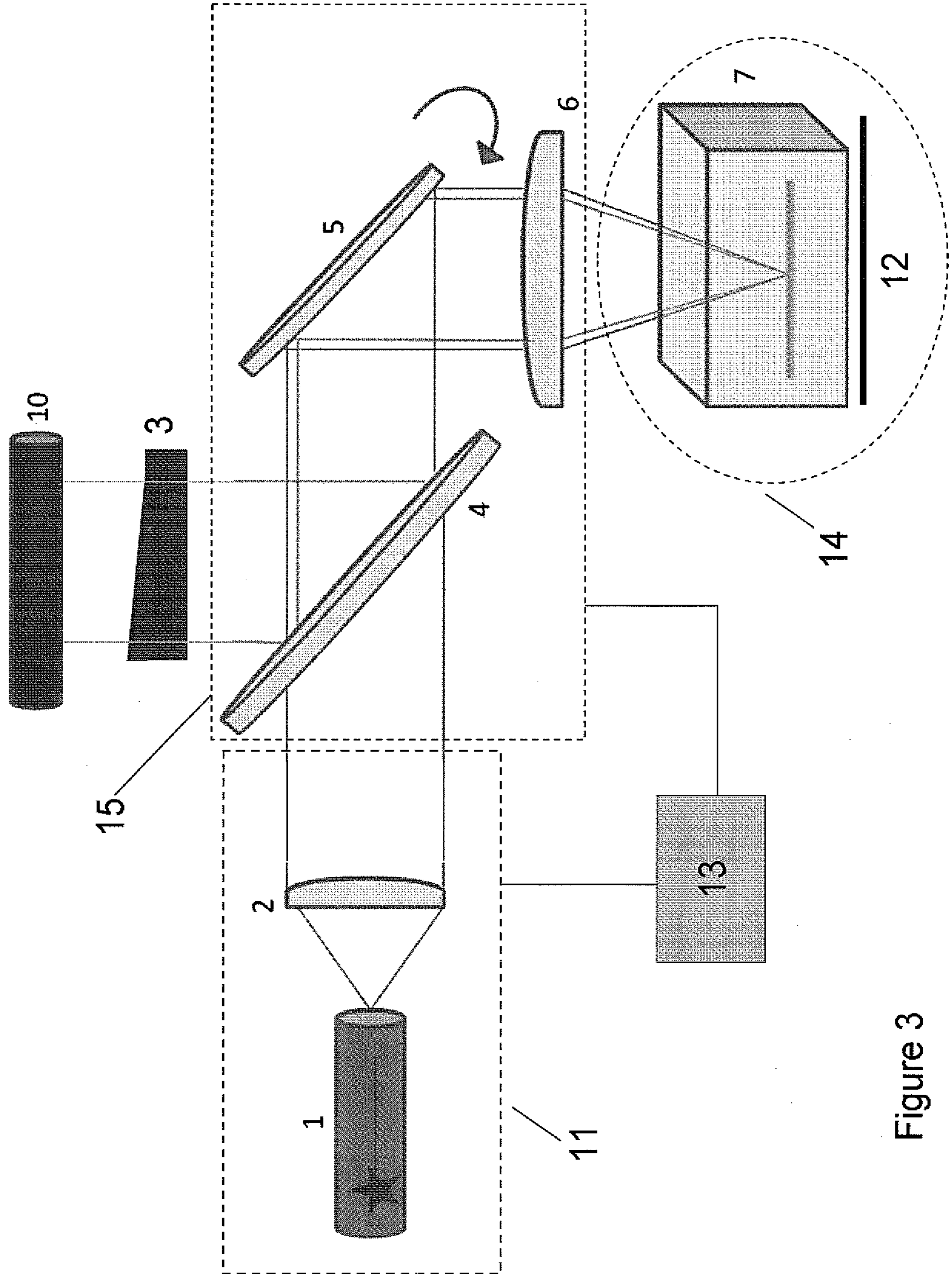

Figure 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2010/050547

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B21/00 G02B21/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FELDMAN M: "Phase shift microscopes" JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B: MICROELECTRONICSPROCESSING AND PHENOMENA, AMERICAN VACUUM SOCIETY, NEW YORK, NY, US, vol. 16, no. 6, 1 November 1998 (1998-11-01), pages 3647-3650, XP012007256 ISSN: 0734-211X * abstract; figures 1c,3 -----	1-39
X	WO 2006/072581 A (UNIV INNSBRUCK [AT]; BERNET STEFAN [AT]; RITSCH-MARTE MONIKA [AT]; JES) 13 July 2006 (2006-07-13) page 7, line 20 - page 8, line 19 figures 1-3 -----	1-39

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 October 2010	03/11/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ward, Seamus

2

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FRANKE-ARNOLD ET AL: "ADVANCES IN OPTICAL ANGULAR MOMENTUM" LASER & PHOTONICS REVIEWS, [Online] vol. 2, no. 4, 2008, pages 299-313, XP002566611 Retrieved from the Internet: URL:http://www3.interscience.wiley.com/cgi-bin/fulltext/120747962/PDFSTART> [retrieved on 2010-02-03] the whole document -----	1-39

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2010/050547

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006072581 A	13-07-2006	NONE	

Index of Claims	Application/Control No. 14339836	Applicant(s)/Patent Under Reexamination ASHRAFI ET AL.
	Examiner GORDON J STOCK JR	Art Unit 2886

✓	Rejected		-	Cancelled		N	Non-Elected		A	Appeal
=	Allowed		÷	Restricted		I	Interference		O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/31/2015								
	1	✓								
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	30	✓								
	31	-								

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	707	(orbital near angular) near momentum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2015/03/18 19:53
S2	715	(orbital near angular) near momentum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 19:53
S3	39	S2 near4 (detect$3 determin$5 sens$3 measur$5 calculat$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 19:54
S4	71	S2 near10 (detect$3 determin$5 sens$3 measur$5 calculat$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:01
S5	32	S4 not S3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:01
S6	832	(orbital near5 angular) near5 moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:05
S7	164	S6 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:06
S8	113	(orbital near4 quantum) near4 number	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:16
S10	185	S6 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near10 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:22
S11	21	S10 not S7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:22

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S12	23	S6 near10 (amount concentration)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/18 20:24
S13	833	(orbital near5 angular) near5 moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:53
S14	17	S13 same concentration	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:53
S15	421	(optic$4 near (vortex vortice))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:57
S16	29880	((optic$4 light beam) near5 (helix helical torsion$4 vortex vortice))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:57
S17	3	S15 same concentration	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:57
S18	542	S16 same concentration	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 14:58
S19	67	S15 and concentration	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/23 15:02
S20	29889	((optic$4 light beam) near5 (helix helical torsion$4 vortex vortice))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:21
S21	3146	S20 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:21
S22	214	S20 same ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:22
S23	38	S20 same ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:22

/GS/

S24	695	S20 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:22
S25	834	(orbital near5 angular) near5 moment$2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:24
S26	185	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near10 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:24
S27	164	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:25
S28	21	S26 not S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:25
S29	184	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3 obtain$3 deriv$5 monitor$3 inspect$3 test$3) near4 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:26
S30	20	S29 not S27	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:27
S31	213	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3 obtain$3 deriv$5 monitor$3 inspect$3 test$3) near10 (amount concentration))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:28
S32	28	S31 not S26	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:28
S33	52	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3 obtain$3 deriv$5 monitor$3 inspect$3 test$3) near4 (absorbance absorption))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:30
S34	82	S25 and ((determin$5 measur$5 detect$3 sens$3 calculat$3 obtain$3 deriv$5 monitor$3 inspect$3 test$3) near10 (absorbance absorption))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:38
S35	30	S34 not S33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:38

/GS/

S36	50	S25 same (amount concentration)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/24 19:40
S55	40	"optical angular momentum"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/03/31 12:47

3/ 31/ 2015 6:32:31 PM
C:\ Users\ gstock\ Documents\ EAST\ Workspaces\ 14339836.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14339836	ASHRAFI ET AL.
	Examiner	**Art Unit**
	GORDON J STOCK JR	2886

CPC- SEARCHED

Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED

Symbol	Date	Examiner

US CLASSIFICATION SEARCHED

Class	Subclass	Date	Examiner

SEARCH NOTES

Search Notes	Date	Examiner
INSPEC using: "optical angular momentum" AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPEC using: "optical angular momentum" AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPECusing: ((detect[*3] or sens[*3] or measure[*5] or determine[*5]) near/4 "orbital angular momentum") AND ((detect[*3] OR sens[*3] OR measure[*5] OR determine[*5]) NEAR/4 concentration)	3/31/15	gjs
INSPEC using: "orbital angular momentum" and (concentration near measur$6)	3/31/15	gjs
INSPEC using: "optical angular momentum" and (concentration near measur$6)	3/31/15	gjs
EAST (uspat, usocr, uspgpub, epo, jpo, derwent, ibm_tdb, fprs) see search history printout	3/18/15; 3/23/15; 3/24/15; 3/31/15	gjs

INTERFERENCE SEARCH

US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196

CONFIRMATION NO. 3583

NEW OR REVISED PPD NOTICE

OC000000072742996

25883
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

NOTICE OF NEW OR REVISED PROJECTED PUBLICATION DATE

The above-identified application has a new or revised projected publication date. The current projected publication date for this application is 09/17/2015. If this is a new projected publication date (there was no previous projected publication date), the application has been cleared by Licensing & Review or a secrecy order has been rescinded and the application is now in the publication queue.

If this is a revised projected publication date (one that is different from a previously communicated projected publication date), the publication date has been revised due to processing delays in the USPTO or the abandonment and subsequent revival of an application. The application is anticipated to be published on a date that is more than six weeks different from the originally-projected publication date.

More detailed publication information is available through the private side of Patent Application Information Retrieval (PAIR) System. The direct link to access PAIR is currently http://pair.uspto.gov. Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Questions relating to this Notice should be directed to the Office of Data Management, Application Assistance Unit at (571) 272-4000, or (571) 272-4200, or 1-888-786-0101.

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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/339,836	07/24/2014	SOLYMAN ASHRAFI	NXGN-32196	3583

25883 7590 11/21/2014

HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

EXAMINER	

ART UNIT	PAPER NUMBER
3644	

NOTIFICATION DATE	DELIVERY MODE
11/21/2014	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

patents@dalpat.com

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Doc Code:
TRACK1.GRANT

Decision Granting Request for Prioritized Examination (Track I or After RCE)	Application No.: 14/339,836

The petition, filed October 1, 2014, requesting reconsideration of the decision, mailed September 23, 2014, which initially dismissed the Request for Prioritized Examination, Track 1, is **GRANTED**.

1. THE REQUEST FILED July 24, 2014 IS **GRANTED.**

   The above-identified application has met the requirements for prioritized examination
   A. ☒ for an original nonprovisional application (Track I).
   B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination.** The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:

   A. filing a **petition for extension of time** to extend the time period for filing a reply;
   B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims**, or a multiple dependent claim;
   C. filing a **request for continued examination**;
   D. filing a notice of appeal;
   E. filing a request for suspension of action;
   F. mailing of a notice of allowance;
   G. mailing of a final Office action;
   H. completion of examination as defined in 37 CFR 41.102; or
   I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to JoAnne Burke at 571-272-4584.

/Brian W. Brown/ — Petitions Examiner, Office of Petitions
[*Signature*] — (Title)

Office of Petitions: Decision Count Sheet

Mailing Month

Application No. 14339836

For US serial numbers: enter number only, no slashes or commas. Ex: 10123456
For PCT: enter "51+single digit of year of filing+last 5 numbers", Ex. for PCT/US05/12345, enter 51512345

Deciding Official: BURKE, JOANNE

Count (1) - Palm Credit 14/339,836

Decision: GRANT

FINANCE WORK NEEDED
☐ Select Check Box for YES

Decision Type: 643 - Track One request

Notes:

Count (2)

Decision: n/a

FINANCE WORK NEEDED
☐ Select Check Box for YES

Decision Type: NONE

Notes:

Count (3)

Decision: n/a

FINANCE WORK NEEDED
☐ Select Check Box for YES

Decision Type: NONE

Notes:

Initials of Approving Official (if required)

If more than 3 decisions, attach 2nd count sheet & mark this box ☐

Printed on:

Office of Petitions: Routing Sheet

4700

Application No. 14/339,836

This application is being forwarded to your office for further processing. A decision has been rendered on a petition filed in this application.

- [X] **GRANTED**
- [ ] **DISMISSED**
- [ ] **DENIED**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Application No.:	14/339,836
Confirmation No.:	3583
Filed:	July 24, 2014
Group No.:	3644
Examiner:	to be assigned
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop OIPE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

PETITION FOR WITHDRAWAL OF DISMISSAL UNDER 37 C.F.R. § 1.181(A)

In accordance with 37 C.F.R. § 1.181(a), Applicant hereby petitions for withdrawal of dismissal and requests reconsideration of prioritized examination.

Applicant is enclosing a Preliminary Amendment to correct the defect in item E II of the Decision Dismissing Request for Prioritized Examination (Track I) and limit the Applicant to 30 claims. Also enclosed is the Decision Dismissing Request for Prioritized Examination.

This petition requires no fees. However, please charge any fee deficiency or credit any overpayment to deposit account number 20-0780/NXGN-32196 of HOWISON & ARNOTT, L.L.P.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
Attorneys for Applicant(s)

/Brian D. Walker, Reg. #37751/

Brian D. Walker
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September 30, 2014

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Serial No.:	14/339,836
Confirmation No.:	3583
Filed:	July 24, 2014
Group:	3644
Examiner:	to be assigned
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Mail Stop Non-Fee Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

PRELIMINARY AMENDMENT

Prior to the initial review, please amend the above-identified application as follows:

Amendments to the Claims begin on page 2 of this paper.

Remarks begin on page 8 of this paper.

In the Claims

This listing of the claims will replace all prior versions, and listings, of the claims in the application.

1. (Original) An apparatus for measuring the concentration of a material within a sample, comprising:

signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample;

a detector for receiving the first signal after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

2. (Original) The apparatus of Claim 1, wherein the signal generation circuitry further comprises:

an emitting source for emitting the first signal comprising a plurality of plane waves;

orbital angular momentum generation circuitry for receiving the first signal and applying the at least one orbital angular momentum to the plane waves of the first signal.

3. (Original) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry for applying a fixed orbital angular momentum to the first signal.

4. (Original) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plane waves of the first signal.

5. (Original) The apparatus of Claim 4, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

6. (Original) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry for applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

7. (Original) The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

8. (Original) The apparatus of Claim 1 further including amplifying circuitry for receiving the first signal after the first signal passes through the sample and amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

9. (Original) The apparatus of Claim 8, wherein the amplifying circuitry further includes a hologram for amplifying the orbital angular momentums associated with the concentration of the material in the sample.

10. (Original) The apparatus of Claim 1, wherein the detector further comprises:

an orbital angular momentum detector for determining the detected value of the orbital angular momentum within the first signal from the sample; and

a processor for determining a concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

11. (Original) The apparatus of Claim 10 further including a user interface associated with the processor comprising:

a set of computer instructions for configuring the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database for storing concentration data from the concentrations determined by the processor.

12. (Original) The apparatus of Claim 11, wherein the user interface further includes a wireless interface for communicating the concentration data to a remote location.

13. (Original) The apparatus of Claim 1, wherein differing values of the detected value of the concentration indicate different concentrations of the material within the sample.

14. (Original) The apparatus of Claim 1, wherein the first signal comprises a light beam.

15. (Original) An apparatus for measuring the concentration of a material within a sample, comprising:

an emitting source for emitting a first light beam comprising a plurality of plane waves;

orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam;

amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith;

a detector for receiving the first light after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith.

16. (Original) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry for applying a fixed orbital angular momentum to the first signal.

17. (Original) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plane waves of the first signal.

18. (Original) The apparatus of Claim 17, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

19. (Original) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry for applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

20. (Original) The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

21. (Original) The apparatus of Claim 15 further comprising a processor for determining a concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

22. (Original) The apparatus of Claim 21 further including a user interface associated with the processor comprising:

a set of computer instructions for configuring the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database for storing concentration data from the concentrations determined by the processor.

23. (Original) The apparatus of Claim 22, wherein the user interface further includes a wireless interface for communicating the concentration data to a remote location.

24. (Original) The apparatus of Claim 15, wherein differing values of the detected value of the concentration indicate different concentrations of the material within the sample.

25. (Original) A method for measuring the concentration of a material within a sample, comprising:

generating a first signal having at least one orbital angular momentum applied thereto;

applying the first signal to the sample;

receiving the first signal after it passes through the sample;

detecting a value of the orbital angular momentum within the received first signal; and

determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

26. (Original) The method of Claim 25, wherein the step of generating further comprises:

emitting the first signal comprising a plurality of plane waves;

receiving the first signal; and

applying the at least one orbital angular momentum to the plane waves of the first signal.

27. (Original) The method of Claim 26, wherein the step of applying further comprises applying a fixed orbital angular momentum to the first signal.

28. (Original) The method of Claim 26, wherein the step of applying further comprises applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

29. (Original) The method of Claim 25 further including:

receiving the first signal after the first signal passes through the sample; and

amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

30. (Original) The method of Claim 25 further including storing concentration data from the determined concentrations.

31. (Canceled)

Remarks

Claim 31 was canceled. Thus, Claims 1 - 30 remain pending in the application.

Please charge any additional fees or deficiencies in fees or credit any overpayment to Deposit Account No. 20-0780/NXGN-32196 of HOWISON & ARNOTT, L.L.P.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
Attorneys for Applicant(s)

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September 30, 2014

Electronic Acknowledgement Receipt

EFS ID:	20286865
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	01-OCT-2014
Filing Date:	24-JUL-2014
Time Stamp:	12:42:32
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Petition for review by the Office of Petitions.	NXG32196PETITIONWithdrawofDismissal.pdf	71686 dda3052f0537e27f671dd6f37bad1f7532f53b75	no	1

Warnings:

Information:

2		NXG32196PAM.pdf	92454 9c3ff1d8e964fe26916b6a70ed423a52203f6ab6	yes	8

Multipart Description/PDF files in .zip description

Document Description	Start	End
Preliminary Amendment	1	1
Claims	2	7
Applicant Arguments/Remarks Made in an Amendment	8	8

Warnings:

Information:

Total Files Size (in bytes):	164140

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/339,836	Filing Date 07/24/2014	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter “0” in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	10/01/2014	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 30	Minus	** 31	= 0	x $40 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	x $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write “0” in column 3.
** If the “Highest Number Previously Paid For” IN THIS SPACE is less than 20, enter “20”.
*** If the “Highest Number Previously Paid For” IN THIS SPACE is less than 3, enter “3”.
The “Highest Number Previously Paid For” (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/NICOLE C. LAWRENCE/

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Commissioner for Patents
United States Patent and Trademark Office
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Alexandria, VA 22313-1450
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HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS TX 75374-1715

MAILED
SEP 23 2014
OFFICE OF PETITIONS

Doc Code: TRACK1.DENY

Decision Dismissing Request for Prioritized Examination (Track I)	Application No.: 14/339,836

1. THE REQUEST FILED July 24, 2014 IS **DISMISSED** BECAUSE:

A. ☐ The application is not a utility application under 35 U.S.C. 111(a) filed by EFS-Web or a plant application under 35 U.S.C. 111(a) filed by paper:
 i. ☐ The application is a utility application that was not filed by EFS-Web.
 ii. ☐ The application is neither a utility application nor a plant application, but rather is a Design application, which is excluded from the Track I program.

B. ☐ The request was not filed with the application or on the same date the application was filed.

C. ☐ One or more of the following fees were not filed with the application or on the same date the application was filed:
 i. ☐ Basic filing fee, as set forth in 37 CFR 1.16(a), or for a plant application, 37 CFR 1.16(c).
 ii. ☐ Search fee, as set forth in 37 CFR 1.16(k), or for a plant application, 37 CFR 1.16(m).
 iii. ☐ Examination fee, as set forth in 37 CFR 1.16(o), or for a plant application, 37 CFR 1.16(q).
 iv. ☐ Publication fee, as set forth in 37 CFR 1.18(d).
 v. ☐ Track I processing fee, as set forth in 37 CFR 1.17(i).
 vi. ☐ Track I prioritized examination fee, as set forth in 37 CFR 1.17(c).

D. ☐ The executed inventor's oath or declaration, **or** an application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) was not filed with the application or on the same date the application was filed.

E. ☒ The application contains or has been amended to contain:
 i. ☐ More than four independent claims.
 ii. ☒ More than thirty total claims.
 iii. ☐ One or more multiple dependent claims.

F. ☐ The Track I program has exceeded its limit of 10,000 requests for the current fiscal year.

G. ☐ Other: ______________________________.

2. CONCLUSION

☒ **<u>ALL</u> of the above defect(s) consist only of one or more of items E (i-iii). Applicant is hereby accorded a <u>non-extendable ONE MONTH</u> time period from the mailing date of this Decision to (1) correct the subject defect(s) and (2) file a petition under 37 CFR 1.181 requesting reconsideration of prioritized examination. If no such petition is timely filed, the application will not undergo prioritized examination.**

-OR-

☐ **The application will not undergo prioritized examination, because the request was not accompanied by all of the required items.**

Telephone inquiries with regard to this decision should be directed to <u>JoAnne Burke</u> at <u>571-272-4584</u>.

/JoAnne Burke/
[*Signature*]

<u>Paralegal Specialist, Office of Petitions</u>
(Title)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	ASHRAFI, Solyman
Serial No.:	14/339,836
Confirmation No.:	3583
Filed:	July 24, 2014
Group:	3644
Examiner:	to be assigned
For:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Licensing and Review (Mail Stop L&R)
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

SUBMISSION OF PROPERTY RIGHTS STATEMENT

In response to the Notice of Property Rights Statement Requirement, the Applicants submit a Statement of Property Rights executed by inventors Solyman ASHRAFI, Nima ASHRAFI and Roger LINQUIST on August 29, 2014.

This Submission requires no fees. However, please charge fee deficiencies or credit any overpayment to Deposit Account No. 20-0780/NXGN-32196 of HOWISON & ARNOTT, L.L.P.

Respectfully submitted,
HOWISON & ARNOTT, L.L.P.
Attorneys for Applicant(s)

/Brian D. Walker, Reg. #37751/

Brian D. Walker
Registration No. 37,751

BDW/als
P.O. Box 741715
Dallas, Texas 75374-1715
Tel: 972-479-0462
Fax: 972-479-0464
August 29, 2014

The following is an example of an acceptable property rights statement. Statements of this type are, of course, only suitable for situations in which NO Agency funds or other considerations were involved in the making or conception of the invention. While this example is in the form of a declaration, a sworn document is equally acceptable.

I(We) Solyman ASHRAFI / Nima ASHRAFI / Roger LINQUIST

citizens of US

residing at Solyman ASHRAFI and Nima ASHRAFI: 5924 New Haven Dr., Plano, TX 75093
Roger LINQUIST: 6508 Turtle Creek Boulevard, Dallas, Texas 75205

declare:

That I(we) made and conceived the invention described and claimed in patent application:

Serial Number 14/339,836 filed in the United States of America on July 24, 2014

titled System and method for making concentration measurements within a sample material using orbital angular momentum

(check and complete either I or II below)

☐ I. *(For Inventors Employed by an Organization)* That I(We) made and conceived this invention while employed by ______. That the invention is related to the work I am (we are) employed to perform and was made within the scope of my (our) employment duties; That the invention was made during working hours and with the use of facilities, equipment, materials, funds, information and services of ______
Other relevant facts are ______

That to the best of my (our) knowledge and belief (and/or) based upon information provided by ______
of ______

--OR--

☒ II. *(For Self-Employed Inventors)* That I (we) made and conceived this invention on my (our) own time using only my (our) own facilities, equipment, materials, funds, information and services. Other relevant factors are n/a

(check III and/or IV below as appropriate)

That to the best of my (our) knowledge and belief:
☒ III. The invention was not made or conceived in the course of, or in connection with, or under the terms of any contract, subcontract or arrangement entered into with or for the benefit of the United States Atomic Energy Commission or its successors: Energy Research and Development Administration or the Department of Energy.

--AND/OR--

☒ IV. The invention was not made (conceived or first actually reduced to practice) under nor is there any relationship of the invention to the performance of any work under any contract of the National Aeronautics and Space Administration.

The undersigned inventors(s) declare further that all statements made herein of his or her (their) own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Inventor's Signature: [signature] Solyman ASHRAFI / Nima ASHRAFI

Post Office Address: 5924 New Haven Drive, Plano, Texas 75093

Date: August 29, 2014

Inventor's Signature: [signature] Roger LINQUIST

Post Office Address: 6508 Turtle Creek Boulevard, Dallas, Texas 75205

Date: 8/29/14

FORM PTOL-456 (Rev. 07-08)

Electronic Acknowledgement Receipt

EFS ID:	20007503
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	SOLYMAN ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	03-SEP-2014
Filing Date:	24-JUL-2014
Time Stamp:	17:40:38
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Any request going to L and R	NXG32196NonNASAStatement Submisson.pdf	75178 998e72a1586d68cb1fa0922e23d9b6b7e3bb6ebf	no	1

Warnings:

Information:

2	Any request going to L and R	NXG32196NonNasaStatementEXE.pdf	137142 b303fbbb569ac0cd20345ab744bb367ade1a8b2a	no	1
Warnings:					
Information:					
		Total Files Size (in bytes):	212320		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/339,836

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE($)	FEE($)		RATE($)	FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	70		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	300		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	360		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	31 minus 20 =	* 11	x 40 =	440	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 210 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1170		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
AMENDMENT A		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1)		(Column 2)	(Column 3)					
AMENDMENT B		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
14/339,836	07/24/2014	3644	1170	NXGN-32196	31	3

CONFIRMATION NO. 3583

25883
HOWISON & ARNOTT, L.L.P
P.O. BOX 741715
DALLAS, TX 75374-1715

FILING RECEIPT

OC000000069970227

Date Mailed: 08/05/2014

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

SOLYMAN ASHRAFI, PLANO, TX;
ROGER LINQUIST, DALLAS, TX;
NIMA ASHRAFI, PLANO, TX;

Applicant(s)

SOLYMAN ASHRAFI, PLANO, TX;
ROGER LINQUIST, DALLAS, TX;
NIMA ASHRAFI, PLANO, TX;

Power of Attorney: The patent practitioners associated with Customer Number 25883

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/951,834 03/12/2014

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Projected Publication Date: To Be Determined - pending completion of Security Review

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****

Title

SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Preliminary Class

244

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

Doc Code: TRACK1.REQ
Document Description: TrackOne Request

PTO/AIA/424 (03-13)

CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION UNDER 37 CFR 1.102(e) (Page 1 of 1)

First Named Inventor:	ASHRAFI, Solyman	Nonprovisional Application Number (if known):	
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1), the prioritized examination fee set forth in 37 CFR 1.17(c), and if not already paid, the publication fee set forth in 37 CFR 1.18(d) have been filed with the request. The basic filing fee, search fee, examination fee, and any required excess claims and application size fees are filed with the request or have been already been paid.
2. The application contains or is amended to contain no more than four independent claims and no more than thirty total claims, and no multiple dependent claims.
3. The applicable box is checked below:

I. ☑ **<u>Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)</u>**

i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via EFS-Web.

---OR---

(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.

ii. The executed inventor's oath or declaration is filed with the application. (37 CFR 1.63 and 1.64)

II. ☐ **<u>Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)</u>**

i. A request for continued examination has been filed with, or prior to, this form.
ii. If the application is a utility application, this certification and request is being filed via EFS-Web.
iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature /Brian D. Walker, Reg. #37751/	Date July 24, 2014
Name (Print/Typed) Brian D. Walker	Practitioner Registration Number 37,751

Note: *This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.**

☑ *Total of ONE forms are submitted.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	NXGN-32196
	Application Number	

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	SOLYMAN		ASHRAFI	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	PLANO	State/Province	TX	Country of Residence i	US

Mailing Address of Inventor:

Address 1	5924 NEW HAVEN DRIVE		
Address 2			
City	PLANO	State/Province	TX
Postal Code	75093	Country i	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	ROGER		LINQUIST	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	DALLAS	State/Province	TX	Country of Residence i	US

Mailing Address of Inventor:

Address 1	6508 TURTLE CREEK BOULEVARD		
Address 2			
City	DALLAS	State/Province	TX
Postal Code	75205	Country i	US

Inventor 3 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	NIMA		ASHRAFI	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	NXGN-32196
	Application Number	

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

City	PLANO	**State/Province**	TX	**Country of Residence** i	US

Mailing Address of Inventor:

Address 1	5924 NEW HAVEN DRIVE		
Address 2			
City	PLANO	**State/Province**	TX
Postal Code	75093	**Country** i	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	25883	
Email Address	ADMIN@DALPAT.COM	Add Email / Remove Email

Application Information:

Title of the Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM		
Attorney Docket Number	NXGN-32196	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		**Suggested Figure for Publication (if any)**	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	NXGN-32196
	Application Number	

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Customer Number	25883

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61951834	2014-03-12

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country i	Filing Date (YYYY-MM-DD)	Access Code i (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	NXGN-32196
	Application Number	

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

Authorization to Permit Access:

☐ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	NXGN-32196
	Application Number	

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES PATENT

SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. Provisional Application No. 61/951,834, filed March 12, 2014, entitled CONCENTRATION MEASUREMENTS USING PHOTON ORBITAL ANGULAR MOMENTUM (Atty. Dkt. No. NXGN-32089), the specification of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to concentration measurements of various organic and non-organic materials, and more particularly, to concentration measurements of organic and non-organic materials using the orbital angular momentum of waves passed through a sample of the material.

BACKGROUND

[0003] Concentration measurements of organic and non-organic materials within human tissue is an increasingly important aspect of healthcare for individuals. The development of non-invasive measurement techniques for monitoring biological and metabolic agents within human tissue is an important aspect of diagnosis therapy of various human diseases and may play a key role in the proper management of diseases.

[0004] One example of a biological agent that may be monitored for within human tissue is glucose. Glucose ($C_6H_{12}O_6$) is a monosaccharide sugar and is one of the most important carbohydrate nutrient sources. Glucose is fundamental to almost all biological processes and is required for the production of ATP adenosine triphosphate and other essential cellular components. The normal range of glucose concentration within human blood is 70-160 mg/dl depending on the time of the last meal, the extent of physical tolerance and other factors. Freely circulating glucose molecules stimulate the release of insulin from the pancreas. Insulin helps glucose molecules to penetrate the cell wall by binding two specific receptors within cell membranes which are normally impermeable to glucose.

[0005] One disease associated with issues related to glucose concentrations is diabetes. Diabetes is a disorder caused by the decreased production of insulin, or by a decreased ability to utilize insulin and transport the glucose across cell membranes. As a result, a high potentially dangerous concentration of glucose can accumulate within the blood (hyperglycemia) during the disease. Therefore, it is of great importance to maintain blood glucose concentration within a normal range in order to prevent possible severe physiological complications.

[0006] One significant role of physiological glucose monitoring is the diagnosis and management of several metabolic diseases, such as diabetes mellitus (or simply diabetes). There are a number of invasive and non-invasive techniques presently used for glucose monitoring. The problem with existing non-invasive glucose monitoring techniques is that a clinically acceptable process has not yet been determined. Standard techniques from the analysis of blood currently involve an individual puncturing a finger and subsequent analysis of collected blood samples from the finger. In recent decades, non-invasive blood glucose monitoring has become an increasingly important topic of investigation in the realm of biomedical engineering. In particular, the introduction of optical approaches have caused some advances within the field. Advances in optics have led to a focused interest in optical imaging technologies and the development of non-invasive imaging systems. The application of optical methods to monitoring in cancer diagnostics and treatment is also a growing field due to the simplicity and low risk of optical detection methods.

[0007] Many optical techniques for sensing different tissue metabolites and glucose in living tissue have been in development over the last 50 years. These methods have been based upon florescent, near infrared and mid-infrared spectroscopy, Raman spectroscopy, photoacoustics, optical coherence tomography and other techniques. However, none of these techniques that have been tried have proved completely satisfactory.

[0008] Another organic component lending itself to optical material concentration sensing involves is human skin. The defense mechanisms of human skin are based on the action of antioxidant substances such as carotenoids, vitamins and enzymes. Beta carotene and lycopene represent more than 70% of the carotenoids in the human organism. The topical or systematic application of beta carotene and lycopene is a general strategy for improving the defense system of the human body. The evaluation and optimization of this treatment requires the measurement of the b-carotene and lycopene concentrations in human tissue, especially in the human skin as the barrier to the environment.

[0009] Thus, an improved non-invasive technique enabling the detection of concentrations of various materials within a human body or other types of samples would have a number of applications within the medical field.

SUMMARY

[0010] The present invention, as disclosed and describe herein, in one aspect thereof, comprises an apparatus for measuring the concentration of a material within a sample. Signal generation circuitry generates a first signal having at least one orbital angular momentum applied thereto and applies the first signal to the sample. A detector for receives the first signal after it passes through the sample and determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying Drawings in which:

[0012] Fig. 1 illustrates a general representation of a manner for determining a concentration of a particular material within a sample using a light beam or other wave;

[0013] Fig. 2 illustrates a light beam having orbital angular momentum imparted thereto;

[0014] Fig. 3 illustrates a series of parallel wavefronts;

[0015] Fig. 4 illustrates a wavefront having a Poynting vector spiraling around a direction of propagation of the wavefront;

[0016] Fig. 5 illustrates a plane wavefront while Fig. 6 helical wavefront;

[0017] Fig. 7 illustrates a plane wave having only variations in the spin vector;

[0018] Fig. 8 illustrates the application of a unique orbital angular momentum to a wave;

[0019] Figs. 9a-9c illustrate the differences between signals having different orbital angular momentum applied thereto;

[0020] Fig. 10 illustrates the propagation of Poynting vectors for various eigenmodes;

[0021] Fig. 11 illustrates a block diagram of an apparatus for providing concentration measurements of various materials using orbital angular momentum;

[0022] Fig. 12 illustrates an emitter of the system of Fig. 11;

[0023] Fig. 13 illustrates a fixed orbital angular momentum generator of the system of Fig. 11;

[0024] Figs. 14a-14d illustrate various holograms for use in applying an orbital angular momentum to a plane wave signal;

[0025] Fig. 15 illustrates the relationship between Hermite-Gaussian modes and Laguerre-Gaussian modes;

[0026] Fig. 16 illustrates super-imposed holograms for applying orbital angular momentum to a signal;

[0027] Fig. 17 illustrates a tunable orbital angular momentum generator for use in the system of Fig. 11;

[0028] Fig. 18 illustrates a block diagram of a tunable orbital angular momentum generator including multiple hologram images therein;

[0029] Fig. 19 illustrates the manner in which the output of the OAM generator may be varied by applying different orbital angular momentums thereto;

[0030] Fig. 20 illustrates an alternative manner in which the OAM generator may convert a Hermite-Gaussian beam to a Laguerre-Gaussian beam;

[0031] Fig. 21 illustrates the manner in which holograms within an OAM generator may twist a beam of light;

[0032] Fig. 22 illustrates the manner in which a sample receives an OAM twisted wave and provides an output wave having a particular OAM signature;

[0033] Fig. 23 illustrates the manner in which orbital angular momentum interacts with a molecule around its beam axis;

[0034] Fig. 24 illustrates a block diagram of the matching circuitry for amplifying a received orbital angular momentum signal;

[0035] Fig. 25 illustrates the manner in which the matching module may use non-linear crystals in order to generate a higher order orbital angular momentum light beam;

[0036] Fig. 26 illustrates a block diagram of an orbital angular momentum detector and user interface;

[0037] Fig. 27 illustrates the effect of sample concentrations upon the spin angular polarization and orbital angular polarization of a light beam passing through a sample;

[0038] Fig. 28 more particularly illustrates the process that alters the orbital angular momentum polarization of a light beam passing through a sample;

[0039] Fig. 29 provides a block diagram of a user interface of the system of Fig. 11;

[0040] Fig. 30 illustrates a network configuration for passing around data collected via devices such as that illustrated in Fig. 11; and

[0041] Fig. 31 provides a block diagram of a more particular embodiment of an apparatus for measuring the concentration of glucose using orbital angular momentum.

DETAILED DESCRIPTION

[0042] Referring now to the drawings, wherein like reference numbers are used herein to designate like elements throughout, the various views and embodiments of system and method for making concentration measurements within a sample material using orbital angular momentum are illustrated and described, and other possible embodiments are described. The figures are not necessarily drawn to scale, and in some instances the drawings have been exaggerated and/or simplified in places for illustrative purposes only. One of ordinary skill in the art will appreciate the many possible applications and variations based on the following examples of possible embodiments.

[0043] Referring now to the drawings, and more particularly to Fig. 1, there is illustrated a general representation of the manner in which the concentration of a particular material sample 102 may be monitored using orbital angular momentum applied to a light beam or other wave transmitted through the material sample 102. The material sample 102 has a beam 104 shined through the length of the material sample 102. After passing through the material sample 102, the exiting beam 106 leaves the material sample and may be analyzed to determine various concentration characteristics within the material sample 102. The manner in which the different characteristics of the material sample 102 may be determined within the exiting beam 106 is achieved with respect to an analysis of the orbital angular momentum signatures that are imparted to the exiting beam 106 by the concentrations within the material sample 102.

[0044] Referring now also to Fig. 2, there is illustrated one embodiment of a beam for use with the system. A light beam 104 consists of a stream of photons 202 within the light beam 104. Each photon has an energy $\pm\hbar\omega$ and a linear momentum of $\pm\hbar k$ which is directed along the light beam axis 204 perpendicular to the wavefront. Independent of the frequency, each photon 202 within the light beam has a spin angular momentum 206 of $\pm\hbar$ aligned parallel or antiparallel to the direction of light beam propagation. Alignment of all of the photons 202 spins gives rise to a circularly polarized light beam. In addition to the circular polarization, the light beams also may carry an orbital angular momentum 208 which does not depend on the circular polarization and thus is not related to photon spin.

[0045] Lasers are widely used in optical experiments as the source of well-behaved light beams of a defined frequency. A laser may be used for providing the light beam 104 as described with respect to Fig. 1. The energy flux in any light beam 104 is given by the Poynting vector which may be calculated from the vector product of the electric and magnetic fields within the light beam. In a vacuum or any isotropic material, the Poynting vector is parallel to the wave vector and perpendicular to the wavefront of the light beam. In a normal laser light, the wavefronts 300 are parallel as illustrated in Fig. 3. The wave vector and linear momentum of the photons are directed along the axis in a z direction 302. The field distributions of such light beams are paraxial solutions to Maxwell's wave equation but although these simple beams are the most common, other possibilities exist.

[0046] For example, beams that have *l* intertwined helical fronts are also solutions of the wave equation. The structure of these complicated beams is difficult to visualize, but their form is familiar from the *l*=3 fusilli pasta. Most importantly, the wavefront has a Poynting vector and a wave vector that spirals around the light beam axis direction of propagation as illustrated in Fig. 4 at 402.

[0047] A Poynting vector has an azimuthal component on the wave front and a non-zero resultant when integrated over the beam cross-section. The spin angular momentum of circularly polarized light may be interpreted in a similar way. A beam with a circularly polarized planer wave front, even though it has no orbital angular momentum, has an azimuthal component of the Poynting vector proportional to the radial intensity gradient. This integrates over the cross-section of the light beam to a finite value. When the beam is linearly polarized, there is no azimuthal component to the Poynting vector and thus no spin angular momentum.

[0048] Thus, the momentum of each photon 202 within the light beam 104 has an azimuthal component. A detailed calculation of the momentum involves all of the electric fields and magnetic fields within the light beam, particularly those electric and magnetic fields in the direction of propagation of the beam. For points within the beam, the ratio between the azimuthal components and the z components of the momentum is found to be l/kr. (where l=_____; k=______; r=______.) The linear momentum of each photon 202 within the light beam 104 is given by $\hbar k$, so if we take the cross product of the azimuthal component within a radius vector, *r*, we obtain an orbital momentum for a photon 202 of $l\hbar$. Note also that the azimuthal component of the wave vectors is *l/r* and independent of the wavelength.

[0049] Referring now to Figs. 5 and 6, there are illustrated plane wavefronts and helical wavefronts. Ordinarily, laser beams with plane wavefronts 502 are characterized in terms of Hermite-Gaussian modes. These modes have a rectangular symmetry and are described by two mode indices m 504 and n 506. There are m nodes in the x direction and n nodes in the y direction. Together, the combined modes in the x and y direction are labeled HG_{mn} 508. In contrast, as shown in Fig. 6 beams with helical wavefronts 602 are best characterized in terms of Laguerre-Gaussian modes which are described by indices *I* 603, the number of intertwined helices 604, and p, the number of radial nodes 606. The Laguerre-Gaussian modes are labeled LG_{mn} 610. For $l \neq 0$, the phase singularity on a light beam 104 results in 0 on axis intensity. When a light beam 104 with a helical wavefront is also circularly polarized, the angular momentum has orbital and spin components, and the total angular momentum of the light beam is $(l \pm \hbar)$ per photon.

[0050] Using the orbital angular momentum state of the transmitted energy signals, physical information can be embedded within the electromagnetic radiation transmitted by the signals. The Maxwell-Heaviside equations can be represented as:

$$\nabla \cdot \mathrm{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t}$$

$$\nabla \cdot \mathrm{B} = 0$$

$$\nabla \times \mathrm{B} = \varepsilon_0 \mu_0 \frac{\partial \mathrm{E}}{\partial t} + \mu_0 \mathrm{j}(\mathrm{t}, \mathrm{x})\text{the}$$

where ∇ is the del operator, E is the electric field intensity and B is the magnetic flux density. Using these equations, we can derive 23 symmetries/conserve quantities from Maxwell's original equations. However, there are only ten well-known conserve quantities and only a few of these are commercially used. Historically if Maxwell's equations where kept in their original quaternion forms, it would have been easier to see the symmetries/conserved quantities, but when they were modified to their present vectorial form by Heaviside, it became more difficult to see such inherent symmetries in Maxwell's equations.

[0051] The conserved quantities and the electromagnetic field can be represented according to the conservation of system energy and the conservation of system linear momentum. Time symmetry, i.e. the conservation of system energy can be represented using Poynting's theorem according to the equations:

$$H = \sum_i m_i \gamma_i c^2 + \frac{\varepsilon_0}{2} \int d^3x \left(|\mathrm{E}|^2 + c^2 |\mathrm{B}|^2 \right)$$

$$\frac{dU^{mech}}{dt} + \frac{dU^{em}}{dt} + \oint_{s'} d^2x' \hat{n}' \cdot S = 0$$

[0052] The space symmetry, i.e., the conservation of system linear momentum representing the electromagnetic Doppler shift can be represented by the equations:

$$P = \sum_i m_i \gamma_i v_i + \varepsilon_0 \int d^3x \left(\mathrm{E} \times \mathrm{B} \right)$$

$$\frac{dp^{mech}}{dt} + \frac{dp^{em}}{dt} + \oint_{s'} d^2x' \hat{n}' \cdot \mathrm{T} = 0$$

[0053] The conservation of system center of energy is represented by the equation:

$$\mathrm{R} = \frac{1}{H} \sum_i (x_i - x_0) m_i \gamma_i c^2 + \frac{\varepsilon_0}{2H} \int d^3x \, (x - x_0) \left(|\mathrm{E}^2| + c^2 |\mathrm{B}^2| \right)$$

[0054] Similarly, the conservation of system angular momentum, which gives rise to the azimuthal Doppler shift is represented by the equation:

$$\frac{dJ^{mech}}{dt} + \frac{dJ^{em}}{dt} + \oint_{s'} d^2x' \hat{n}' \cdot \mathrm{M} = 0$$

[0055] For radiation beams in free space, the EM field angular momentum J^{em} can be separated into two parts:

$$J^{em} = \varepsilon_0 \int_{V'} d^3x' (E \times A) + \varepsilon_0 \int_{V'} d^3x' E_i [(x' - x_0) \times \nabla] A_i$$

[0056] For each singular Fourier mode in real valued representation:

$$J^{em} = -i\frac{\varepsilon_0}{2\omega} \int_{V'} d^3x' (E^* \times E) - i\frac{\varepsilon_0}{2\omega} \int_{V'} d^3x' E_i [(x' - x_0) \times \nabla] E_i$$

[0057] The first part is the EM spin angular momentum S^{em}, its classical manifestation is wave polarization. And the second part is the EM orbital angular momentum L^{em} its classical manifestation is wave helicity. In general, both EM linear momentum P^{em}, and EM angular momentum $J^{em} = L^{em} + S^{em}$ are radiated all the way to the far field.

[0058] By using Poynting theorem, the optical vorticity of the signals may be determined according to the optical velocity equation:

$$\frac{\partial U}{\partial t} + \nabla \cdot S = 0,$$

where S is the Poynting vector

$$S = \frac{1}{4}\left(\mathrm{E} \times \mathrm{H}^* + \mathrm{E}^* \times \mathrm{H}\right),$$

and U is the energy density

$$U = \frac{1}{4}\left(\varepsilon|\mathrm{E}|^2 + \mu_0 |\mathrm{H}|^2\right),$$

with E and H comprising the electric field and the magnetic field, respectively, and ε and μ_0 being the permittivity and the permeability of the medium, respectively. The optical vorticity V may then be determined by the curl of the optical velocity according to the equation:

$$V = \nabla \times v_{opt} = \nabla \times \left(\frac{\mathrm{E} \times \mathrm{H}^* + \mathrm{E}^* \times \mathrm{H}}{\varepsilon |\mathrm{E}|^2 + \mu_0 |\mathrm{H}|^2} \right)$$

[0059] Referring now to Figs. 7 and 8, there are illustrated the manner in which a signal and an associated Poynting vector of the signal vary in a plane wave situation (Fig. 7) where only the spin vector is altered, and in a situation wherein the spin and orbital vectors are altered in a manner to cause the Poynting vector to spiral about the direction of propagation (Fig. 8).

[0060] In the plane wave situation, illustrated in Fig. 7, when only the spin vector of the plane wave is altered, the transmitted signal may take on one of three configurations. When the spin vectors are in the same direction, a linear signal is provided as illustrated generally at 704. It should be noted that while 704 illustrates the spin vectors being altered only in the x direction to provide a linear signal, the spin vectors can also be altered in the y direction to provide a linear signal that appears similar to that illustrated at 704 but in a perpendicular orientation to the signal illustrated at 704. In linear polarization such as that illustrated at 704, the vectors for the signal are in the same direction and have a same magnitude.

[0061] Within a circular polarization as illustrated at 706, the signal vectors 712 are 90 degrees to each other but have the same magnitude. This causes the signal to propagate as illustrated at 706 and provide the circular polarization 714 illustrated in Fig. 7. Within an elliptical polarization 708, the signal vectors 716 are also 90 degrees to each other but have differing magnitudes. This provides the elliptical polarizations 718 illustrated for the signal propagation 408. For the plane waves illustrated in Fig. 7A, the Poynting vector is maintained in a constant direction for the various signal configurations illustrated therein.

[0062] The situation in Fig. 8 illustrates when a unique orbital angular momentum is applied to a signal. When this occurs, Poynting vector S 810 will spiral around the general direction of propagation 812 of the signal. The Poynting vector 810 has three axial components S_φ, S_p and S_z which vary causing the vector to spiral about the direction of propagation 612 of the signal. The changing values of the various vectors comprising the Poynting vector 810 may cause the spiral of the Poynting vector to be varied in order to enable signals to be transmitted on a same wavelength or frequency as will be more fully described herein. Additionally, the values of the orbital angular momentum indicated by the Poynting vector 410 may be measured to determine concentrations associated with particular materials being processed by a concentration scanning mechanism.

[0063] Figs. 9a-9c illustrate the differences in signals having a different helicity (i.e., orbital angular momentum applied thereto). The differing helicities would be indicative of differing concentration of materials within a sample that a beam was being passed through. By determining the particular orbital angular momentum signature associated with a signal, the concentration amounts of the material could be determined. Each of the spiraling Poynting vectors associated with a signal 902, 904 and 906 provides a different-shaped signal. Signal 902 has an orbital angular momentum of +1, signal 904 has an orbital angular momentum of +3 and signal 906 has an orbital angular momentum of -4. Each signal has a distinct orbital angular momentum and associated Poynting vector enabling the signal to be indicative of a particular concentration of material that is associated with the detected orbital angular momentum. This allows determinations of concentrations of various types of materials to be determined from a signal since the orbital angular momentums are separately detectable and provide a unique indication of the concentration of the particular material that has affected the orbital angular momentum of the signal transmitted through the sample material.

[0064] Fig. 10 illustrates the propagation of Poynting vectors for various Eigen modes. Each of the rings 1020 represents a different Eigen mode or twist representing a different orbital angular momentum. Each of the different orbital angular momentums is associated with a particular concentration of a particular material. Detection of orbital angular momentums provide an indication of the associated material concentration that is being monitored by the apparatus. Each of the rings 1020 represents a different concentration of a selected material that is being monitored. Each of the Eigen modes has a Poynting vector 1022 for generating the rings indicating different material concentrations.

[0065] Referring now to Fig. 11, there is illustrated a block diagram of the apparatus for providing concentration measurements of various materials responsive to the orbital angular momentum detected by the apparatus in accordance with the principles described herein above.

An emitter 1102 transmits wave energy 1104 that comprises a series of plane waves. The emitter 1102 may provide a series of plane waves such as those describes previously with respect to Fig. 3. The orbital angular momentum generation circuitry 1106 generates a series of waves having an orbital angular momentum applied to the waves 1108 in a known manner. The orbital angular momentum generation circuitry 706 may utilize holograms or some other type of orbital angular momentum generation process as will be more fully described herein below. The orbital angular momentum twisted waves 708 are applied to a sample material 1110 under test. The sample material 1110 contains a material, and the concentration of the material is determined via a concentration detection apparatus in accordance with the process described herein.

[0066] A series of output waves 1112 from the sample material 710 exit the sample and have a particular orbital angular momentum imparted thereto as a result of the concentration of the particular material under study within the sample material 710. The output waves 1112 are applied to a matching module 1114 that includes a mapping aperture for amplifying a particular orbital angular momentum generated by the specific material under study. The matching module 1114 will amplify the orbital angular momentums associated with the particular concentration of material that is detected by the apparatus. The amplified OAM waves 1116 are provided to a detector 1118. The detector 1118 detects OAM waves relating to the concentration of a material within the sample and provides this concentration information to a user interface 1120. The user interface 1120 interprets the concentration information and provides relevant concentration indication to an individual or a recording device.

[0067] Referring now to Fig. 12, there is more particularly illustrated the emitter 1102. The emitter 1102 may emit a number of types of energy waves 1104 to the OAM generation module 1106. The emitter 1102 may emit optical waves 1200, electromagnetic waves 1202, acoustic waves 1204 or any other type of particle waves 1206. The emitted waves 1104 are plane waves such as those illustrated in Fig. 7 having no orbital angular momentum applied thereto and may come from a variety of types of emission devices and have information included therein. In one embodiment, the emission device may comprise a laser. Plane waves have wavefronts that are parallel to each other having no twist or helicity applied thereto, and the orbital angular momentum of the wave is equal to 0. The Poynting vector within a plane wave is completely in line with the direction of propagation of the wave.

[0068] The OAM generation module 1106 processes the incoming plane wave 1104 and imparts a known orbital angular momentum onto the plane waves 1104 provided from the emitter 1102. The OAM generation module 1106 generates twisted or helical electromagnetic, optic, acoustic or other types of particle waves from the plane waves of the emitter 702. A helical wave 1108 is not aligned with the direction of propagation of the wave but has a procession around direction of propagation as shown in Fig. 5. The OAM generation module 1106 may comprise in one embodiment a fixed orbital angular momentum generator 1302 as illustrated in Fig. 13. The fixed orbital angular momentum generator 1302 receives the plane waves 1104 from the emitter 1102 and generates an output wave 1304 having a fixed orbital angular momentum applied thereto.

[0069] The fixed orbital angular momentum generator 1302 may in one embodiment comprise a holographic image for applying the fixed orbital angular momentum to the plane wave 1104 in order to generate the OAM twisted wave 904. Various types of holographic images may be generated in order to create the desired orbital angular momentum twist to an optical signal that is being applied to the orbital angular momentum generator 1102. Various examples of these holographic images are illustrated in Fig. 14a-14d. In one embodiment, the conversion of the plane wave signals transmitted from the emitter 1102 by the orbital angular momentum generation circuitry 706 may be achieved using holographic images.

[0070] Most commercial lasers emit an HG_{00} (Hermite-Gaussian) mode 1502 (Fig. 15) with a planar wave front and a transverse intensity described by a Gaussian function. Although a number of different methods have been used to successfully transform an HG_{00} Hermite-Gaussian mode 1502 into a Laguerre-Gaussian mode 1504, the simplest to understand is the use of a hologram.

[0071] The cylindrical symmetric solution u_{pl} (r,φ,z) which describes Laguerre-Gaussian beams, is given by the equation:

$$u_{pl}(r,\phi,z)=\frac{C}{(1+z^2/z_R^2)^{1/2}}\left[\frac{r\sqrt{2}}{w(z)}\right]^l L_p^l\left[\frac{2r^2}{w^2(z)}\right]\exp\left[\frac{-r^2}{w^2(z)}\right]\exp\left[\frac{-ikr^2z}{2(z^2+z_R^2)}\right]\exp(-il\phi)$$
$$\times\exp\left[i(2p+l+1)\tan^{-1}\frac{z}{z_R}\right]$$

Where z_R is the Rayleigh range, w(z) is the radius of the beam, L_P is the Laguerre polynomial, C is a constant, and the beam waist is at z=0.

[0072] In its simplest form, a computer generated hologram is produced from the calculated interference pattern that results when the desired beam intersects the beam of a conventional laser at a small angle. The calculated pattern is transferred to a high resolution holographic film. When the developed hologram is placed in the original laser beam, a diffraction pattern results. The first order of which has a desired amplitude and phase distribution. This is one manner for implementing the OAM generation module 1106. A number of examples of holographic images for use within a OAM generation module are illustrated with respect to Figs. 14a-14e.

[0073] There are various levels of sophistication in hologram design. Holograms that comprise only black and white areas with no grayscale are referred to as binary holograms. Within binary holograms, the relative intensities of the two interfering beams play no role and the transmission of the hologram is set to be zero for a calculated phase difference between zero and π, or unity for a phase difference between π and 2π. A limitation of binary holograms is that very little of the incident power ends up in the first order diffracted spot, although this can be partly overcome by blazing the grating. When mode purity is of particular importance, it is also possible to create more sophisticated holograms where the contrast of the pattern is varied as a function of radius such that the diffracted beam has the required radial profile.

[0074] A plane wave shining through the holographic images 1402 will have a predetermined orbital angular momentum shift applied thereto after passing through the holographic image 1402. OAM generator 1102 is fixed in the sense that a same image is used and applied to the beam being passed through the holographic image. Since the holographic image 1402 does not change, the same orbital angular momentum is always applied to the beam being passed through the holographic image 1402. While Fig. 14a-14e illustrate a number of embodiments of various holographic images that might be utilized within the orbital angular momentum generator 1102, it will be realized that any type of holographic image 1402 may be utilized in order to achieve the desired orbital angular momentum within an beam being shined through the image 1402.

[0075] In another example of a holographic image illustrated in Fig. 16, there is illustrated a hologram that utilizes two separate holograms that are gridded together to produce a rich number of orbital angular momentum (l). The superimposed holograms of Fig. 16 have an orbital angular momentum of l=1 and l=3 which are superimposed upon each other to compose the composite vortex grid 1602. The holograms utilized may also be built in a manner that the two holograms are gridded together to produce a varied number of orbital angular momentums (l) not just on a line (l= +1, l=0, l= -1) but on a square which is able to identify the many variables more easily. Thus, in the example in Fig. 16, the orbital angular momentums along the top edge vary from +4 to +1 to -2 and on the bottom edge from +2 to -1 to -4. Similarly, along the left edge the orbital angular momentums vary from +4 to +3 to +2 and on the right edge from -2 to -3 to -4. Across the horizontal center of the hologram the orbital angular momentums provided vary from +3 to 0 to -3 and along the vertical axis vary from +1 to 0 to -1. Thus, depending upon the portion of the grid a beam may pass through, varying orbital angular momentum may be achieved.

[0076] Referring now to Fig. 17, in addition to a fixed orbital angular momentum generator, the orbital angular momentum generation circuitry 1106 may also comprise a tunable orbital angular momentum generator circuitry 1702. The tunable orbital angular momentum generator 1702 receives the input plane wave 1104 but additionally receives one or more tuning parameters 1704. The tuning parameters 1704 tune the tunable OAM generator 1702 to apply a selected orbital angular momentum so that the tuned OAM wave 1706 that is output from the OAM generator 1702 has a selected orbital angular momentum value applied thereto.

[0077] This may be achieved in any number of fashions. In one embodiment, illustrated in Fig. 18, the tunable orbital angular momentum generator 1002 may include multiple hologram images 1802 within the tunable OAM generator 1702. The tuning parameters 1704 enable selection of one of the holographic images 1806 in order to provide the desired OAM wave twisted output signal 1706 through a selector circuit 1804. Alternatively, the gridded holographic image such as that described in Fig. 16 may be utilized and the beam shined on a portion of the gridded image to provide the desired OAM output. The tunable OAM generator 1702 has the advantage of being controlled to apply a particular orbital angular momentum to the output orbital angular momentum wave 1706 depending upon the provided input parameter 1704. This enables the concentrations of a variety of different materials to be monitored, or alternatively, for various different concentrations of the same material to be monitored.

[0078] Referring now to Fig. 18, there is more particularly implemented a block diagram of a tunable orbital angular momentum generator 1702. The generator 1702 includes a plurality of holographic images 1802 for providing orbital angular momentums of various types to a provided light signal. These holographic images 1802 are selected responsive to a selector circuitry 1804 that is responsive to the input tuning parameters 1704. The selected filter 1806 comprises the holographic image that has been selected responsive to the selector controller 1804 and receives the input plane waves 1104 to provide the tuned orbital angular momentum wave output 1706. In this manner, signals having a desired orbital angular momentum may be output from the OAM generation circuitry 1106.

[0079] Referring now to Fig. 19, there is illustrated the manner in which the output of the OAM generator 1106 may vary a signal by applying different orbital angular momentum thereto. Fig. 19 illustrates helical phase fronts in which the Poynting vector is no longer parallel to the beam axis and thus has an orbital angular momentum applied thereto. In any fixed radius within the beam, the Poynting vector follows a spiral trajectory around the axis. Rows are labeled by 1, the orbital angular momentum quantum number, L= $l\hbar$ is the beams orbital angular momentum per photon within the output signal. For each l, the left column 1902 is the light beam's instantaneous phase. The center column 1904 comprises the angular intensity profiles and the right column 1906 illustrates what occurs when such a beam interferes with a plane wave and produces a spiral intensity pattern. This is illustrated for orbital angular momentums of -1, 0, 1, 2 and 3 within the various rows of Fig. 19.

[0080] Referring now to Fig. 20, there is illustrated an alternative manner in which the OAM generator 1106 may convert a Hermite-Gaussian beam output from an emitter 1102 to a

Laguerre-Gaussian beams having imparted therein an orbital angular momentum using mode converters 2004 and a Dove prism 2010. The Hermite-Gaussian mode plane waves 2002 are provided to a $\pi/2$ mode convertor 2004. The $\pi/2$ mode convertor 2004 produce beams in the Laguerre-Gaussian modes 2006. The Laguerre-Gaussian modes beams 2006 are applied to either a π mode convertor 2008 or a dove prism 2010 that reverses the mode to create a reverse Laguerre-Gaussian mode signal 2012.

[0081] Referring now to Fig. 21, there is illustrated the manner in which holograms within the OAM generator 1106 generate a twisted light beam. A hologram 2102 can produce light beam 2104 and light beam 2106 having helical wave fronts and associated orbital angular momentum *lh* per photon. The appropriate hologram 2102 can be calculated or generated from the interference pattern between the desired beam form 2104, 2106 and a plane wave 2108. The resulting holographic pattern within the hologram 2102 resembles a diffraction grating, but has a l-pronged dislocation at the beam axis. When the hologram is illuminated with the plane wave 2108, the first-order diffracted beams 2104 and 2106 have the desired helical wave fronts to provide the desired first ordered diffracted beam display 2110.

[0082] Referring now to Fig. 22, there is more particularly illustrated the manner in which the sample 1110 receives the input OAM twisted wave 1108 provided from the OAM generator 1106 and provides an output OAM wave 1112 having a particular OAM signature associated therewith that depends upon the concentration of a particular monitored material within the sample 1110. The sample 1110 may comprise any sample that is under study and may be in a solid form, liquid form or gas form. The sample material 1110 that may be detected using the system described herein may comprise a variety of different materials. As stated previously, the material may comprise liquids such as blood, water, oil or chemicals. The various types of carbon bondings such as C-H, C-O, C-P, C-S or C-N may be provided for detection. The system may also detect various types of bondings between carbon atoms such as a single bond (methane or Isooctane), dual bond items (butadiene and benzene) or triple bond carbon items such as acetylene.

[0083] The sample 1110 may include detectable items such as organic compounds including carbohydrates, lipids (cylcerol and fatty acids), nucleic acids (C,H,O,N,P) (RNA and DNA) or various types of proteins such as polyour of amino NH_2 and carboxyl COOH or aminos such as tryptophan, tyrosine and phenylalanine. Various chains within the samples 1110 may also be detected such as monomers, isomers and polymers. Enzymes such as ATP and ADP within the samples may be detected. Substances produced or released by glands of the body may be in the sample and detected. These include items released by the exocrine glands via tube/ducts, endocrine glands released directly into blood samples or hormones. Various types of glands that may have their secretions detected within a sample 1110 include the hypothalamus, pineal and pituitary glands, the parathyroid and thyroid and thymus, the adrenal and pancreas glands of the torso and the hormones released by the ovaries or testes of a male or female.

[0084] The sample 1110 may also be used for detecting various types of biochemical markers within the blood and urine of an individual such as melanocytes and keratinocytes. The sample 1110 may include various parts of the body to detect defense substances therein. For example, with respect to the skin, the sample 1110 may be used to detect carotenoids, vitamins, enzymes, b-carotene and lycopene. With respect to the eye pigment, the melanin/eumelanin, dihydroxyindole or carboxylic may be detected. The system may also detect various types of materials within the body's biosynthetic pathways within the sample 1110 including hemoglobin, myoglobin, cytochromes, and porphyrin molecules such as protoporphyrin, coporphyrin, uroporphyrin and nematoporphyrin. The sample 1110 may also contain various bacterias to be detected such as propion bacterium, acnes. Also various types of dental plaque bacteria may be detected such as porphyromonos gingivitis, prevotella intremedi and prevotella nigrescens. The sample 1110 may also be used for the detection of glucose in insulin within a blood sample 1110.

[0085] The orbital angular momentum within the beams provided within the sample 1110 may be transferred from light to matter molecules depending upon the rotation of the matter molecules. When a circularly polarized laser beam with a helical wave front traps a molecule in an angular ring of light around the beam axis, one can observe the transfer of both orbital and spin angular momentum. The trapping is a form of optical tweezing accomplished without mechanical constraints by the ring's intensity gradient. The orbital angular momentum transferred to the molecule makes it orbit around the beam axis as illustrated at 2302 of Fig. 23. The spin angular momentum sets the molecule spinning on its own axis as illustrated at 2304.

[0086] The output OAM wave 1112 from the sample 1110 will have an orbital angular momentum associated therewith that is different from the orbital angular momentum provided on the input OAM wave 1108. The difference in the output OAM wave 1112 will depend upon the material contained within the sample 1110 and the concentration of these materials within the sample 1110. Differing materials of differing concentration will have unique orbital angular momentums associated therewith. Thus, by analyzing the particular orbital angular momentum signature associated with the output OAM wave 1112, determinations may be made as to the materials present within the sample 1110 and the concentration of these materials within the sample may also be determined.

[0087] Referring now to Fig. 24, the matching module 1114 receives the output orbital angular momentum wave 1112 from the sample 1110 that has a particular signature associated therewith based upon the orbital angular momentum imparted to the waves passing through the sample 1110. The matching module 1114 amplifies the particular orbital angular momentum of interest in order to provide an amplified wave having the desired orbital angular momentum of interest 2416 amplified. The matching module 1114 may comprise a matching aperture that amplifies the detection orbital angular momentum associated with a specific material or characteristic that is under study. The matching module 1114 may in one embodiment comprise a holographic filter such as that described with respect to Figs. 14a-14d in order to amplify the desired orbital angular momentum wave of interest. The matching module 1114 is established based upon a specific material of interest that is trying to be detected by the system. The matching module 1114 may comprise a fixed module using holograms as illustrated in Figs. 14a-14d or a tunable module in a manner similar to that discussed with respect to the OAM generation module 1106. In this case, a number of different orbital angular momentums could be amplified by the matching module in order to detect differing materials or differing concentration of materials within the sample 1110. Other examples of components for the matching module 1114 include the use of quantum dots, nanomaterials or metamaterials in order to amplify any desired orbital angular momentum values within a received wave form from the sample 1110.

[0088] Referring now to Fig. 25, the matching module 1114 rather than using holographic images in order to amplify the desired orbital angular momentum signals may use non-linear crystals in order to generate higher orbital angular momentum light beams. Using a non-linear crystal 2502, a first harmonic orbital angular momentum beam 2504 may be applied to a non-linear crystal 2502. The non-linear crystal 2502 will create a second order harmonic signal 2506.

[0089] Referring now to Fig. 26, there is more particularly illustrated the detector 1118 to which the amplified orbital angular momentum wave 1116 from the matching circuit 1114 in order that the detector 1118 may extract desired OAM measurements 2602. The detector 1118 receives the amplified OAM waves 1116 and detects and measures observable changes within the orbital angular momentum of the emitted waves due to the concentration of a particular material under study within the sample 1110. The detector 1118 is able to measure observable changes within the emitted amplified OAM wave 1116 from the state of the input OAM wave 1108 applied to the sample 1110. The extracted OAM measurements 2602 are applied to the user interface 1120. The manner in which the detector 1118 may detect differences within the orbital angular momentum is more particularly illustrates with respect to Fig. 27-29.

[0090] Fig. 27 illustrates the difference in impact between spin angular polarization and orbital angular polarization due to passing of a beam of light through a sample 2702. In sample 2702a, there is illustrated the manner in which spin angular polarization is altered responsive to a beam passing through the sample 2702a. The polarization of a wave having a particular spin angular momentum 2704 passing through the sample 2702a will rotate from a position 2704 to a new position 2706. The rotation occurs within the same plane of polarization. In a similar manner, as illustrated with respect to sample 2702b, an image appears as illustrated generally at 2708 before it passes through the sample 2702b. Upon passing the image through the sample 2702b the image will rotate from the position illustrated at 2710 to a rotated position illustrated at 2712. The amount of rotation is dependent upon the level of concentration of the material being detected within the sample 2702. Thus, as can be seen with respect to the sample 2702 of Fig. 27, both the spin angular polarization and the orbital angular momentum will change based upon the concentration of materials within the sample 2702. By measuring the amount of rotation of the image caused by the change in orbital angular momentum, the concentration of a particular material may be determined.

[0091] This overall process can be more particularly illustrated in Fig. 28. A light source 2802 shines a light beam through expanding optics 2804. The expanded light beam is applied through a metalab generated hologram 2806 that imparts an orbital angular momentum to the beam. The twisted beam from the hologram 2806 is shined through a sample 2808 having a particular length L. This causes the generation of a twisted beam on the output side of the sample 2808 to create a number of detectable waves having various orbital angular momentums 2810 associated therewith. The image 2812 associated with the light beam that is applied to sample 2808 will rotate an angle φ depending upon the concentration of the material within the sample 2808. The rotation φ of the image 2812 is different for each value orbital angular momentum $-l$ or $+l$. The change in rotation of the image Δφ may be described according to the equation:

$$\Delta\varphi = \varphi_l - \varphi_{-l} = f(l, L, C)$$

Where l is orbital angular momentum number, L is the path length of the sample and C is the concentration of the material being detected.

[0092] Thus, since the length of the sample L is known and the orbital angular momentum may be determined using the process described herein, these two pieces of information may be able to calculate a concentration of the material within the provided sample.

[0093] The above equation may be utilized within the user interface more particularly illustrated in Fig. 29. The user interface 1120 processes the OAM measurements 2502 using an internal algorithm 2902 that provides for the generation of concentration information 2904 that may be displayed in some type of user display. The algorithm would in one embodiment utilize that equation described herein above in order to determine the concentration based upon the length of a sample and the detected variation in orbital angular momentum. The process for calculating the concentration may be done in a laboratory setting where the information is transmitted wirelessly to the lab or the user interface can be associated with a wearable device connected to a meter or cell phone running an application on the cell phone connected via a local area network or wide area network to a personal or public cloud. The user interface 2920 of the device can either have a wired or wireless connection utilizing Bluetooth, ZigBee or other wireless protocols.

[0094] Referring now to Fig. 30, there is illustrated the manner in which the various data accumulated within the user interface 1120 that has been collected in the manner described herein above may be stored and utilized for higher level analysis. Various devices 3002 for collecting data as described herein above may communicate via private network clouds 3004 or with a public cloud 3006. When communicating with a private cloud 3004, the devices 3002 merely store information that is associated with a particular user device that is for use with respect to analysis of the user associated with that user device. Thus, an individual user could be monitoring and storing information with respect to their present glucose concentrations in order to monitor and maintain their diabetes.

[0095] Alternatively, when information is compiled from multiple devices 3002 within the public cloud 3006, this information may be provided directly to the public cloud 3006 from the individual devices 3002 or through the private clouds 3004 of the associated network devices 3002. Utilizing this information within the public cloud 3006 large databases may be established within servers 3008 associated with the public cloud 3006 to enable large scale analysis of various health related issues associated with the information processed from each of the individual devices 3002. This information may be used for analyzing public health issues.

[0096] Thus, the user interface 1120 in addition to including the algorithm 2902 for determining concentration information 2904 will include a wireless interface 2906 enabling the collected information to be wirelessly transmitted over the public or private cloud as described with respect to Fig. 30. Alternatively, the user interface may comprise a storage database 2908 enabling the collected information to be locally stored rather than transmitted wirelessly to a remote location.

[0097] Referring now to Fig. 31, there is illustrated a particular example of a block diagram of a particular apparatus for measuring the concentration of glucose using the orbital angular momentum of photons of a light beam shined through a glucose sample. The process creates a second-order harmonic with helical light beam using a non-linear crystal such as that described with respect to Fig. 25. The emission module 2402 generates plain electromagnetic waves that are provided to an OAM generation module 3104. The OAM generation module 3104 generates light waves having an orbital angular momentum applied thereto using holograms to create a wave having an electromagnetic vortex. The OAM twisted waves are applied to the sample 3106 that is under study in order to detect the glucose concentration within a sample of blood. A rotated signature exits the sample 3106 in the manner described previously with respect to Figs. 27-28 and is provided to the matching module 3108. The matching module 3108 will amplify the orbital angular momentum such that the observed concentrations may be calculated from the orbital momentum of the signature of the glucose. These amplified signals are provided to detection module 3110 which measures the radius of the beam w(z) or the rotation of the image provided to the sample via the light beam. This detected information is provided to the user interface that include a sensor interface wired or wireless Bluetooth or ZigBee connection to enable the provision of the material to a reading meter or a user phone for the display of concentration information with respect to the sample.

[0098] In this manner concentrations of various types of material as describe herein may be determined utilizing the orbital angular momentum signatures of the samples under study and the detection of these materials or their concentrations within the sample determine as described.

[0099] It will be appreciated by those skilled in the art having the benefit of this disclosure that this system and method for making concentration measurements within a sample material using orbital angular momentum provides a non-invasive manner for detecting material concentration. It should be understood that the drawings and detailed description herein are to be regarded in an illustrative rather than a restrictive manner, and are not intended to be limiting to the particular forms and examples disclosed. On the contrary, included are any further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments apparent to those of ordinary skill in the art, without departing from the spirit and scope hereof, as defined by the following claims. Thus, it is intended that the following claims be interpreted to embrace all such further modifications, changes, rearrangements, substitutions, alternatives, design choices, and embodiments.

WHAT IS CLAIMED IS:

1. An apparatus for measuring the concentration of a material within a sample, comprising:

signal generation circuitry for generating a first signal having at least one orbital angular momentum applied thereto and applying the first signal to the sample;

a detector for receiving the first signal after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

2. The apparatus of Claim 1, wherein the signal generation circuitry further comprises:

an emitting source for emitting the first signal comprising a plurality of plane waves;

orbital angular momentum generation circuitry for receiving the first signal and applying the at least one orbital angular momentum to the plane waves of the first signal.

3. The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry for applying a fixed orbital angular momentum to the first signal.

4. The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plane waves of the first signal.

5. The apparatus of Claim 4, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

6. The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry for applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

7. The apparatus of Claim 2, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

8. The apparatus of Claim 1 further including amplifying circuitry for receiving the first signal after the first signal passes through the sample and amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

9. The apparatus of Claim 8, wherein the amplifying circuitry further includes a hologram for amplifying the orbital angular momentums associated with the concentration of the material in the sample.

10. The apparatus of Claim 1, wherein the detector further comprises:

an orbital angular momentum detector for determining the detected value of the orbital angular momentum within the first signal from the sample; and

a processor for determining a concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

11. The apparatus of Claim 10 further including a user interface associated with the processor comprising:

a set of computer instructions for configuring the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database for storing concentration data from the concentrations determined by the processor.

12. The apparatus of Claim 11, wherein the user interface further includes a wireless interface for communicating the concentration data to a remote location.

13. The apparatus of Claim 1, wherein differing values of the detected value of the concentration indicate different concentrations of the material within the sample.

14. The apparatus of Claim 1, wherein the first signal comprises a light beam.

15. An apparatus for measuring the concentration of a material within a sample, comprising:

an emitting source for emitting a first light beam comprising a plurality of plane waves;

orbital angular momentum generation circuitry for receiving the first light beam and applying at least one orbital angular momentum to the plane waves of the first light beam;

amplifying circuitry for receiving the first light beam after the first light beam passes through the sample and amplifying a first portion of the light beam having a predetermined value of the orbital angular momentum associated therewith;

a detector for receiving the first light after it passes through the sample and determining the concentration of the material within the sample based on a detected value of orbital angular momentum within the amplified portion of the light beam having the predetermined value of the orbital angular momentum associated therewith.

16. The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a fixed orbital angular momentum generation circuitry for applying a fixed orbital angular momentum to the first signal.

17. The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry further includes a hologram for applying the at least one orbital angular momentum to the plane waves of the first signal.

18. The apparatus of Claim 17, wherein the hologram comprise a pair of superimposed holograms comprising a composite vortex grid.

19. The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises a tunable orbital angular momentum generation circuitry for applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

20. The apparatus of Claim 15, wherein the orbital angular momentum generation circuitry comprises:

at least one pi/2 mode converter for converting the first signal from Hermite-Guassian modes to Laguerre-Gaussian modes;

a converter for converting the first signal in the Laguerre-Gaussian modes to reversed Laguerre-Gaussian modes.

21. The apparatus of Claim 15 further comprising a processor for determining a concentration of the material within the sample responsive to the detected value of the orbital angular momentum.

22. The apparatus of Claim 21 further including a user interface associated with the processor comprising:

a set of computer instructions for configuring the processor to determine the concentration of the material within the sample responsive to the detected value of the orbital angular momentum;

a database for storing concentration data from the concentrations determined by the processor.

23. The apparatus of Claim 22, wherein the user interface further includes a wireless interface for communicating the concentration data to a remote location.

24. The apparatus of Claim 15, wherein differing values of the detected value of the concentration indicate different concentrations of the material within the sample.

25. A method for measuring the concentration of a material within a sample, comprising:

generating a first signal having at least one orbital angular momentum applied thereto;

applying the first signal to the sample;

receiving the first signal after it passes through the sample;

detecting a value of the orbital angular momentum within the received first signal; and

determining the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

26. The method of Claim 25, wherein the step of generating further comprises:

emitting the first signal comprising a plurality of plane waves;

receiving the first signal; and

applying the at least one orbital angular momentum to the plane waves of the first signal.

27. The method of Claim 26, wherein the step of applying further comprises applying a fixed orbital angular momentum to the first signal.

28. The method of Claim 26, wherein the step of applying further comprises applying a selected orbital angular momentum to the first signal responsive to at least one tuning parameter provided to the tunable orbital angular momentum generation circuitry.

29. The method of Claim 25 further including:

receiving the first signal after the first signal passes through the sample; and

amplifying a first portion of the signal having the detected value of the orbital angular momentum associated therewith.

30. The method of Claim 25 further including storing concentration data from the determined concentrations.

31. The method of Claim 25 further including communicating the concentration data to a remote location.

ABSTRACT

Signal generation circuitry generates a first signal having at least one orbital angular momentum applied thereto and applies the first signal to the sample. A detector for receives the first signal after it passes through the sample and determines the concentration of the material within the sample based on a detected value of orbital angular momentum with the first signal received from the sample.

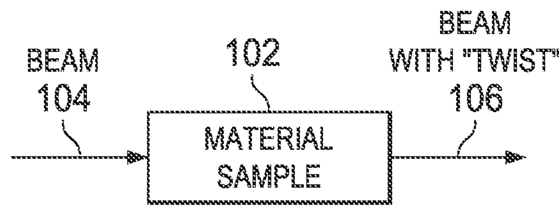


FIG. 1

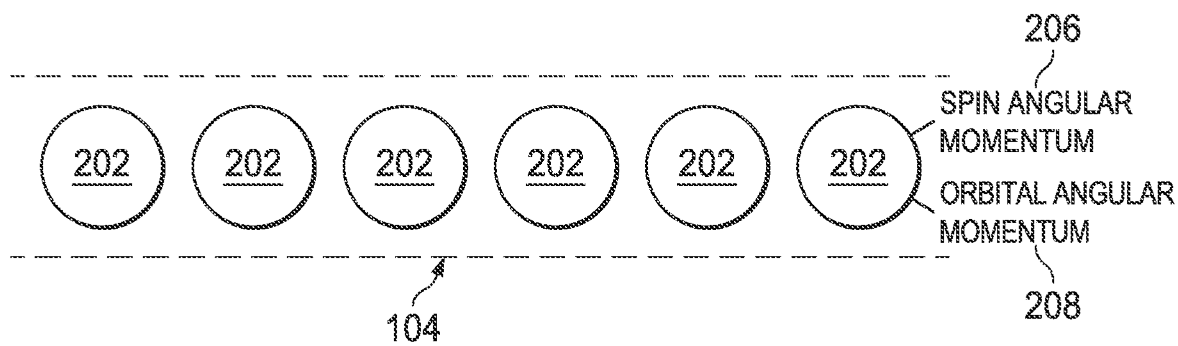


FIG. 2

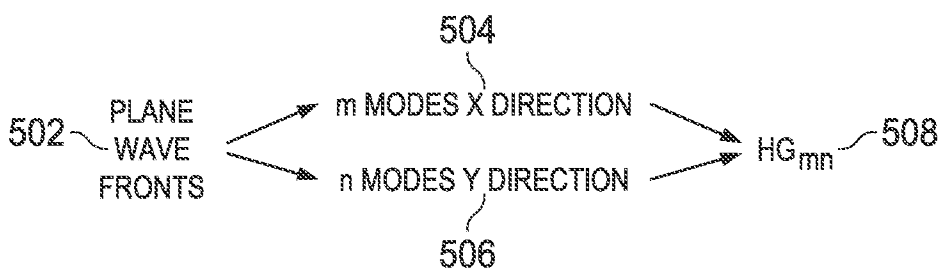


FIG. 5

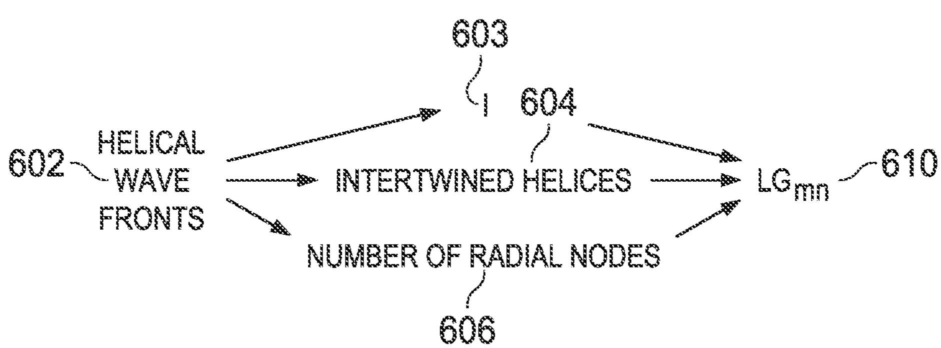


FIG. 6

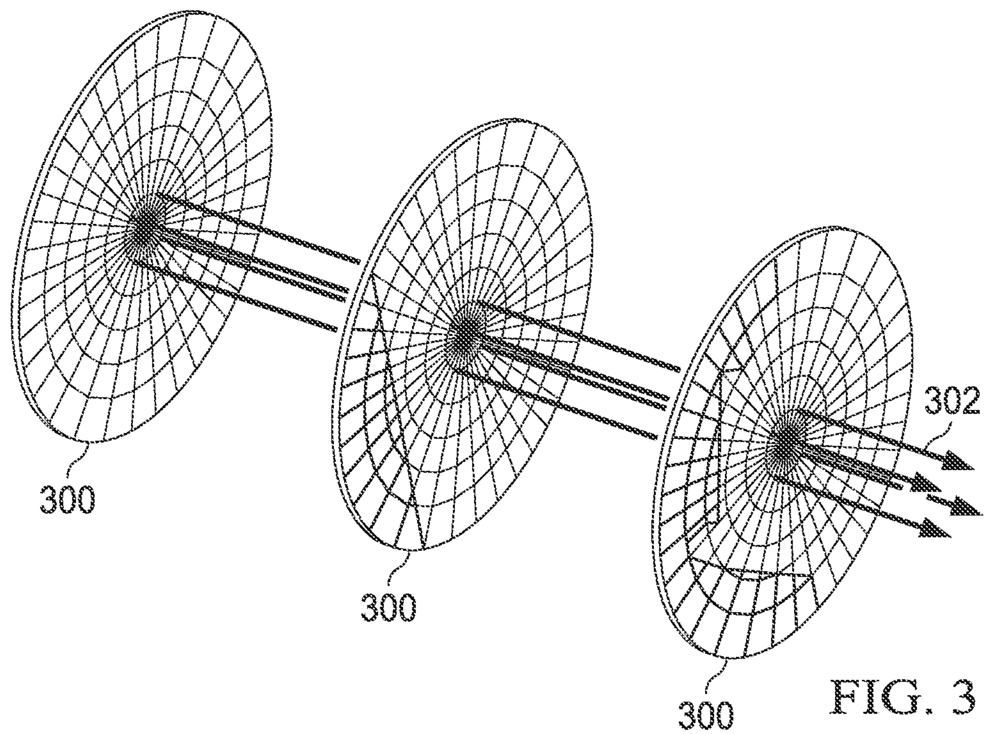


FIG. 3

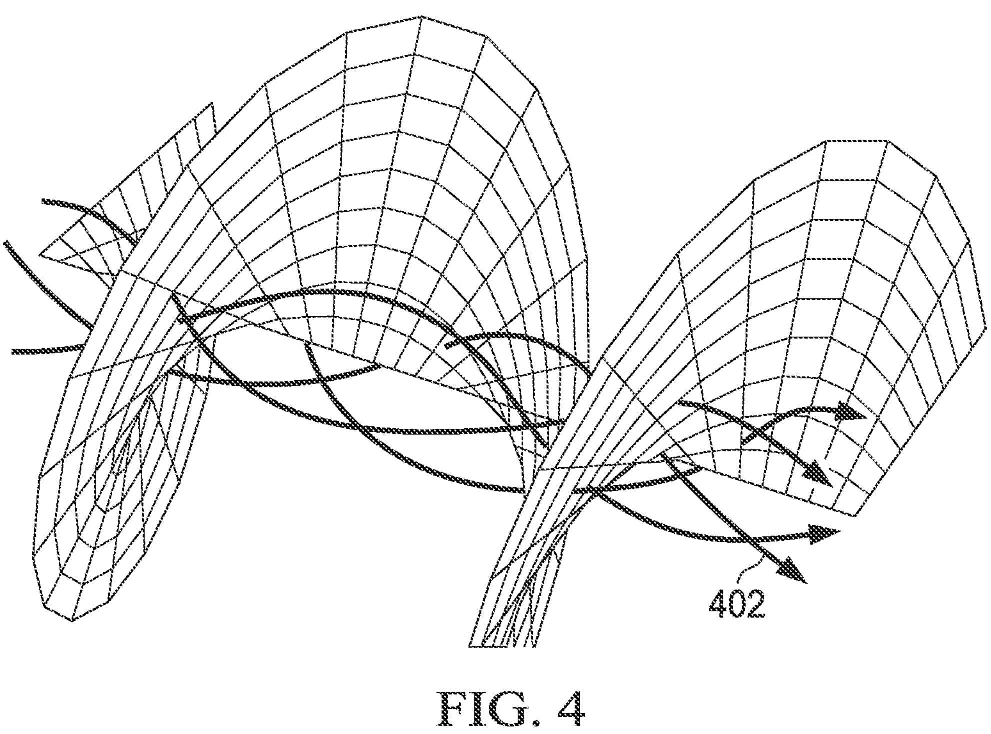


FIG. 4

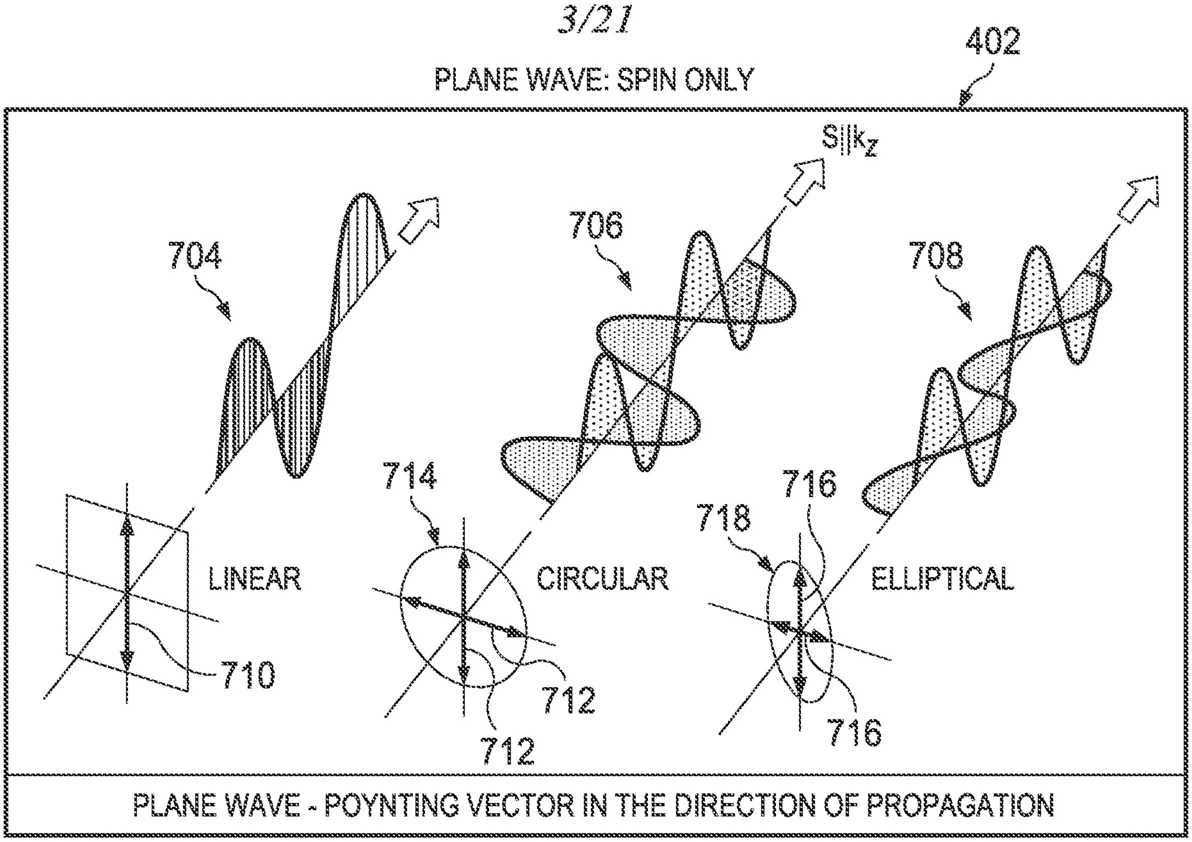


FIG. 7

LAGUERRE-GAUSS: SPIN AND ORBITAL

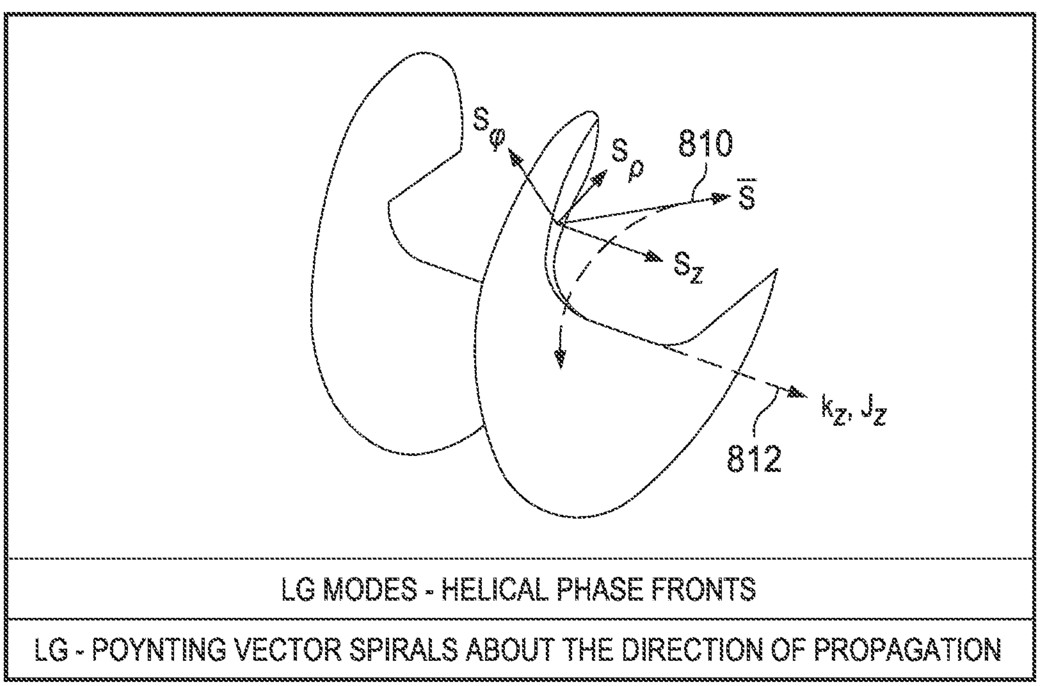


FIG. 8

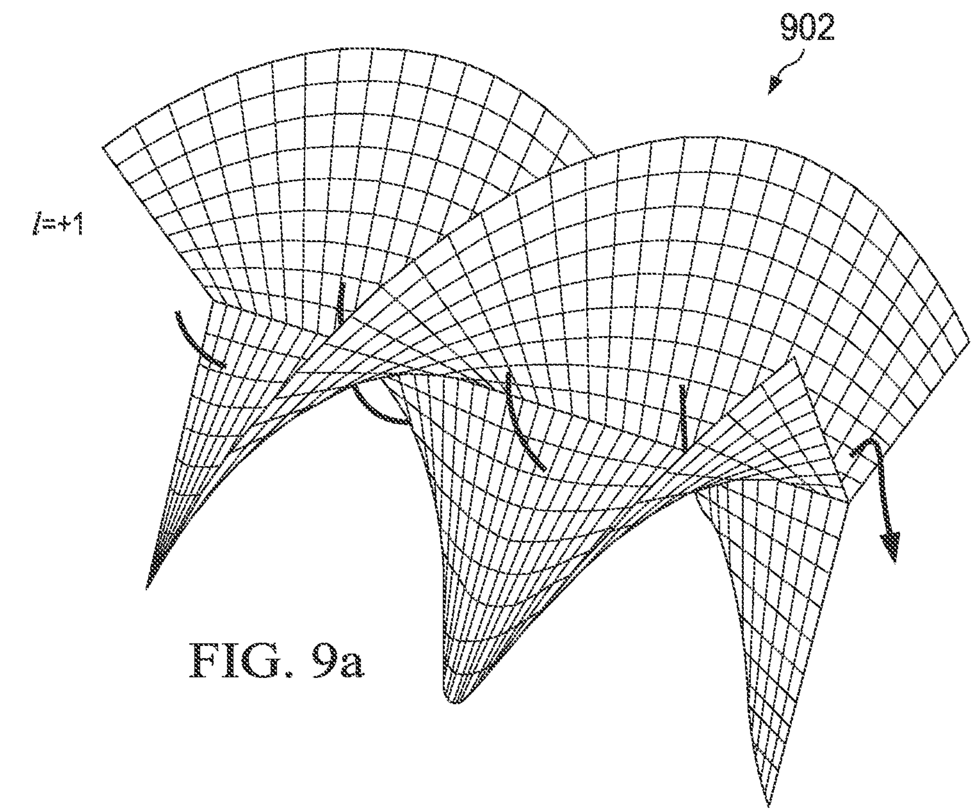


FIG. 9a

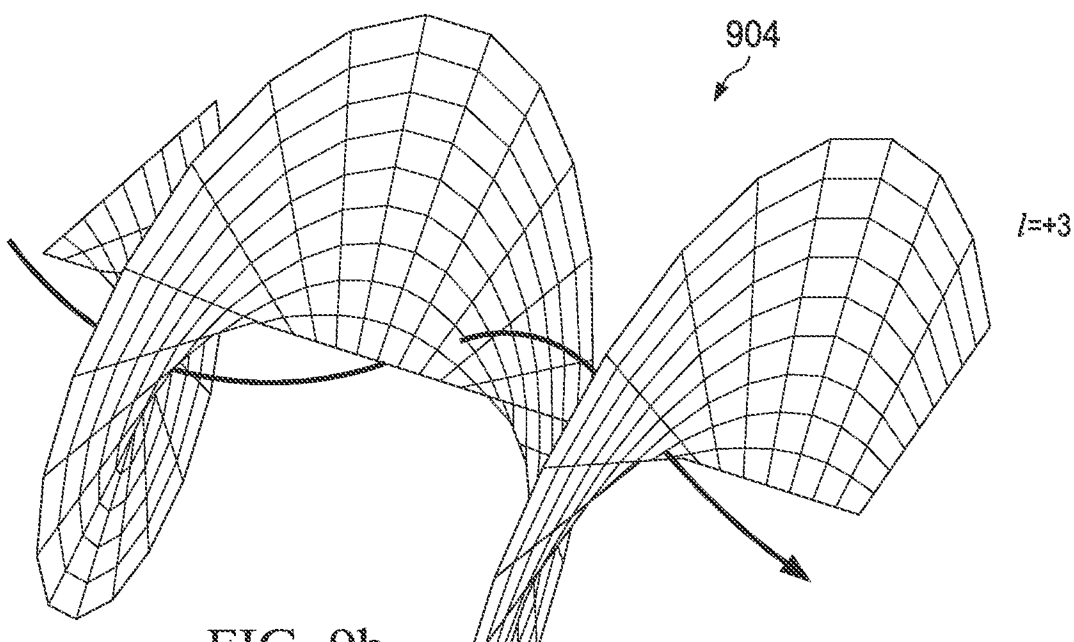


FIG. 9b

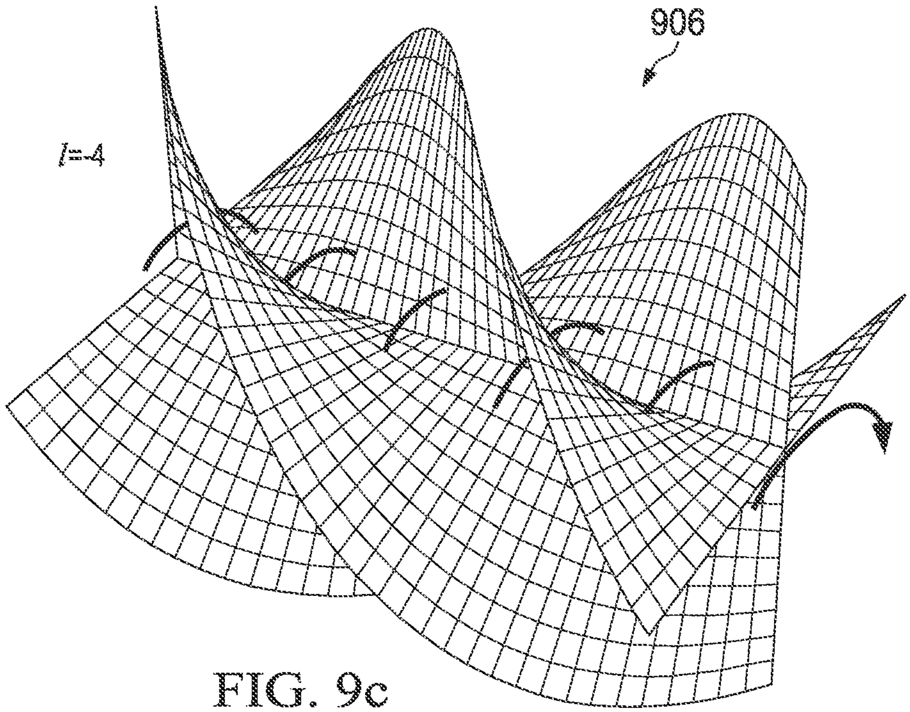


FIG. 9c

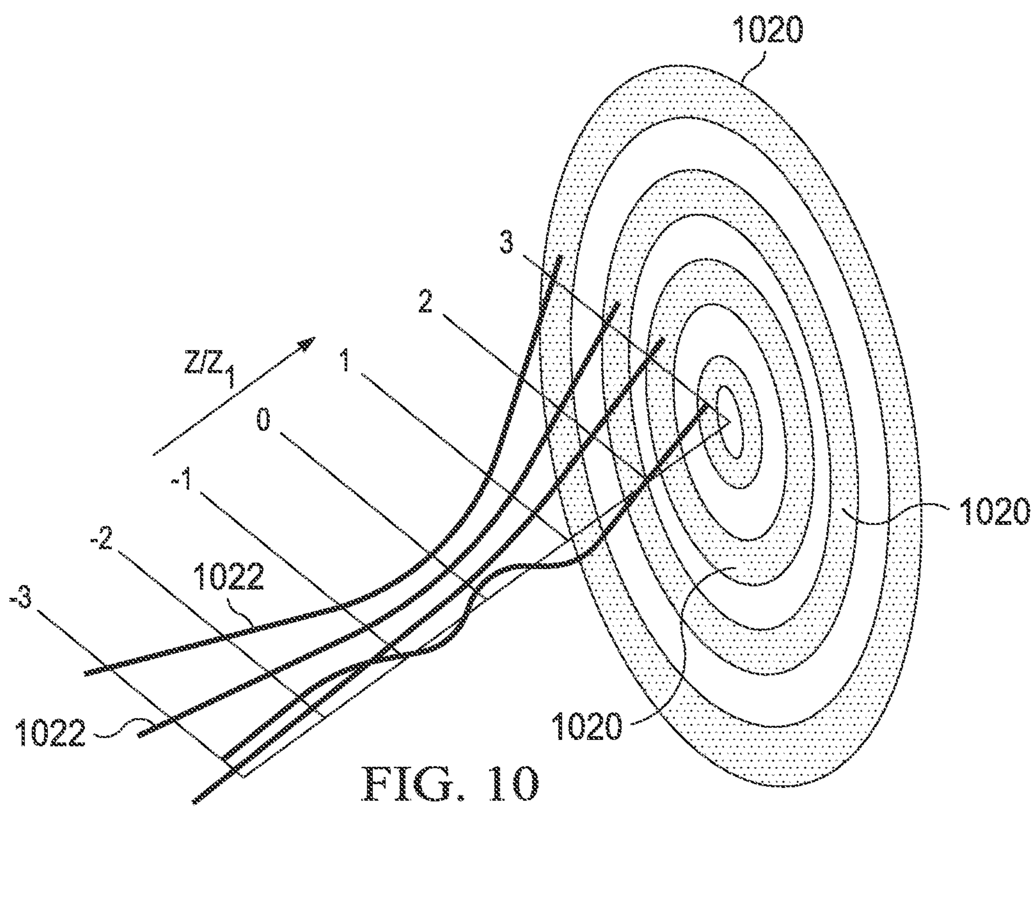


FIG. 10

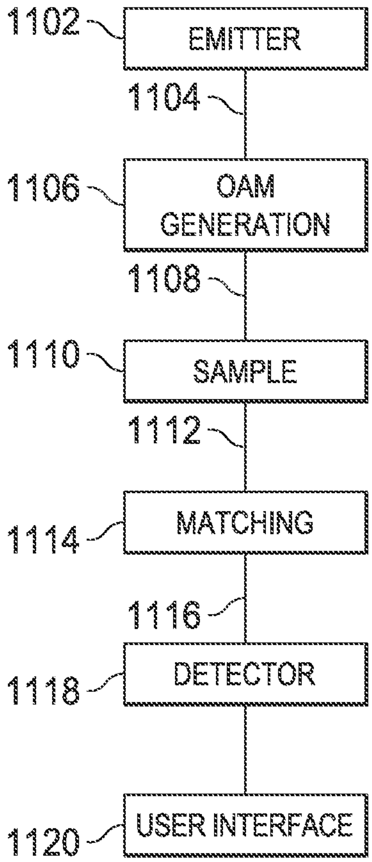


FIG. 11

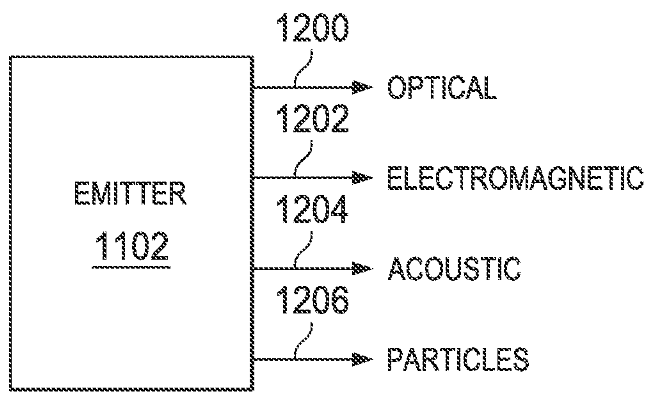


FIG. 12

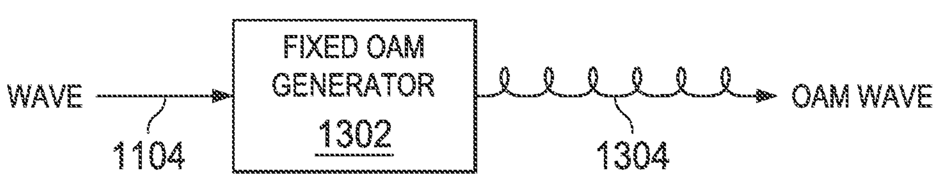


FIG. 13

FIG. 14a

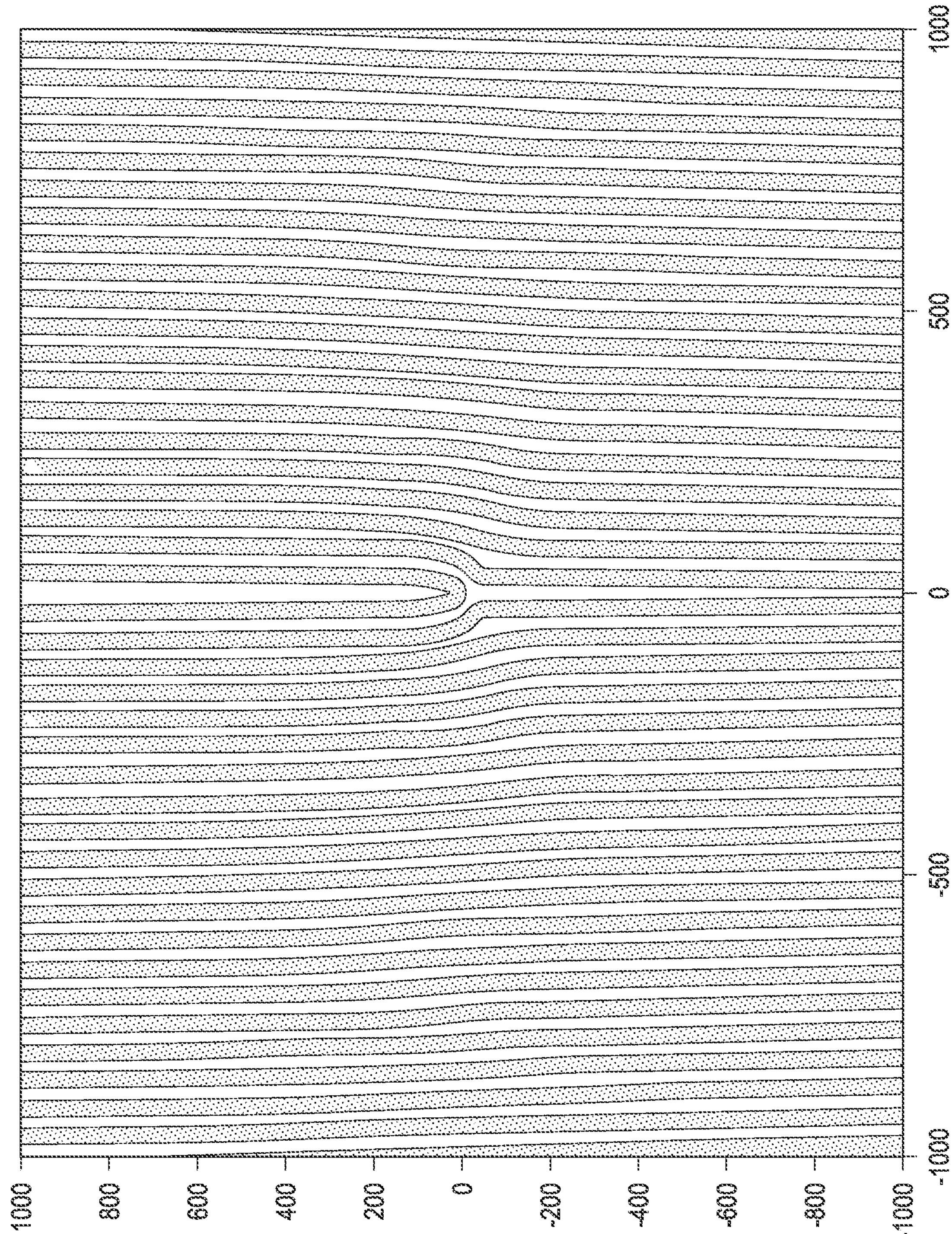


FIG. 14b

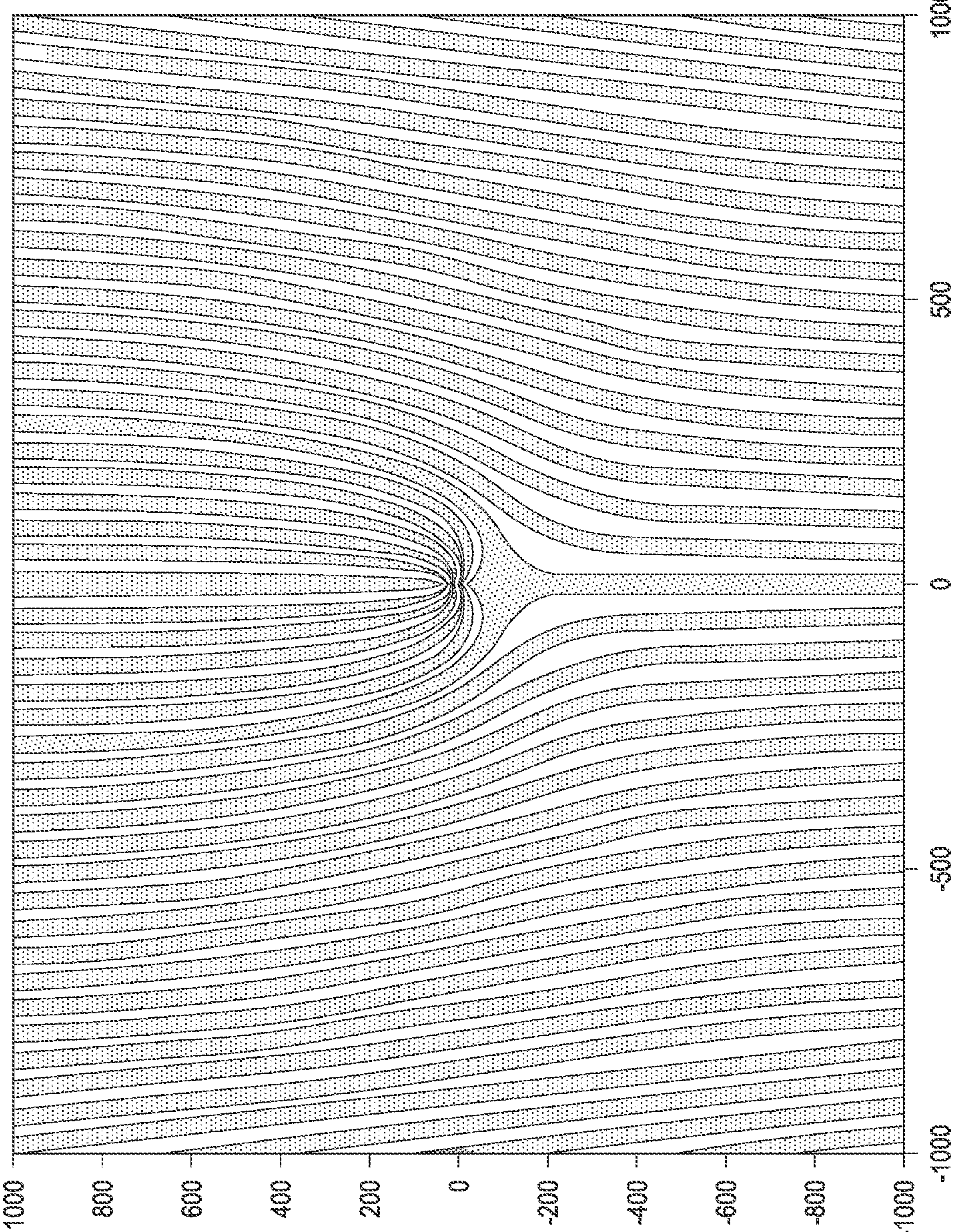


FIG. 14c

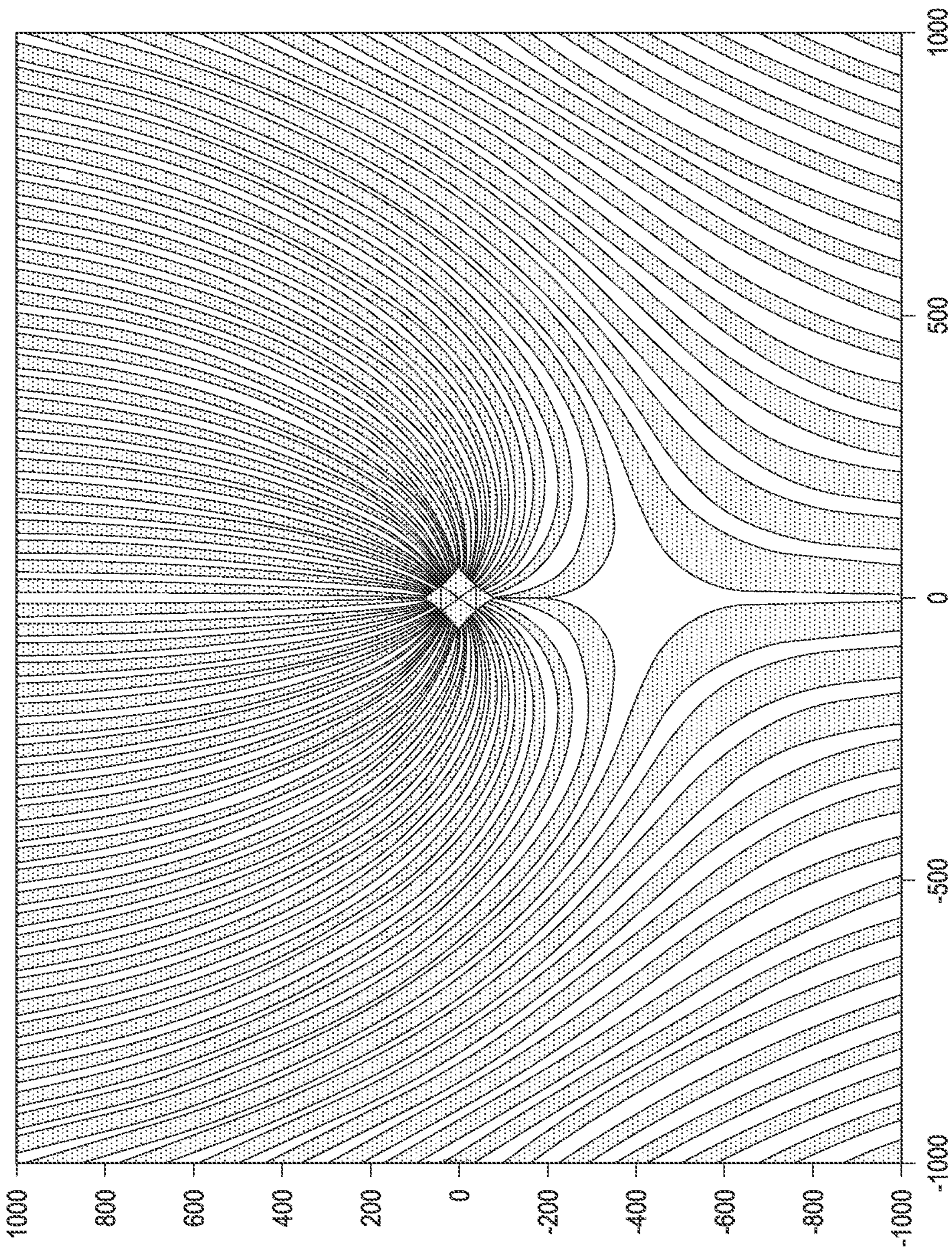
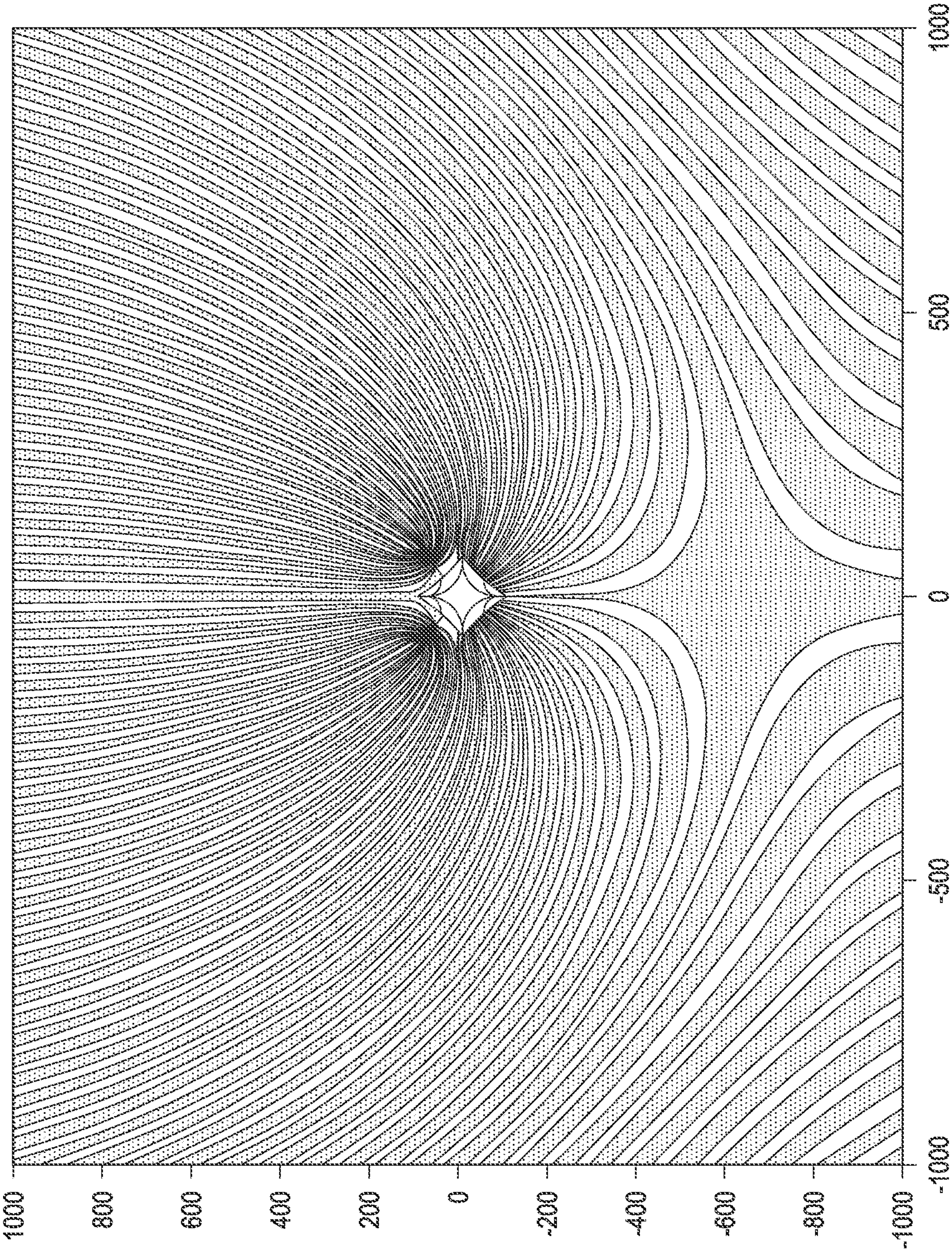


FIG. 14d



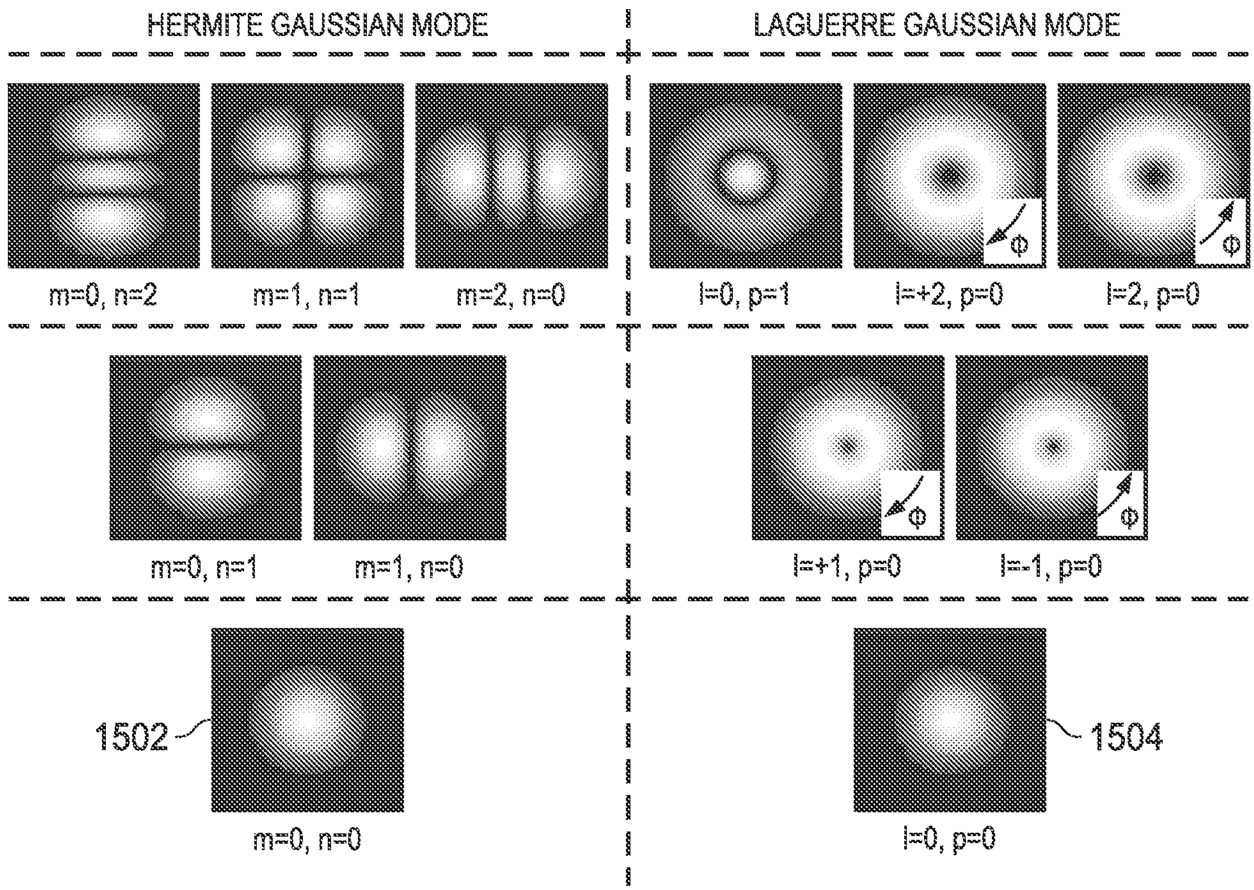

HERMITE GAUSSIAN MODE
LAGUERRE GAUSSIAN MODE
m=0, n=2
m=1, n=1
m=2, n=0
l=0, p=1
l=+2, p=0
l=2, p=0
m=0, n=1
m=1, n=0
l=+1, p=0
l=-1, p=0
1502
m=0, n=0
1504
l=0, p=0

FIG. 15

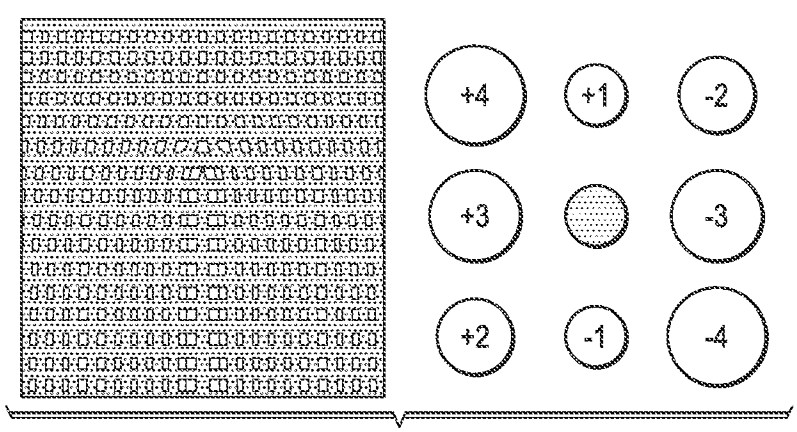

+4
+1
-2
+3
-3
+2
-1
-4

FIG. 16

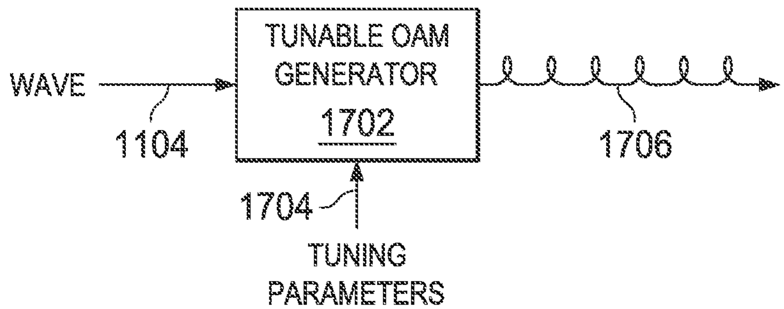

TUNABLE OAM GENERATOR
1702
WAVE
1104
1706
1704
TUNING PARAMETERS

FIG. 17

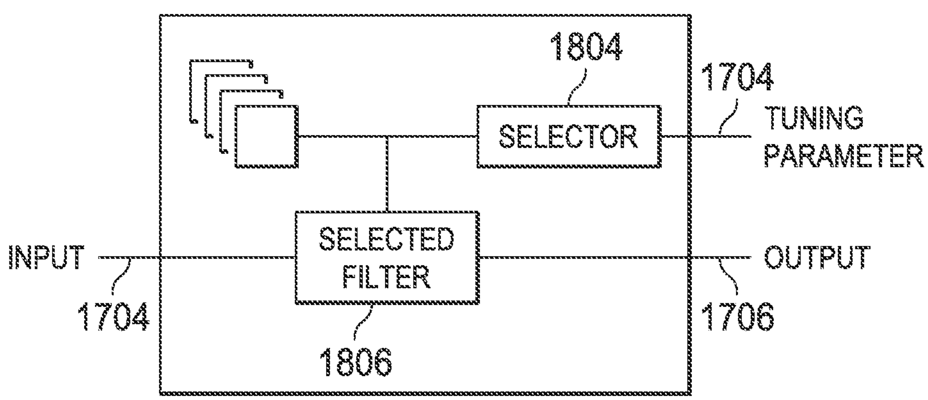

1804
1704
SELECTOR
TUNING PARAMETER
SELECTED FILTER
INPUT
OUTPUT
1704
1706
1806

FIG. 18

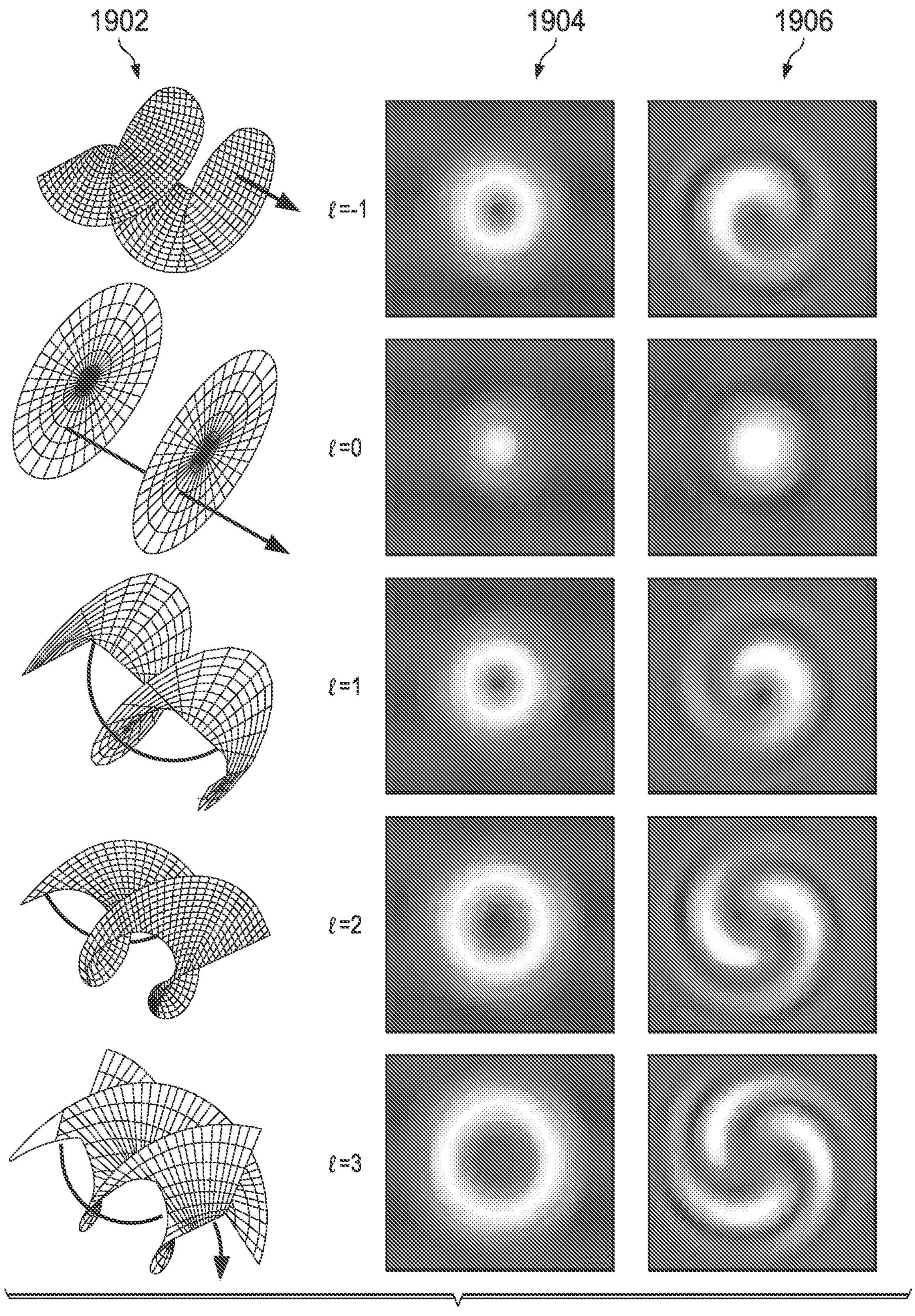


FIG. 19

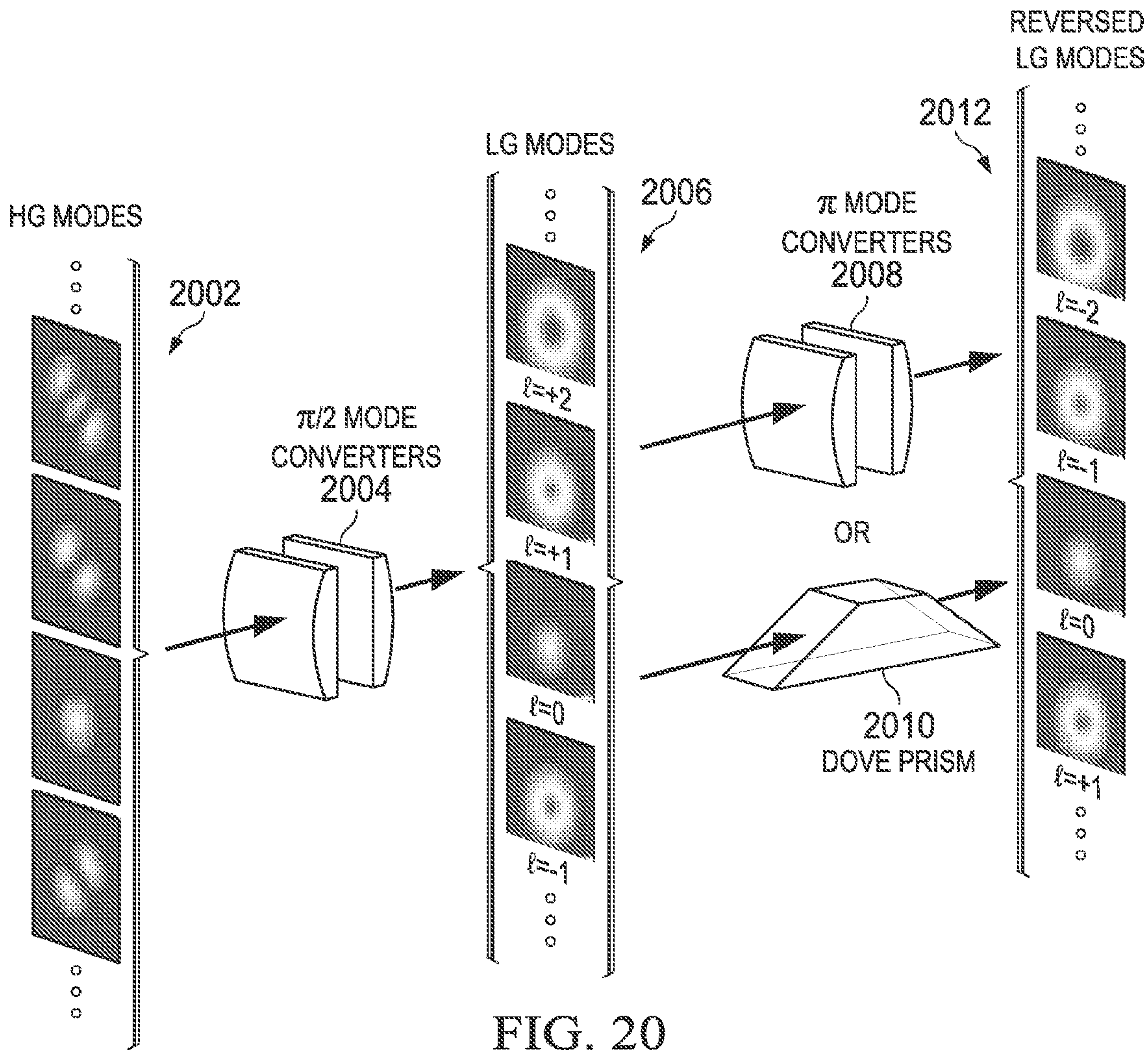

HG MODES
2002
π/2 MODE
CONVERTERS
2004
LG MODES
2006
ℓ=+2
ℓ=+1
ℓ=0
ℓ=-1
π MODE
CONVERTERS
2008
OR
2010
DOVE PRISM
2012
REVERSED
LG MODES
ℓ=-2
ℓ=-1
ℓ=0
ℓ=+1

FIG. 20

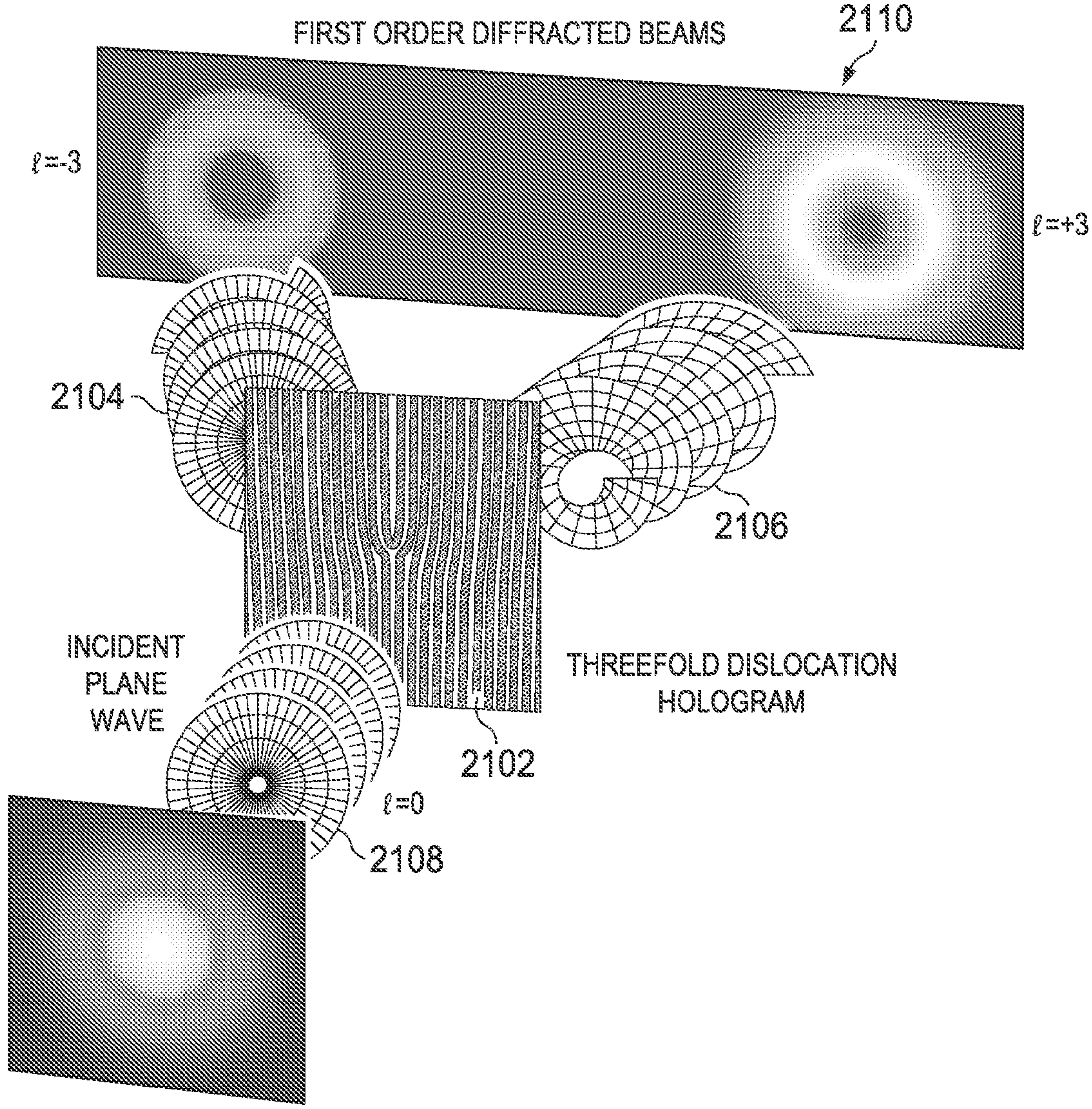

FIRST ORDER DIFFRACTED BEAMS
2110
ℓ=-3
ℓ=+3
2104
2106
INCIDENT
PLANE
WAVE
THREEFOLD DISLOCATION
HOLOGRAM
2102
ℓ=0
2108

FIG. 21


INPUT
OAM WAVE
SAMPLE
1110
OUTPUT
OAM WAVE
1108
1112

FIG. 22

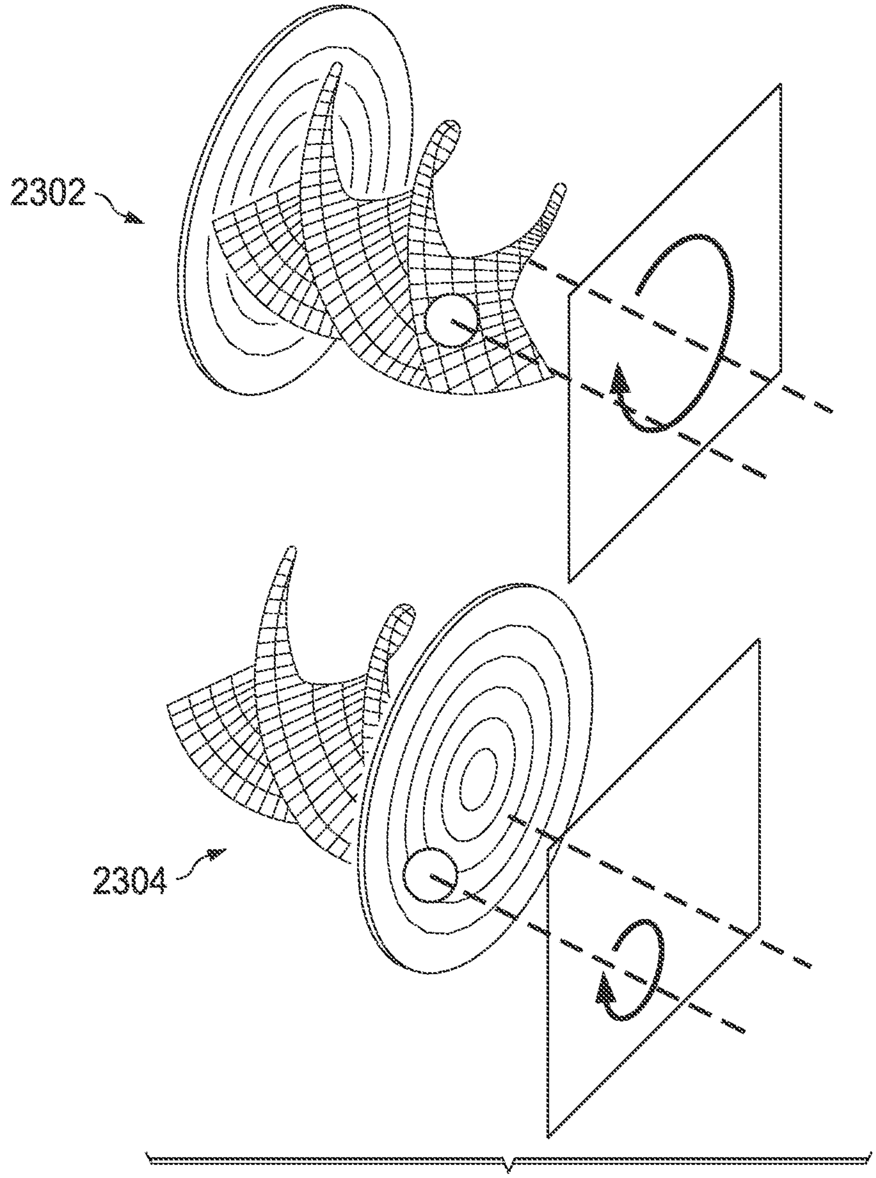

2302
2304

FIG. 23

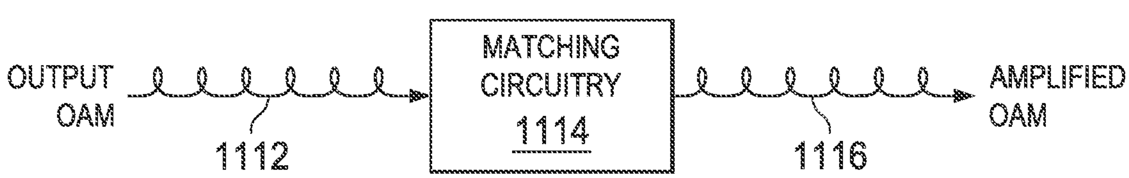

OUTPUT OAM
1112
MATCHING CIRCUITRY 1114
1116
AMPLIFIED OAM

FIG. 24

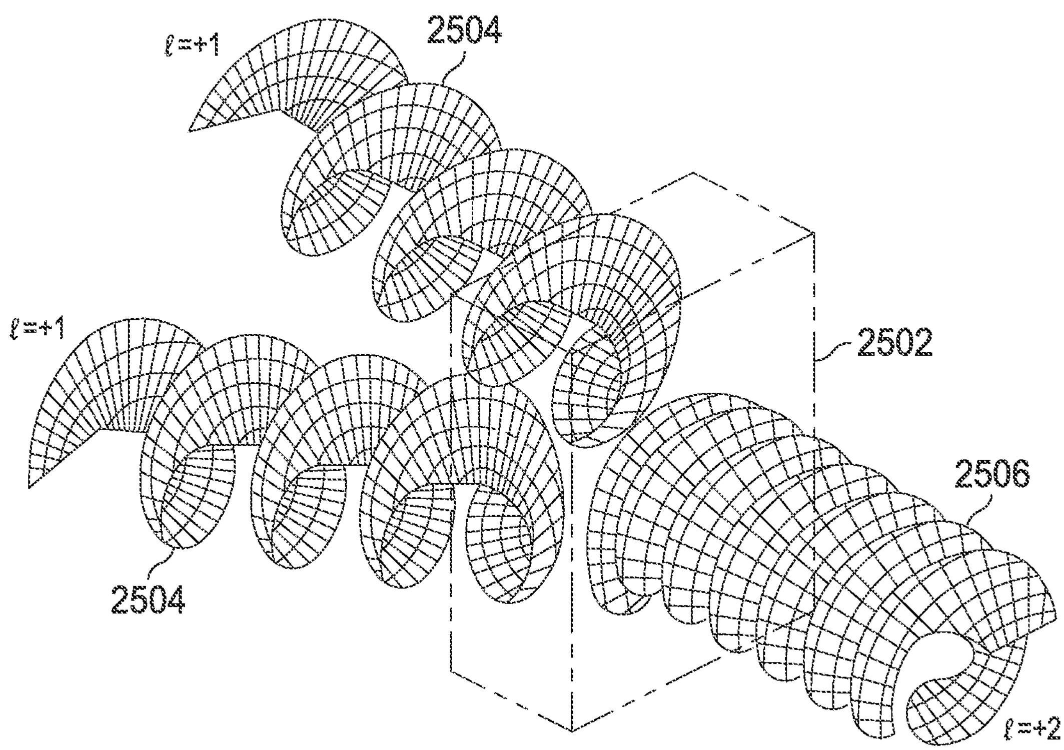

ℓ=+1
2504
ℓ=+1
2502
2506
2504
ℓ=+2

FIG. 25

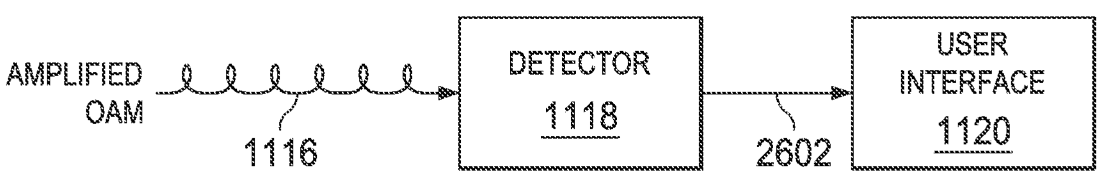

AMPLIFIED
OAM
1116
DETECTOR
1118
2602
USER
INTERFACE
1120

FIG. 26

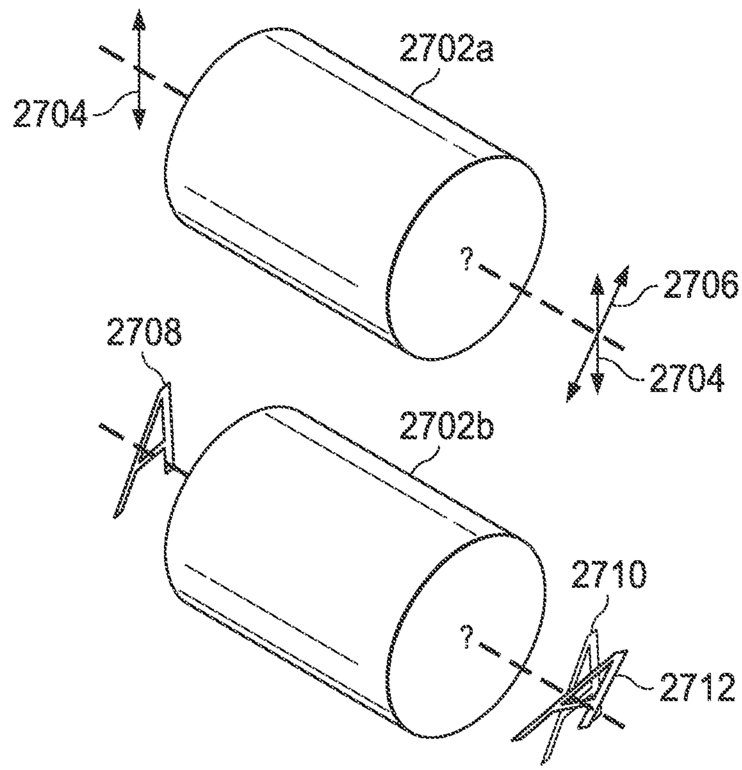

2702a
2704
2706
2704
2708
2702b
2710
2712

FIG. 27

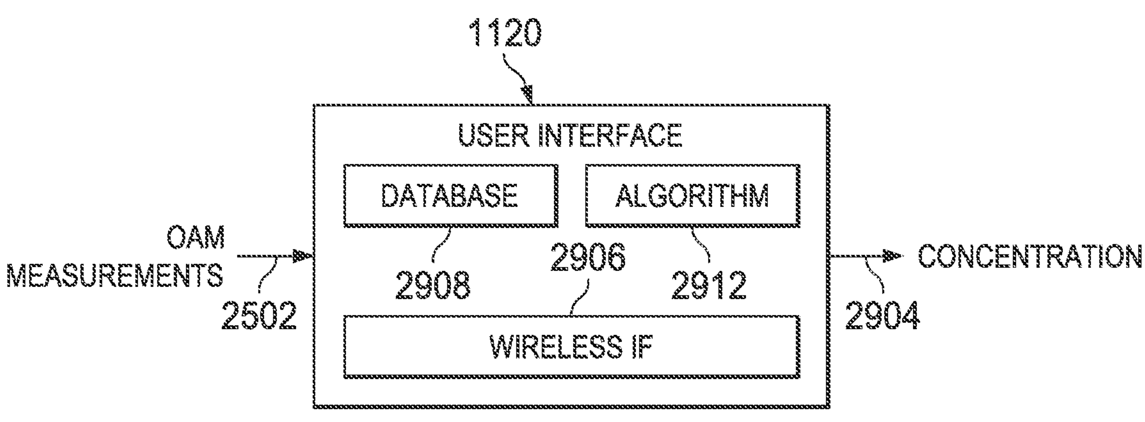

1120
USER INTERFACE
DATABASE
ALGORITHM
OAM MEASUREMENTS
2502
2908
2906
2912
CONCENTRATION
2904
WIRELESS IF

FIG. 29

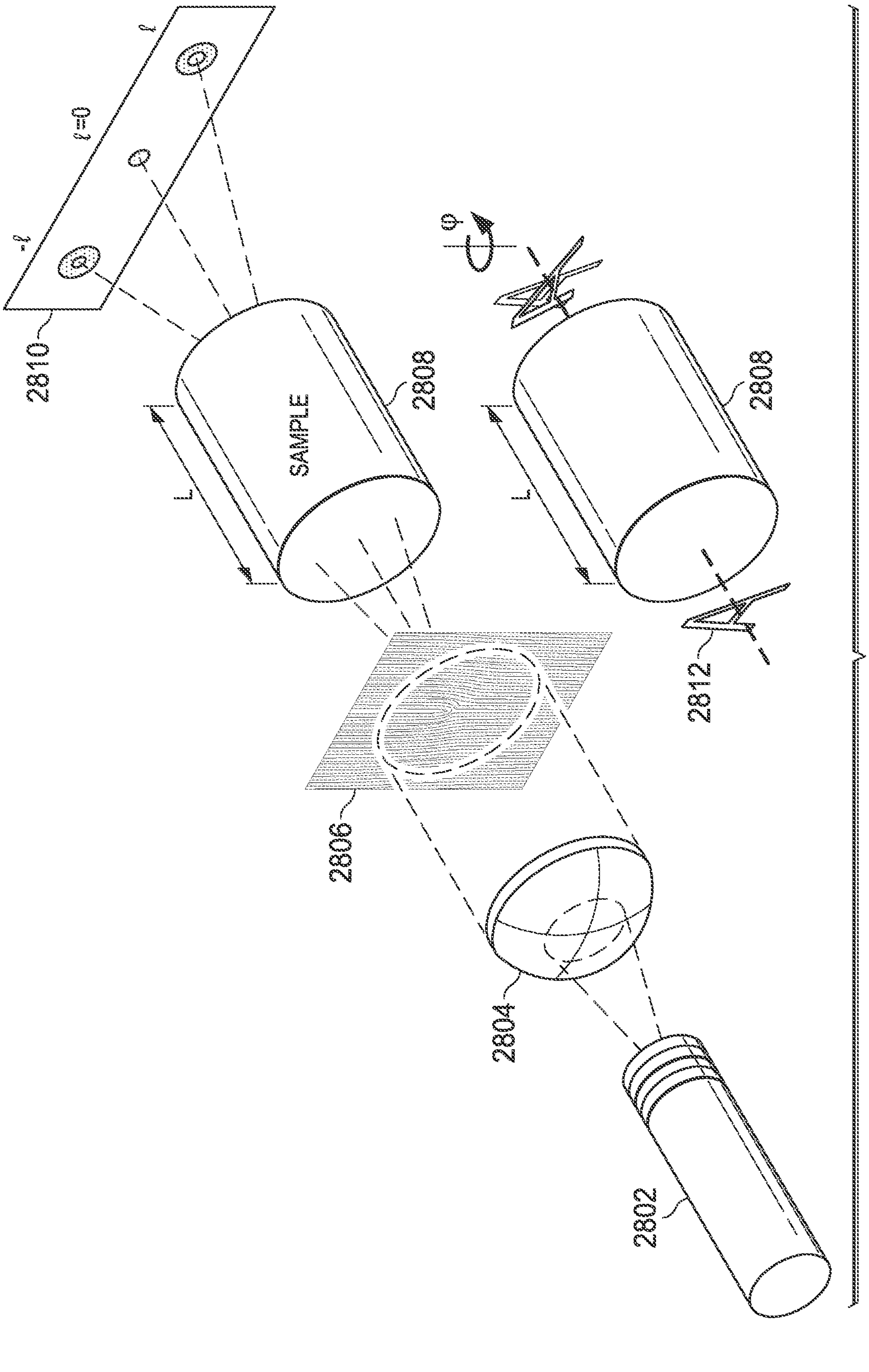


FIG. 28

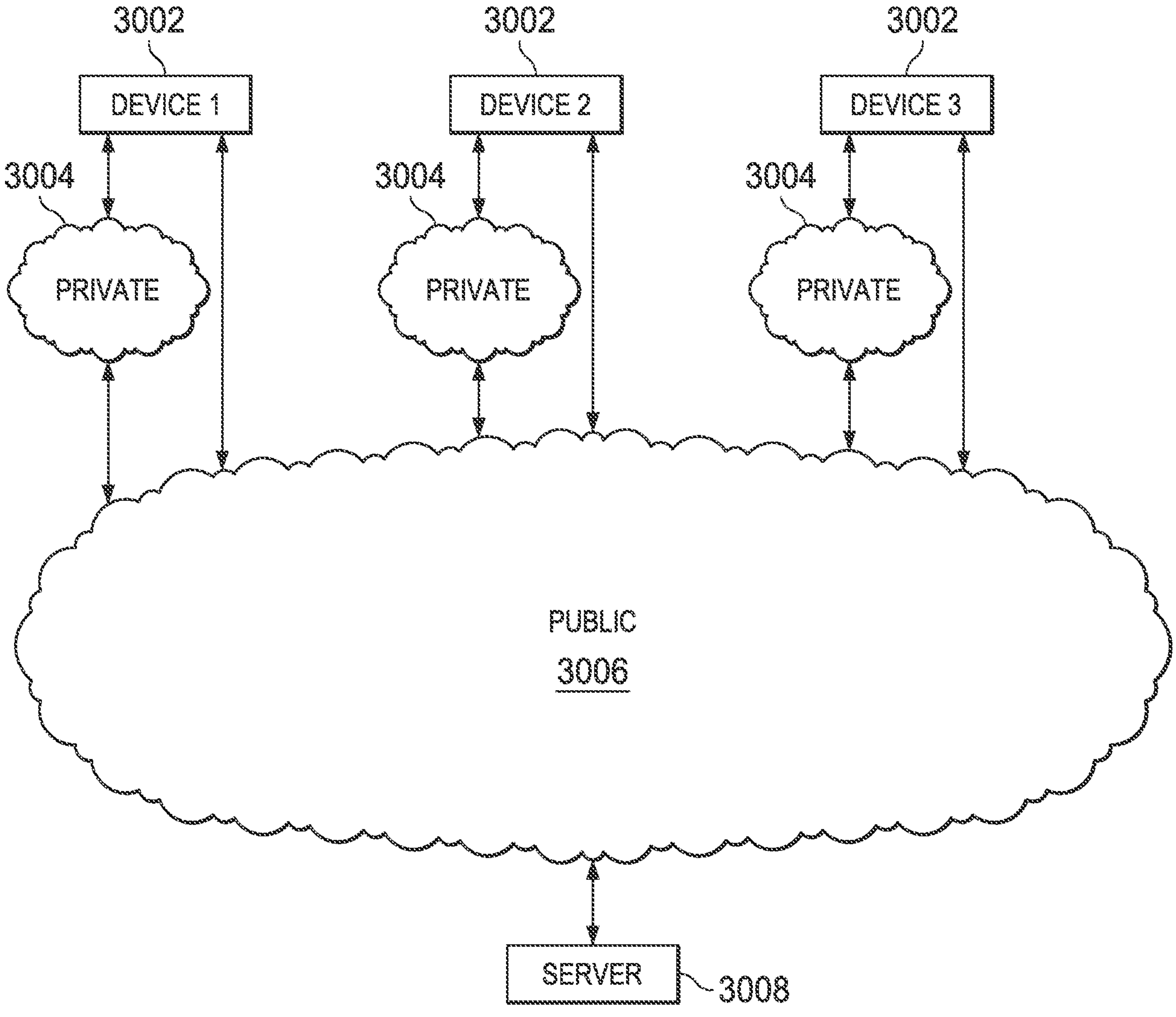

3002
DEVICE 1
3002
DEVICE 2
3002
DEVICE 3
3004
PRIVATE
3004
PRIVATE
3004
PRIVATE
PUBLIC
3006
SERVER
3008

FIG. 30

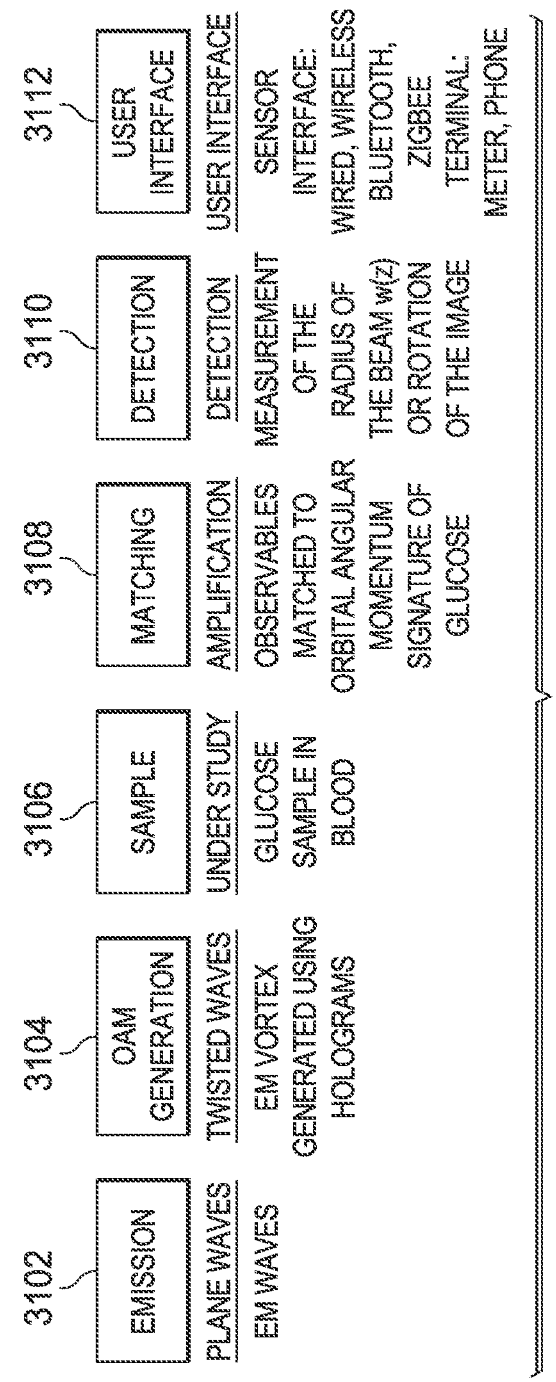

3102
EMISSION
PLANE WAVES
EM WAVES
3104
OAM GENERATION
TWISTED WAVES
EM VORTEX GENERATED USING HOLOGRAMS
3106
SAMPLE
UNDER STUDY
GLUCOSE SAMPLE IN BLOOD
3108
MATCHING
AMPLIFICATION
OBSERVABLES MATCHED TO ORBITAL ANGULAR MOMENTUM SIGNATURE OF GLUCOSE
3110
DETECTION
DETECTION
MEASUREMENT OF THE RADIUS OF THE BEAM w(z) OR ROTATION OF THE IMAGE
3112
USER INTERFACE
USER INTERFACE
SENSOR INTERFACE: WIRED, WIRELESS BLUETOOTH, ZIGBEE
TERMINAL: METER, PHONE

FIG. 31

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

As the below named inventor, I hereby declare that:

This declaration is directed to:

☑ The attached application, or

☐ United States application or PCT international application number ____________

filed on ____________.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Roger LINQUIST Date (Optional) : ____________

Signature: Roger Linquist

Note: An application data sheet (PTO/AIA/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/SB/AIA01 form for each additional inventor.

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

As the below named inventor, I hereby declare that:

This declaration is directed to:

- [✓] The attached application, or
- [ ] United States application or PCT international application number ____________
  filed on ____________.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Nima ASHRAFI Date (Optional): ____________

Signature: [signature]

Note: An application data sheet (PTO/AIA/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/SB/AIA01 form for each additional inventor.

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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM

As the below named inventor, I hereby declare that:

This declaration is directed to:

☑ The attached application, or

☐ United States application or PCT international application number ____________

filed on ____________.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Solyman ASHRAFI Date (Optional): ____________

Signature: [signature]

Note: An application data sheet (PTO/AIA/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/SB/AIA01 form for each additional inventor.

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
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NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	
Filing Date	July 24, 2014
First Named Inventor	ASHRAFI, Solyman
Title	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
Art Unit	
Examiner Name	
Attorney Docket Number	NXGN-32196

SIGNATURE of Applicant or Patent Practitioner

Signature	/Brian D. Walker, Reg. #37751/	Date (Optional)	
Name	Brian D. Walker	Registration Number	37,751
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of ONE forms are submitted.

Doc Code: PA..
Document Description: Power of Attorney

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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 25883

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

☑ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☐ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	[signature]	Date (Optional)	06/24/2014
Name	Nima ASHRAFI		
Title			

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of THREE forms are submitted.

Doc Code: PA..
Document Description: Power of Attorney

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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 25883

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

☑ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☐ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Roger Linquist	Date (Optional)	6/24/14
Name	Roger LINQUIST		
Title			

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of THREE forms are submitted.

Doc Code: PA..
Document Description: Power of Attorney

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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 25883

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

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Firm or Individual Name					
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Country					
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I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

☑ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☐ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	[signature]	Date (Optional)	6/24/2014
Name	Solyman ASHRAFI		
Title			

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of THREE forms are submitted.

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	Solyman ASHRAFI
Filer:	Brian D. Walker/Annie Pyczko
Attorney Docket Number:	NXGN-32196

Filed as Small Entity

Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	70	70
Utility Search Fee	2111	1	300	300
Utility Examination Fee	2311	1	360	360
Request for Prioritized Examination	2817	1	2000	2000
Pages:				
Claims:				
Claims in excess of 20	2202	11	40	440
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Publ. Fee- Early, Voluntary, or Normal	1504	1	0	0
PROCESSING FEE, EXCEPT PROV. APPLS.	2830	1	70	70

Petition:
Patent-Appeals-and-Interference:
Post-Allowance-and-Post-Issuance:
Extension-of-Time:
Miscellaneous:

	Total in USD ($)	**3240**

Electronic Acknowledgement Receipt

EFS ID:	19669662
Application Number:	14339836
International Application Number:	
Confirmation Number:	3583
Title of Invention:	SYSTEM AND METHOD FOR MAKING CONCENTRATION MEASUREMENTS WITHIN A SAMPLE MATERIAL USING ORBITAL ANGULAR MOMENTUM
First Named Inventor/Applicant Name:	Solyman ASHRAFI
Customer Number:	25883
Filer:	Brian D. Walker
Filer Authorized By:	
Attorney Docket Number:	NXGN-32196
Receipt Date:	24-JUL-2014
Filing Date:	
Time Stamp:	14:48:05
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$3240
RAM confirmation Number	1027
Deposit Account	200780
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	TrackOne Request	NXG32196Track1RQST.pdf	113850 6f2ac02c04ea7f69e8fa63df7a0c9d379196a2d4	no	1

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
2	Application Data Sheet	NXG32196ADS.pdf	1504799 1c0bf19d43a6c10fa7d25c1db9ebd6bf3f544d4d	no	7

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
3		NXG32196PATUtilityApp.pdf	235324 e8c3acd17a5557e8534800aa886f2d8a53b089b8	yes	35

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	28
Claims	29	34
Abstract	35	35

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
4	Drawings-only black and white line drawings	NXG32196FRMLDWGS.pdf	1266358 1e9046a344d5f44fc4f5e8c538511b6425218e15	no	21

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
5	Oath or Declaration filed	NXG32196DECLinquistEXE.pdf	122428 9626083fd10e34bf1f2c44ff727c58c1eb36d270	no	1

Warnings:

Information:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
6	Oath or Declaration filed	NXG32196DECNAshrafiEXE.pdf	123769 ee0a425ad785a3b5dc0886310364abc150d2d4cd	no	1

Warnings:

Information:

7	Oath or Declaration filed	NXG32196DECSAshrafiEXE.pdf	129961 8b2418abe21ff857f2eacb7f0406d9b6d4b189ce	no	1
Warnings:					
Information:					
8	Power of Attorney	NXG32196POAEXE.pdf	530125 e279422ae2eda81a7c2f2b23d8807f3081932ee0	no	4
Warnings:					
Information:					
9	Fee Worksheet (SB06)	fee-info.pdf	42057 8447f2ff292436cef47e679fa5f2f53e5e634467	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	4068671		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

SCORE Placeholder Sheet for IFW Content

Application Number: 14339836 Document Date: 07/24/2014

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

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