(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 436 769 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
20.09.2023 Bulletin 2023/38

(21) Application number: **17773324.3**

(22) Date of filing: **31.03.2017**

(51) International Patent Classification (IPC):
G01B 11/26 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
G01B 15/00; G01B 9/02; G01B 11/26; G01N 23/20; G04F 5/14; H01J 37/04; H01J 37/244; H01J 37/26;
A61B 5/0059; G01B 2290/55; H01J 2237/06383; H01J 2237/24557; H01J 2237/24578; H01J 2237/24585; H01J 2237/2614

(86) International application number:
PCT/CN2017/079105

(87) International publication number:
WO 2017/167294 (05.10.2017 Gazette 2017/40)

(54) METHOD FOR NON-CONTACT ANGLE MEASUREMENT

VERFAHREN ZUR BERÜHRUNGSLOSEN WINKELMESSUNG

PROCÉDÉ DE MESURE D’ANGLE SANS CONTACT

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **31.03.2016 US 201662316507 P**

(43) Date of publication of application:
06.02.2019 Bulletin 2019/06

(60) Divisional application:
23185557.8

(73) Proprietors:
- **Ken, Weng-Dah**
  Hsinchu City 300, Taiwan (TW)
- **Kan, Fang-Chi**
  Taipei City 116, Taiwan (TW)

(72) Inventors:
- **Ken, Weng-Dah**
  Hsinchu City 300, Taiwan (TW)
- **Kan, Fang-Chi**
  Taipei City 116, Taiwan (TW)

(74) Representative: **Straus, Alexander et al**
2K Patent- und Rechtsanwälte - München
Keltenring 9
82041 Oberhaching (DE)

(56) References cited:
CN-A- 1 411 786
CN-A- 103 412 304
CN-A- 103 913 132
US-A- 6 057 541
US-B1- 7 796 782
US-B2- 8 094 924
US-B2- 8 217 724

- **HUIHUA KENNY CHIANG ET AL: "OPTICAL ALIGNMENT AND TILT-ANGLE MEASUREMENT TECHNIQUE BASED ON LLOYD’S MIRROR ARRANGEMENT", OPTICS LETTERS, OPTICAL SOCIETY OF AMERICA, US, vol. 17, no. 14, 15 July 1992 (1992-07-15) , pages 1024-1025, XP000288968, ISSN: 0146-9592**
- **C. W. GILLARD ET AL: "Segmented Mirror Edge Alignment Sensor", PROCEEDINGS OF SPIE, vol. 0444, 8 November 1983 (1983-11-08), pages 310-318, XP055630146, ISSN: 0277-786X, DOI: 10.1117/12.937990**
- **Anton Zeilinger ET AL: "Single-and double-slit diffraction of neutrons", Reviews of Modern Physics, October 1988 (1988-10), XP055630476, Retrieved from the Internet: URL:https://journals.aps.org/rmp/pdf/10.1103/RevModPhys.60.1067 [retrieved on 2019-10-09]**

(Cont. next page)

- **Anonymous: "Lloyd’s mirror - Wikipedia", , 28 December 2015 (2015-12-28), XP055630522, Retrieved from the Internet: URL:https://en.wikipedia.org/w/index.php?title=Lloyd’s_mirror&oldid=697198851 [retrieved on 2019-10-09]**

Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/316,507, filed on March 31, 2016 and entitled "Non-contact Angle Measuring Tools and Methods Answered Unanswered,".

TECHNICAL FIELD

[0002] The present invention relates to remote angle measurement methods.

BACKGROUND

R. In regard to prior art patent applications:

[0003] Chiang, Huihua Kenny, et al. "Optical alignment and tilt-angle measurement technique based on Lloyd's mirror arrangement." Optics letters 17.14, 1992, describes a non-contacting optical alignment and tilt-angle measurement technique that is particularly useful for the alignment of planar waveguide end-fire coupling in a macroscopic scale alignment or measurement. The technique uses the Lloyds mirror fringe pattern, which is usually described as a two-point- source interference pattern formed between a point source and its virtual image through a mirror surface at a distance of light source. By using that technique, an interference pattern is formed from the interference between two line sources; thus their interference patterns are the same, and the superimposed interference pattern is rotated in an opposite direction to the waveguide surface. This technique utilizes traditional Lloyd's mirror fringes, and, consequently, one limitation of this technique is that the surfaces of the object to be aligned must be polished to a mirror surface for target objects alignment in a macroscopic space.

1) Remote Angle Measurement:

[0004] Prior arts for angle measurement tools and methods have some drawbacks, e.g. requiring long base lines or target objects for alignments, requiring contact mode to determine an angle and its directions, requiring complicated optical alignment steps, not fitting into a small space or object which target resided in, accuracy being not good enough and a measurement cycle time is long, and so on.

[0005] In a prior art (CN 103913132A) disclosed for Laser based angle measurement tools and methods. The prior art discloses a laser angle measuring gauge which is composed of a gauge body, a first stand bar, a second stand bar, a first laser device and a second laser device connected. The laser angle measuring gauge is simple in structure and convenient to use, and non-contact type measurement of various angles is achieved. On the other hands, that TWO Laser angle measurement tools requires manual alignment for the two different directions of TWO different objects in macroscopic metrics to determine the angle between to point of interests. However, this type of method and tool cannot easily perform the ONE Laser one-pass measurement and/or automatic computing the inner angle in between two microscopic plane surfaces jointed together.

[0006] In another prior art (Motamedi et al. (US7796782)) disclosed a method measures the distance between two arbitrary points of interest from the user position by determining the range and angle between the two points with only ONE Laser beam. Please refer to FIGS. 1A, 1B and Col. 4, lines 33-54 of Motamedi. Col. 4, lines 33-54 of Motamedi discloses "When the laser beam 10 strikes the scanning mirror 26, the reflection from the mirror 26 forms a stationary circular beam directed to a target plane 27... If an AC voltage is applied with a DC bias that places the cantilever beam 24 in position 2 (see FIG. 1B), FIG. 1A and FIG. 1B can be seen as illustration of the movement of the scan beams 16 and 18. In this case, the angle formed between the scan beams 16 and 18 is referred to herein as the "scan angle" 2α. Note that scan angle 2α can also be measured as the two times of angle α between the position 3 and position 4, of the cantilever beam 24", so according to Col. 4, lines 33-54 of Motamedi, Motamedi needs to apply the AC voltage to cantilever beam 24 to control movement of cantilever beam 24, wherein reflected light of laser beam 10 is also moved with the movement of cantilever beam 24. Therefore, a distance corresponding to straight scan line 28 on target plane 27 can be measured by scan angle 2α and measurements of a distance from scanner 11 to each of two endpoints 20 and 22 of scan beams 16 and 18. Therefore, because measurement of the distance of straight scan line 28 corresponds to scan angle 2α and the distance from scanner 11 to each of two endpoints 20 and 22, measure method of Motamedi is more complicated (that is, Motamedi needs complicated optical alignment steps to measure the distance of straight scan line 28.

[0007] In some other angle measurement known methods, it required long base lines or target objects for alignments. It required either in contact mode as to determine the angle, or its directions required complicated optical alignment steps which cannot fit into a small space or object which target DUT (samples or Device-Under-Test) resided in. The accuracy of those methods or tools are not good enough and its measurement cycle time is quite long without having the automation capability.

SUMMARY

[0008] The scope of the present invention is defined by the set of claims. The present invention provides a method for performing a non-contact angle measurement. The method comprises providing an apparatus comprising a particle source for generating boson or fermion particles; and a detector for detecting a plurality of

peaks or valleys of an interference pattern generated by the boson or fermion particles corresponding to a slit, a bump, or a hole of a first plane and matter waves associated with the boson or fermion particles reflected by a second plane, wherein an angle θ between the first plane and the second plane is defined by a joint region of objects under test and wherein the slit, a bump, or a hole is spaced apart from the joint region by a first distance; exposing the objects under test to boson or fermion particles; and detecting the angle θ between the first plane and the second plane of the objects under test. Angular locations of the plurality of peaks or valleys of the interference pattern, the first distance between a joint region of the first plane and the second plane, and a second distance between the detector and the slit are used for deciding an angle between the first plane and the second plane.

[0009] According to an embodiment the second plane is composed of transparent materials, dielectric materials, semi-conductive materials, conductive materials or dark materials; the reflectance of the dark material is less than 50%.

[0010] According to an embodiment the boson or fermion particles emitted by the particle source are associated with one or more equivalent wavelengths; the one equivalent wavelength is in between 0.1 to 400 nm.

[0011] According to an embodiment the slit has a short side length dimension with a third distance, and the one equivalent wavelength is less than 1/10-1/20 of the first distance or less than 1/5-1/10 of the third distance.

[0012] According to an embodiment the method is associated with a 3D non-contact Holograph image measurement tool.

[0013] According to an embodiment wherein the particle source placed at a first side of the first plane, the detector placed at a second side of the first plane, and the second side of the first plane is opposite to the first side of the first plane.

[0014] According to an embodiment the angle is between 15 to 165 degrees and the detector is located on a third plane or along an arc line directions.

[0015] According to an embodiment the non-contact angle measuring apparatus operates in a partial vacuum and low humidity environment.

[0016] According to an embodiment the first plane is placed along a first direction and the second plan is placed along a second direction, wherein the second direction is different from the first direction.

[0017] All additional examples provided herein are for illustrational purposes solely in order for the skilled person to fully understand the invention.

CC. Non-contact mode angle measuring apparatus:

[0018] Please refer to FIG. 110, and FIG. 110 is a diagram illustrating a non-contact angle measuring apparatus 1100 according to a first embodiment of the present invention. When particle 11000 (e.g. Photon or fermion) generated by coherent source 11002 passes through slit 11004 (or hole of any shape) of object 11006, plane 11008 can reflect matter wave associated with the particle 11000, wherein as shown in FIG. 110, the object 11006 is placed along a first direction, and the plane 11008 is placed along a second direction, wherein an angle θ between the first plane and the second plane is defined by a joint region of the object 11006 and the plane 11008, the slit 11004 is spaced apart a first distance D1 from the joint region, the plane 11008 can be composed of transparent materials, dark materials, dielectric materials, semi-conductive materials, or conductive materials, and the second direction is different from the first direction. In addition, the angle θ is better for a angle measurement apparatus if it is in between 15o to 165o for getting the best accurate angle measurement result, wherein 1) "transparent material" means the incident Light particles' transmission rate is about larger than 50%, or the reflectance is less than 50% while light incidence angle is about normal to the plane, 2) "dark material" means the incident Light particles' absorption rate is about larger than 50%, or the reflectance is less than 50% while light incidence angle is about normal to the plane.

[0019] The particle source 11002 can be a particle source for generating boson or fermion particles, wherein the boson or fermion particles emitted by the particle source 11002 are associated with one or multiple equivalent wavelengths (in between 0.1 to 400 nm).

[0020] Therefore, by following the Huygens principle, wavefront of reflected matter wave (i.e. reflected away from the plane 11008) of the particle 11000 can combine with original matter wavefront of the particle 11000 so as to form substantially half double-slit interference pattern 11009 on screen 11010 and detector 11012, wherein the detector 11012 can be a boson or fermion intensity detector, the half double-slit interference pattern 11009 is boson interference patterns (when the coherent source 10902 is the boson particle source) or fermion interference patterns (when the coherent source 10902 is the fermion particle source), and the detector 11012 is spaced apart from the slit 11004 by a second distance D2. Therefore, the detector 11012 can decide the angle θ by detecting a plurality peaks or valleys of the half double-slit interference pattern 11009, wherein a principle of the detector 11012 deciding the angle θ can be referred to the well-known Young's Double-slit Interference theory, so the further description thereof is omitted for simplicity.

[0021] In addition, the slit 11004 has a short side length with a third distance, wherein the one or multiple equivalent wave lengths is less than 1/10~1/20 of the first distance D1 or less than 1/5~1/10 of the third distance. In addition, as shown in FIG. 110, the detector 11012 can be located on a plane of the screen 11010 or along a linear, straight or an arc line direction.

[0022] In addition, the non-contact angle measuring apparatus 1100 needs to operate in a partial vacuum, low humidity, enclosed environment when 1) the coherent source 10902 is the fermion particle source, or 2) the high measurement accuracy is required for the boson particle source.

[0023] In addition, in another embodiment of the present invention, first plane 11102, and second plane 11104 of a non-contact angle measuring object or apparatus 1110 are shown in FIG. 111A, wherein sacrificial bump 11106 is located on the second plane 11104. Therefore, detector 11108 can detect a plurality of peaks or valleys of the interference patterns generated by boson or fermion particles generated by coherent source 11110 and got scattered corresponding to the sacrificial bump 11106 and reflected by the first plane 11102. Therefore, an angle θ shown in FIG. 111A can be determined by the plurality peaks or valleys of the interference patterns.

[0024] Similarly, as shown in FIG. 111B, shallow dip (or hole) 11112 is located on third plane 11114. Therefore, the detector 11108 can detect a plurality peaks or valleys of the interference patterns generated by boson or fermion particles (generated by coherent source 11110) corresponding to the dip 11112 and reflected by the first plane 11102. Therefore, an angle θ shown in FIG. 111B can be determined by the plurality peaks or valleys of the interference pattern.

[0025] Utilities for the non-contact angle measuring apparatuses 1100, 1110 of the present invention are shown as follows:

1) Can have ultra-fine accuracy for an angle measurement for all macroscopic scale or atomic level fine structures, with or without sacrificial layer or hole; 2) There is no needs for long base lines or target objects for alignments the incidence beam of particles; 3) There is no needs for using direct contact mode to determine the angle and its directions; 4) There is no needs for complicated optical alignment steps before measurement steps; 5) It can be fitting into a small space or object which target (sample or device under test) resided in; 6) The accuracy will be good enough and the measurement cycle time is short; and 7) Can be creating measurements in between many combinations of the points or edges of the 3D models or objects under test.

[0026] In addition, the non-contact angle measuring apparatuses 1100, 1110 also have some advantages as follows: as you move the pointer over the 3D model, the non-contact angle measuring apparatuses 1100, 1110 supports four types of measurements: perpendicular distance between two straight edges, linear distance between two points, the radius of circular edges, and the angle between two edges (or three points), you can associate the measurement apparatus with a 3D non-contact Holograph Image measurements tool along with specific x-section views. If the default view is active when a measurement is added, a new measurement view is created, and you can also display comments on the image display or screen while taking measurements. These comments (also called measurement markups) are preserved after the document is closed and saved back to a computer storage space.

[0027] To sum up, the present disclosure utilizes matter wave of bosons (e.g. Photon) and/or fermions (e.g. electron, neutron) to apply to non-contact angle measuring apparatus.

[0028] Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

Claims

1. A method for performing a non-contact angle measurement, comprising:

   providing an apparatus comprising: a particle source (11002, 11110) for generating boson or fermion particles (11000); and
   a detector (11012, 11108) for detecting a plurality of peaks or valleys of an interference pattern (11009) generated by the boson or fermion particles corresponding to a slit (11004), a bump (11106), or a hole (11112) of a first plane (11006, 11104, 11114) and matter waves associated with the boson or fermion particles reflected by a second plane (11008, 11102), wherein an angle (θ) between the first plane and the second plane is defined by a joint region of objects under test (11006, 11008) and wherein the slit, bump, or hole is spaced apart from the joint region by a first distance (D 1);
   exposing the objects under test to boson or fermion particles; and
   detecting the angle θ between the first plane and the second plane of the objects under test;
   wherein angular locations of the plurality peaks or valleys of the interference pattern, the first distance (D1), and a second distance (D2) between the detector and the slit are used for deciding an angle between the first plane and the second plane.

2. The method of claim 1, wherein the second plane (11008, 11102) is composed of transparent materials, dielectric materials, semi-conductive materials, conductive materials or dark materials, wherein the reflectance of the dark material is less than 50%.

3. The method of claim 1, wherein the boson or fermion particles emitted by the particle source (11002, 11110) are associated with one or more equivalent

wavelengths, wherein the one equivalent wavelength is in between 0.1 to 400 nm.

4. The method of claim 3, wherein the slit (11004) has a short side length dimension with a third distance, and the one equivalent wavelength is less than 1/10~1/20 of the first distance or less than 1/5~1/10 of the third distance.

5. The method of claim 1, wherein it is associated with a 3D non-contact Holograph Image measurement tool.

6. The method of claim 1, wherein the particle source (11002) placed at a first side of the first plane (11006), the detector (11012) placed at a second side of the first plane, and the second side of the first plane is opposite to the first side of the first plane.

7. The method of claim 1, wherein the angle is between 15 to 165 degrees, and the detector is located on a third plane or along an arc line directions.

8. The method of claim 1, wherein the non-contact angle measuring apparatus operates in a partial vacuum and low humidity environment.

9. The method of claim 1, wherein the first plane (11006, 11104, 11114) is placed along a first direction and the second plane (11008, 11102) is placed along a second direction, wherein the second direction is different from the first direction.

Patentansprüche

1. Verfahren zur Durchführung einer berührungslosen Winkelmessung, welches umfasst:

   Bereitstellen einer Vorrichtung mit:

   einer Teilchenquelle (11002, 11110) zum Erzeugen von Bosonen- oder Fermionteilchen (11000); und
   einem Detektor (11012, 11108) zum Erfassen mehrerer Spitzen oder Täler eines Interferenzmusters (11009), das durch die Bosonen- oder Fermionenteilchen erzeugt wird, die einem Spalt (11004), einer Beule (11106) oder einem Loch (11112) einer ersten Ebene (11006, 11104, 11114) entsprechen, und Materiewellen, die mit den Bosonen- oder Fermionenteilchen verbunden sind, die von einer zweiten Ebene (11008, 11102) reflektiert werden, worin ein Winkel (θ) zwischen der ersten Ebene und der zweiten Ebene durch einen Verbindungsbereich der zu prüfenden Objekte (11006, 11008) definiert ist und worin der Spalt, die Beule oder das Loch von dem Verbindungsbereich um einen ersten Abstand (D1) beabstandet ist;

   Aussetzen der zu prüfenden Objekte gegenüber Bosonen- oder Fermionteilchen; und
   Erfassen des Winkels θ zwischen der ersten Ebene und der zweiten Ebene der zu prüfenden Objekte;
   wobei Winkelpositionen mehrerer Spitzen oder Täler des Interferenzmusters, der erste Abstand (D1) und ein zweiter Abstand (D2) zwischen dem Detektor und dem Spalt zum Bestimmen eines Winkels zwischen der ersten Ebene und der zweiten Ebene verwendet werden.

2. Verfahren nach Anspruch 1, worin die zweite Ebene (11008, 11102) aus transparenten Materialien, dielektrischen Materialien, halbleitenden Materialien, leitenden Materialien oder dunklen Materialien besteht, wobei der Reflexionsgrad des dunklen Materials weniger als 50% beträgt.

3. Verfahren nach Anspruch 1, worin die von der Teilchenquelle (11002, 11110) emittierten Bosonen- oder Fermionteilchen mit einer oder mehreren äquivalenten Wellenlängen assoziiert sind, wobei die eine äquivalente Wellenlänge zwischen 0,1 und 400 nm liegt.

4. Verfahren nach Anspruch 3, worin der Spalt (11004) eine kurze Seitenlängenabmessung mit einem dritten Abstand aufweist und die eine äquivalente Wellenlänge weniger als 1/10-1/20 des ersten Abstands oder weniger als 1/5-1/10 des dritten Abstands beträgt.

5. Verfahren nach Anspruch 1, wobei es mit einem berührungslosen 3D-Holographie-Bildmessgerät verbunden ist.

6. Verfahren nach Anspruch 1, wobei die Teilchenquelle (11002) auf einer ersten Seite der ersten Ebene (11006) angeordnet wird, der Detektor (11012) auf einer zweiten Seite der ersten Ebene angeordnet wird und die zweite Seite der ersten Ebene der ersten Seite der ersten Ebene gegenüberliegt.

7. Verfahren nach Anspruch 1, worin der Winkel zwischen 15 und 165 Grad beträgt und der Detektor auf einer dritten Ebene oder entlang einer Bogenlinienrichtung angeordnet wird.

8. Verfahren nach Anspruch 1, worin die berührungslose Winkelmessvorrichtung in einer Umgebung mit Teilvakuum und geringer Luftfeuchtigkeit arbeitet.

9. Verfahren nach Anspruch 1, worin die erste Ebene (11006, 11104, 11114) entlang einer ersten Richtung angeordnet ist und die zweite Ebene (11008, 11102) entlang einer zweiten Richtung angeordnet ist, worin sich die zweite Richtung von der ersten Richtung unterscheidet.

Revendications

1. Méthode pour effectuer une mesure d'angle sans contact, comprenant:

fournir un appareil comprenant:

une source de particules (11002, 11110) pour générer des particules de boson ou de fermion (11000); et
un détecteur (11012, 11108) pour détecter une pluralité de pics ou de vallées d'une figure d'interférence (11009) générée par les particules de boson ou de fermion correspondant à une fente (11004), une bosse (11106), ou un trou (11112) d'un premier plan (11006, 11104, 11114) et les ondes de matière associées aux particules de boson ou de fermion réfléchies par un second plan (11008, 11102), dans lequel un angle (θ) entre le premier plan et le second plan est défini par une zone de jonction des objets testés (11006, 11008) et dans lequel la fente, la bosse ou le trou est espacé de la zone de jonction d'une première distance (D1);

exposer les objets testés à des particules de boson ou de fermion; et
détecter l'angle θ entre le premier plan et le second plan des objets testés;
dans lequel les positions angulaires de la pluralité de pics ou de vallées de la figure d'interférence, la première distance (D1) et une seconde distance (D2) entre le détecteur et la fente sont utilisées pour décider d'un angle entre le premier plan et le second plan.

2. Méthode de la revendication 1, dans laquelle le second plan (11008, 11102) est composé de matériaux transparents, de matériaux diélectriques, de matériaux semiconducteurs, de matériaux conducteurs ou de matériaux sombres, la réflectance du matériau sombre étant inférieure à 50%.

3. Méthode de la revendication 1, dans laquelle les particules de boson ou de fermion émises par la source de particules (11002, 11110) sont associées à une ou plusieurs longueurs d'onde équivalentes, la longueur d'onde équivalente se situant entre 0,1 et 400 nm.

4. Méthode de la revendication 3, dans laquelle la fente (11004) a une dimension latérale courte avec une troisième distance, et la longueur d'onde équivalente est inférieure à 1/10-1/20 de la première distance ou inférieure à 1/5-1/10 de la troisième distance.

5. Méthode de la revendication 1, dans laquelle elle est associée à un outil de mesure d'image holographique 3D sans contact.

6. Méthode de la revendication 1, dans laquelle la source de particules (11002) est placée sur un premier côté du premier plan (11006), le détecteur (11012) est placé sur un second côté du premier plan, et le second côté du premier plan est opposé au premier côté du premier plan.

7. Méthode de la revendication 1, dans laquelle l'angle est compris entre 15 et 165 degrés, et le détecteur est situé sur un troisième plan ou le long d'un arc de direction.

8. Méthode de la revendication 1, dans laquelle l'appareil de mesure d'angle sans contact fonctionne dans un environnement de vide partiel et de faible humidité.

9. Méthode de la revendication 1, dans laquelle le premier plan (11006, 11104, 11114) est placé le long d'une première direction et le second plan (11008, 11102) est placé le long d'une seconde direction, la seconde direction étant différente de la première.

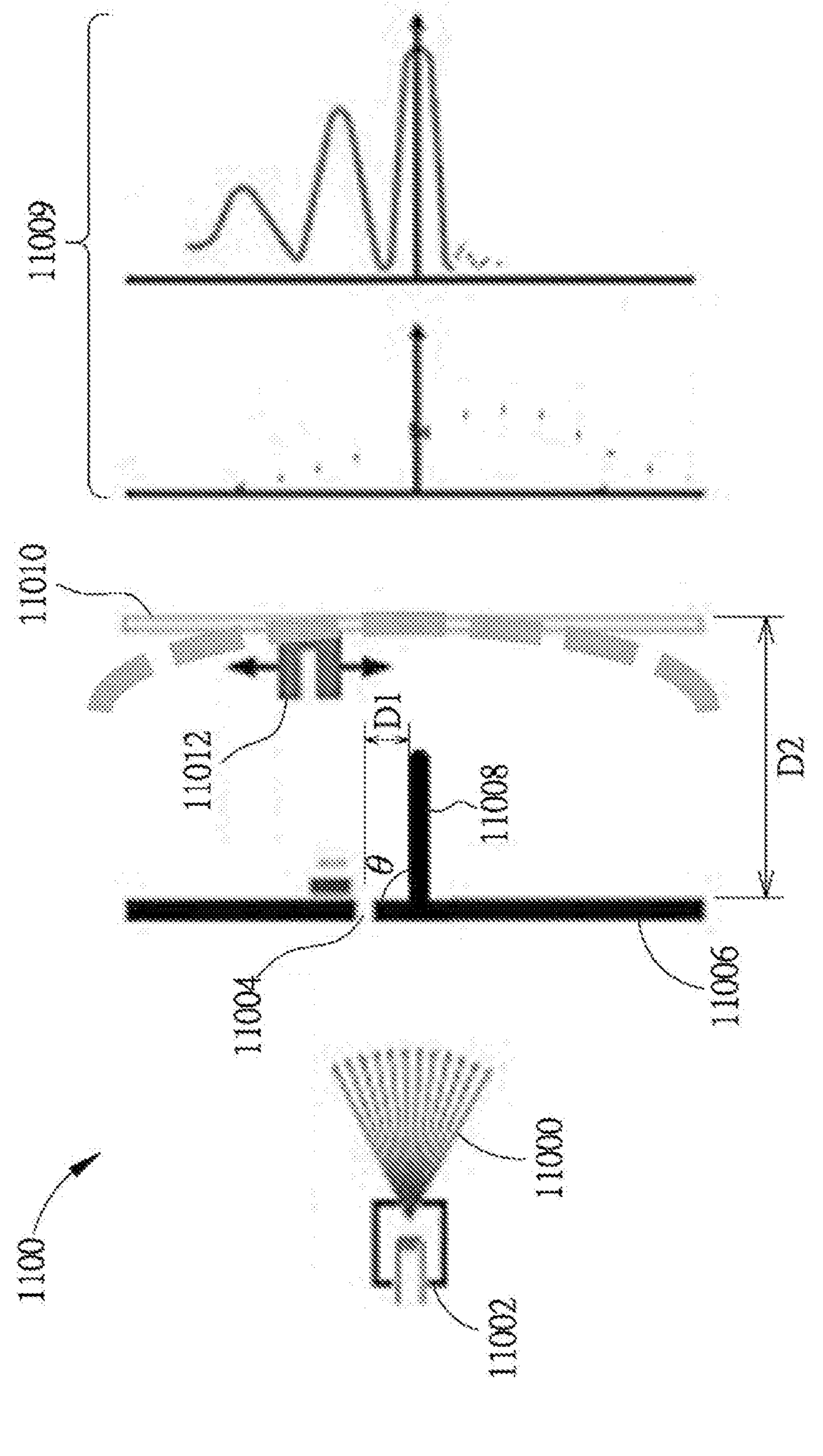

FIG. 110

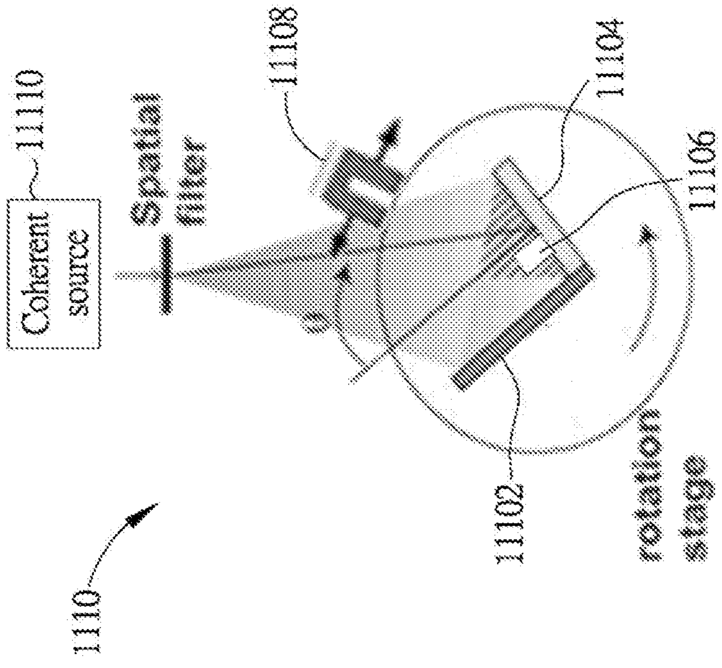

FIG. 111A

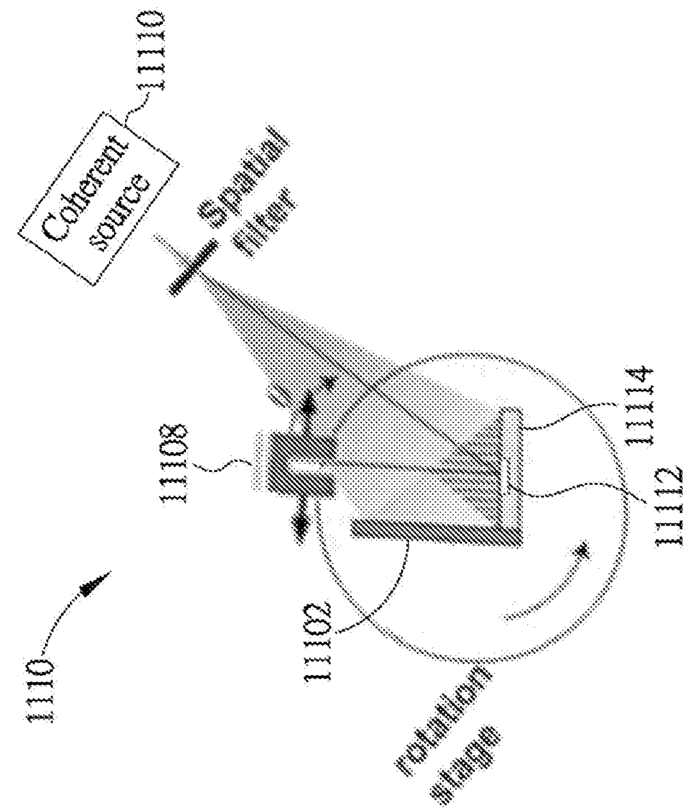

FIG. 111B

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 62316507 **[0001]**
- CN 103913132 A **[0005]**
- US 7796782 B, Motamedi **[0006]**

Non-patent literature cited in the description

- **CHIANG, HUIHUA KENNY et al.** Optical alignment and tilt-angle measurement technique based on Lloyd's mirror arrangement. *Optics letters,* 1992, vol. 17 (14 **[0003]**