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(54) Title: TERAHERTZ POLARIZER AND MODULATOR

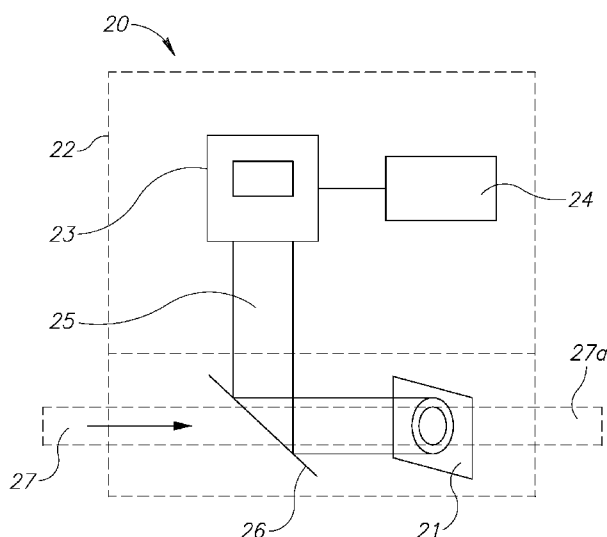


FIG.2

(57) Abstract: A controllable polarizer for terahertz radiation, the polarizer comprising a polarizer plate, the polarizer plate comprising a plurality of nanowires, and a control element, the control element including a light source, such that the control element is operable to illuminate the polarizer plate to selectively photoexcite the nanowires.

Title: Terahertz Polarizer and Modulator

[1] The present application relates to a controllable polarizer for terahertz radiation, a modulator for terahertz radiation and a transmitter for terahertz radiation.

Background to the Invention

[2] Terahertz waves occupy a section of the electromagnetic spectrum, from about 50 GHz to 10 THz, between microwaves and infrared light. Both microwaves and near-infrared light are widely used in modern technologies. In particular, microwave links are extensively used in communication networks as radio relays. Optical fibers provide the backbone of the internet and international communication networks, carrying light at infrared wavelengths over long distances with very low attenuation. Between these two regions of the electromagnetic spectrum, the terahertz region remains substantially unused.

[3] A reason for the lack of use of the terahertz region has been a lack of intense radiation sources and a lack of optoelectronic components, such as detectors and modulators, which work in this range. While THz sources have become available, practical THz modulators are still not satisfactory.

[4] It is known to provide intensity modulation of THz waves, for example by using optically modulated silicon wafers and electrically modulated metamaterials. However, known modulators do not provide a sufficiently high switching speed for use in communication applications. It is also known to provide polarizers, using parallel fine wires on a grid, or carbon nanotubes arranged on a suitable substrate, but modulators which permit control of the polarization of THz radiation are not available.

Summary of the Invention

[5] According to a first aspect of the invention we provide a controllable polarizer for terahertz radiation, the polarizer comprising a polarizer plate, the polarizer plate comprising a plurality of nanowires, and a control element, the control element including a light source, such that the control element is operable to illuminate the polarizer to selectively photoexcite the nanowires.

[6] The plurality of nanowires may be disposed on a substrate generally transparent to terahertz radiation.

[7] The nanowires may be generally aligned.

- [8] The nanowires may comprise semiconducting nanowires.
- [9] The nanowires comprise any binary, ternary or quaternary alloy of Group III-V semiconductors.
- [10] The nanowires may comprise GaAs nanowires.
- [11] The nanowires may comprise GaAs – AlGaAs nanowires.
- [12] The nanowires may comprise InP nanowires, InAs nanowires or InSb nanowires.
- [13] The semiconducting nanowires may comprise semi-conducting carbon nanotubes.
- [14] The nanowires may be formed by deposition, or by etching a semiconductor layer.
- [15] The control element may be operable to illuminate the polarizer plate with light having a wavelength to cause photoexcitation of the nanowires.
- [16] The control element may be operable to illuminate the polarizer plate with light having an axis of polarization substantially aligned with the nanowires.
- [17] The control element may comprise a control polarizer.
- [18] The control light source may comprise a laser diode.
- [19] The controllable polarizer may comprise a modulation element to modulate the illuminating light.
- [20] According to a second aspect of the invention we provide a modulator for terahertz radiation, the modulator comprising a controllable polarizer according to the first aspect of the invention, and an auxiliary polarizer plate having an axis of polarization.
- [21] The axis of polarization of the auxiliary polarizer plate may be orthogonal to an axis of polarization of the polarizer plate.
- [22] The modulator may comprise a second control element, the second control element including a second control light source, such that the control element is operable to illuminate the auxiliary polarizer plate.
- [23] According to a third aspect of the invention we provide a transmitter for terahertz radiation, the transmitter comprising a modulator according the second aspect of the invention, and a

coherent THz source to generate a beam of terahertz radiation, wherein the beam passes through the polarizer plate and auxiliary polarizer plate to provide an output beam, and wherein the output beam is modulated by operation of the control element.

[24] The control element may comprise a light source comprising a laser diode, and a laser diode controller, wherein operation of the control element may comprise controlling the laser diode.

[25] The transmitter may further comprise a polarization control element to control the polarization of the output beam before the beam passes through the polarizer plate and auxiliary polarizer plate.

Brief Description of the Drawings

[26] An embodiment of the invention is described by way of example only with reference to the accompanying drawings, wherein;

[27] Fig. 1a is an image of semiconducting nanowires grown on a growth substrate,

[28] Fig. 1b is a diagrammatic illustration of a method of transferring the nanowires of Fig. 1a to a substrate of a polarizer plate,

[29] Fig. 1c is diagrammatic illustration of a polarizer plate,

[30] Fig. 1d is an image of nanowires on a polarizer plate after transfer,

[31] Fig 2. is a diagrammatic illustration of a controllable polarizer embodying the present invention,

[32] Fig. 3 is a diagrammatic illustration of a modulator embodying the present invention,

[33] Fig. 4 is a diagrammatic illustration of a further modulator embodying the present invention, and

[34] Fig.5 is a diagrammatic illustration of a yet further modulator embodying the present invention,

[35] Fig. 6 is a graph showing transmission of THz radiation through a polarizer plate at different fluence levels of near infrared light,

[36] Fig. 7 is a graph showing transmission of THz radiation through polarizer plates with different numbers of nanowire layers,

[37] Fig. 8a is a perspective view of a semi-conductor wafer for use in another method of fabricating a polarizer plate,

[38] Fig. 8b is a perspective view of the semiconductor wafer of Fig. 8a after etching,

[39] Fig. 9a is a perspective view of a semiconductor and substrate for use in another method of fabricating a polarizer plate, and

[40] Fig. 9b is a perspective view of the semiconductor and substrate of Fig. 9a after etching.

Detailed Description of the Preferred Embodiments

[41] With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

[42] Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is applicable to other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

[43] Semiconductor nanowires are microscopic rods of inorganic semiconductor, such as Si or III-V semiconductors, typically ~50 nm wide and ~5 μ m long. Typically, nanowires are grown on a semiconductor wafer, for example by the vapour-liquid-solid mechanism such as metal-organic chemical vapour deposition, or by selective area epitaxy. Advantageously the nanowire growth can be directed using gold nanoparticles. The nanowires typically grow perpendicular to the surface of

the wafer, and can be grown without defects at high density. A scanning electron microscope image of GaAs nanowires grown on a GaAs wafer is shown in Fig. 1a.

[44] A characteristic of semiconductors is that of photoexcitation. Ordinarily, a semiconductor will have relatively few free charge carriers. However when a semiconductor is illuminated with light in an appropriate wavelength range, excitation occurs and the transmission characteristics of the semiconductor at THz wavelengths change. When this occurs in nanowires, the photo excited nanowires block THz radiation with an axis of polarization parallel to the long axis of the nanowires.

[45] To provide a polarizer plate for the present invention, the nanowires are transferred to a substrate as illustrated in Fig. 1b. The wafer is shown at 10 and the nanowires at 11. By drawing the substrate 12 across the wafer 10 as shown by arrow 13, the nanowires 11 separate from the wafer 10 and adhere to the surface 12a of the substrate 12. The nanowires 11 are held firmly on the surface 12 by van der Waals forces. By drawing the substrate 12 across the wafer 10 in a constant direction 13, the nanowires 11 are generally aligned, that is the long axes of the nanowires 11 extend in approximately the same direction. The resulting substrate is illustrated in Fig. 1c, the nanowires 11 being generally aligned in direction A. In the image of nanowires in Fig. 1d, it can be seen that the alignment is not perfectly consistent but that there is a preferred axis or direction, and this is sufficient for a polarizer plate using the substrate 12 to be used as described below. Other transfer or alignment methods may be used, such as electrophoresis, growing nanowires in separated rows on catalyst pads, embedding nanowires in polydimethylsiloxane (PDMS) polymer film to enable the nanowires to be transferred from a growth surface and bond them in place, and so on. The nanowires can be generally aligned by the process of transfer to the substrate, or known alignment techniques can be used.

[46] A controllable polarizer for THz radiation is shown at 20 in Fig. 2. A polarizer plate is shown at 21, comprising nanowires on a substrate as described above. The substrate 12 is transparent or substantially transparent to THz radiation, for example quartz. A control element is shown at 22, comprising an optical module 23 and a controller 24. The control element 22 is operable to generate a control beam 25 which illuminates the surface of polarizer plate 21. In this example, a beam splitter 26 directs the control beam 25 to the polarizer plate 21, aligned with a THz radiation beam 27. The polarizer plate 21 is oriented such that the general direction of orientation of the nanowires is shown at A.

[47] When the nanowires 11 of the polarizer plate are not illuminated, there are relatively few free charge carriers, and transmitted THz beam 27a will be unpolarized or retain its original

polarization. By illuminating the polarizer plate 21 with control beam 25, where the axis of polarization of the control beam is generally aligned with the axis of the nanowires, the nanowires are photoexcited. The polarizer plate 21 will then block the polarization component of the THz radiation beam 27 which is aligned with the axis of the nanowires. Transmitted THz beam 27a will be polarized in a direction transverse to axis A. Accordingly, at its simplest it will be apparent that an easily controllable polarizer can be implemented in this way.

[48] In general, nanowires will have maximum absorption when an illuminating optical beam is polarised parallel to the nanowire axis. However for some crystal structures, maximum absorption can occur when the longitudinal axis of the nanowires is transverse or perpendicular to the axis of polarisation of the optical beam. Accordingly, depending on the type of the nanowire, the orientation of the axis of polarization of the control beam may need to be transverse relative to the nanowire axes rather than parallel. As such, although in the specific examples described herein the control beam is polarized parallel to the longitudinal axis of the nanowires and the transmitted THz beam is polarized perpendicular to the nanowire axis, it will be apparent that the various beam polarization states and relative orientation of the nanowires may be adapted as necessary depending on the characteristic of the nanowires, while still allowing the THz modulator to operate as described herein.

[49] Figs. 3 to 5 show examples of how a controllable polarizer 20 can be used in THz modulators or transmitters. In addition, an example of the control module 22 is shown in more detail. A source comprising a diode laser is shown at 30, in this example a near-infra red (NIR) or visible laser diode. Beam expansion, conditioning and collimation optics are shown generally at 31. An optical modulator is shown at 32 and a controllable polarizer, for example a polarizing filter mounted on a rotation stage, is shown at 33. The laser diode 30, optical modulator 32 and controllable polarizer 33 are under the control of controller 24. The laser diode and optical modulator can be separately operated to control the intensity of control beam 25, to illuminate or not illuminate the polarizer plate 21. The controllable polarizer 33 allows the axis of polarization of control beam 25 to be correctly aligned with axis A of polarizer plate 21 to maximise absorption.

[50] To provide intensity modulation, as shown in Fig 3 an auxiliary polarizer plate is included. Alternative positions of the auxiliary polarizer plate are shown at 40. The auxiliary polarizer plate 40 may be any appropriate known polarizer. The axis of polarization of the auxiliary polarizer plate is shown at B, i.e. such that the THz beam passing through auxiliary polarizer plate 40 is polarized so that it is polarized parallel to axis A of polarizer plate 21. Accordingly, when the polarizer plate 21 is not illuminated by control beam 25, polarizer plate 21 is transparent to the THz beam 27 and the

output beam 27a has a relatively high intensity. When the polarizer plate 21 is illuminated, the combination of the photoexcited polarizer plate 21 and auxiliary polarizer plate 40 cause the beam 27 to be absorbed, at the later of the polarizer plate 21 and auxiliary polarizer plate 40 depending on where the auxiliary polarizer plate is located in the beam line. Output beam 27a will then be at a relatively low intensity, depending on the extinction ratio achievable by the polarizer plates. Accordingly, by supplying input control signal I to the controller 24 and modulating the control beam 25, an output signal O can be encoded in the THz output beam. The switching frequency is limited by how fast the laser diode 30 or modulator 32 can be operated, which, based on existing technology, can be extremely high (>10 GHz).

[51] In an alternative shown in Fig. 4, a second nanowire-based polarizer plate 41 is used as the auxiliary polarizer plate. The axis of the polarizer plate 21 is shown as A1 and the second polarizer plate 41 is shown at A2, disposed such that they are mutually orthogonal. The polarizer plate 21 and second polarizer plate 41 are positioned so that both are illuminated by control beam 25. It will be apparent that this configuration allows a number of possible modulation techniques. By selecting the axis of polarization of control beam 25 such that it is only aligned with axis A1 or A2, the polarization of output beam 27a can be switched between orthogonal states, permitting polarization-shift keying of the output beam 27a to transmit data. Alternatively, by selecting the plane of polarization the control beam 25 to be at 45° to A1 and A2, both polarizer plates 21, 41 can be activated. In this way, the beam 27 can be blocked or passed depending on the state of the control beam 25, providing another method of intensity modulation. In Fig 4, a coherent THz source is shown at 50, with its associated control electronics 51. The system thus becomes a controllable THz transmitter, operable to generate a THz beam with encoded information.

[52] Fig. 5 shows a further refinement of Fig. 4, where a second control module 22' is provided to generate and modulate a second control beam 25', such that control beams 25, 25' are orthogonally polarized to excite a respective one of polarizer plates 21, 41. By providing a second control module 22', polarizer plate 21 and second polarizer plate 41 can be independently illuminated, at different intensities. By controlling the intensities of the control beams 25, 25' the output beam 27a can be controlled to provide arbitrary polarization states. Where desirable, a polarization control element 28 may be provided to control the polarization state of the THz beam 27 before it passes through the polarizer plates 21, 41. The polarization control element 28 may be a linear polarizer, such that the beam 27 is polarized at 45° to both the polarizer plates 21, 41. Where the beam 27 is polarized, the polarization control element 28 may alternatively be a quarter wave plate, such that the beam

27 is circularly polarized, or a half-wave plate to permit the axis of polarization of beam 27 to be rotated if needed.

[53] The response of a polarizer plate 21, 41 with a single layer of nanowires to incident THz radiation is shown in Fig. 6. The relative photoinduced change in transmission of the THz electric field, $\Delta E/E$, is plotted as a function of pump polarisation. The nanowire grid polarizer was placed at an angle of 0° relative to the terahertz polarisation. $\Delta E/E$ was measured for different near-infrared photoexcitation fluences of 4, 10, 20, 40, 100 and 200 $\mu\text{J}/\text{cm}^2$, as labelled. A cosine-squared relationship with the pump polarisation, as expected from Malus's law, was fitted to the data (solid lines). The data deviates from Malus's law for the higher photoexcitation fluences, due to band-filling and electron mobility reduction in the nanowires at high photoexcited carrier densities, but the change in transmission shows the expected variation.

[54] The extinction ratios achievable can depend on the alignment and fill factor of the nanowires. In the current example a fill factor of 10% can be achieved. Ideally the nanowires should not touch or overlap, but by providing an insulating outer layer, such as AlGaAs on GaAs nanowires, higher fill factors can be achieved. Alternatively, laminated layers of nanowires could be used, in which nanowires are deposited on polymer sheets which are transparent to both the THz beam and the control beams. Multiple sheets may be laminated with the nanowire directions generally aligned, to provide a higher fill factor without the problem of overlapping nanowires. The effect of using 1 to 4 layers of nanowires is shown in Fig.7. The relative photoinduced change in transmission of the THz electric field, $\Delta E/E$, is plotted as a function of pump polarisation, immediately after photoexcitation, for a photoexcitation fluence of 20 $\mu\text{J}/\text{cm}^2$. The nanowire grid polariser was placed at an angle of 0° relative to the terahertz polarisation, and the polarisation of the pump was varied. A cosine-squared relationship with the pump polarisation, as expected from Malus's law, was fitted to the data (solid lines). As is clear from the figure, increasing the number of nanowire layers increases the modulation depth of the polariser.

[55] Further methods of forming or fabricating a polarizer plate or a layer for a polarizer plate comprising nanowires are illustrated in Figs. 8a, 8b, 9a and 9b. In a first method, a thin semiconductor wafer is provided as shown at 60 in Fig. 8a. A grid 61 is formed as shown in fig. 8b by any suitable method, for example by photolithography and etching. such as wet chemical or dry (reactive ion) etching, or alternatively through direct laser writing or ablation. The grid 61 comprises a series of lines 62 etched through the wafer 61, effectively defining a plurality of nanowires 63 supported at each end by the unetched area 64 of the wafer 61. In an alternative as shown in figs. 9a and 9b, a semiconductor film 70 is deposited on a substrate 71. The substrate 71

preferably comprises a material transparent to THz radiation and near infrared radiation, for example quartz. In a similar manner to the etching process described above, a grid 72 comprising a series of lines 73 is etched into the semiconductor film 70 through to the substrate 71, thus defining an array of nanowires 74. The nanowires 63, 74 may have any suitable dimensions. For example, the width of the nanowires may be in the range 100 nm to 20 μm , in this example about 1 μm .

[56] Accordingly, modulators and transmitters based on the polarizer plates as described herein can be used to modulate a THz beam at the modulation frequencies required by modern communication networks. The transmitters and modulators could be for wireless communication systems, or transmitted by low dispersion fibre links designed to carry THz frequencies. In addition, due to the very fast switching speeds available to laser diodes, the control beam can be modulated to provide any appropriate waveform, potentially providing a useful research tool.

[57] Although specific examples of semiconductors are given above, in general any binary, ternary or quaternary alloy of Group III-V semiconductors may be selected, or indeed any type of semiconductor. Although inorganic semiconductor nanowires are primarily discussed herein because of their relative ease of fabrication, the polarizer may also be implemented using semiconducting carbon nanotubes, and the term 'semiconducting nanowires' should be read as including semiconducting carbon nanotubes.

[58] In the above description, an embodiment is an example or implementation of the invention. The various appearances of "one embodiment", "an embodiment" or "some embodiments" do not necessarily all refer to the same embodiments.

[59] Although various features of the invention may be described in the context of a single embodiment, the features may also be provided separately or in any suitable combination. Conversely, although the invention may be described herein in the context of separate embodiments for clarity, the invention may also be implemented in a single embodiment.

[60] Furthermore, it is to be understood that the invention can be carried out or practiced in various ways and that the invention can be implemented in embodiments other than the ones outlined in the description above.

[61] Meanings of technical and scientific terms used herein are to be commonly understood as by one of ordinary skill in the art to which the invention belongs, unless otherwise defined.

CLAIMS

1. A controllable polarizer for terahertz radiation, the polarizer comprising;
a polarizer plate, the polarizer plate comprising a plurality of nanowires, and
a control element, the control element including a light source, such that the control element is operable to illuminate the polarizer to selectively photoexcite the nanowires.
2. A controllable polarizer according to claim 1 wherein the plurality of nanowires are disposed on a substrate generally transparent to terahertz radiation
3. A controllable polarizer according to claim 1 or claim 2, wherein the nanowires are generally aligned.
4. A controllable polarizer according to any one of the preceding claims wherein the nanowires comprise semiconducting nanowires.
5. A controllable polarizer according to claim 4 wherein the nanowires comprise any binary, ternary or quaternary alloy of Group III-V semiconductors.
6. A controllable polarizer according to claim 4 wherein the nanowires comprise GaAs nanowires.
7. A controllable polarizer according to claim 6 wherein the nanowires comprise GaAs – AlGaAs nanowires.
8. A controllable polarizer according to claim 4 wherein the nanowires comprise InP nanowires, InAs nanowires or InSb nanowires.
9. A controllable polarizer according to any one of claims 4 to 8 wherein the nanowires are formed by deposition, or by etching a semiconductor layer.
10. A controllable polarizer according to claim 4 wherein the semiconducting nanowires comprise semi-conducting carbon nanotubes.
11. A controllable polarizer according to any one of the preceding claims wherein the control element is operable to illuminate the polarizer plate with light having a wavelength to cause photoexcitation of the nanowires.

12. A controllable polarizer according to any one of the preceding claims wherein the control element is operable to illuminate the polarizer plate with light having an axis of polarization substantially aligned with the nanowires.
13. A controllable polarizer according to claim 12 wherein the control element comprises a control polarizer.
14. A controllable polarizer according to any one of the preceding claims wherein the light source comprises a laser diode.
15. A controllable polarizer according to any one of the preceding claims comprising a modulation element to modulate the illuminating light.
16. A modulator for terahertz radiation, the modulator comprising a controllable polarizer according to any one of the preceding claims, and

an auxiliary polarizer plate having an axis of polarization.
17. A modulator according to claim 16 wherein the axis of polarization of the auxiliary polarizer plate is orthogonal to an axis of polarization of the polarizer plate.
18. A modulator according to claim 16 or claim 17 wherein the auxiliary polarizer plate further comprises a plurality of nanowires disposed on a substrate generally transparent to terahertz radiation.
19. A modulator according to claim 18 comprising a second control element, the second control element including a second control light source, such that the control element is operable to illuminate the auxiliary polarizer plate.
20. A transmitter for terahertz radiation, the transmitter comprising,

a modulator according to any one of claims 16 to 19, and

a coherent THz source to generate an output beam of terahertz radiation,

wherein the beam passes through the polarizer plate and auxiliary polarizer plate to provide an output beam,

wherein the output beam is modulated by operation of the control element.

21. A transmitter according to claim 20 wherein the control element comprises a light source comprising a laser diode, and a laser diode controller, wherein operation of the control element comprises controlling the laser diode.
22. A transmitter according to claim 20 or claim 21 further comprising a polarization control element to control the polarization of the output beam before the beam passes through the polarizer plate and auxiliary polarizer plate.

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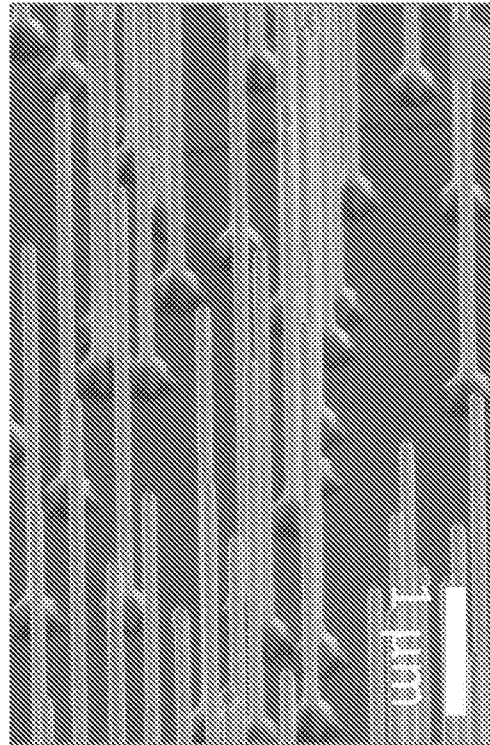


FIG.1A

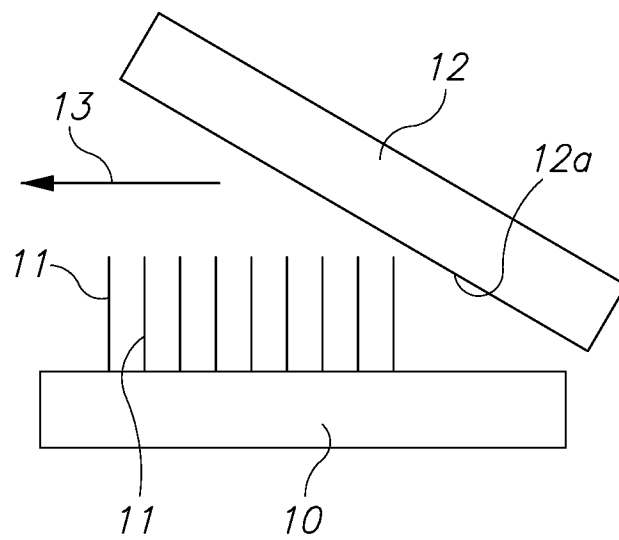


FIG.1B

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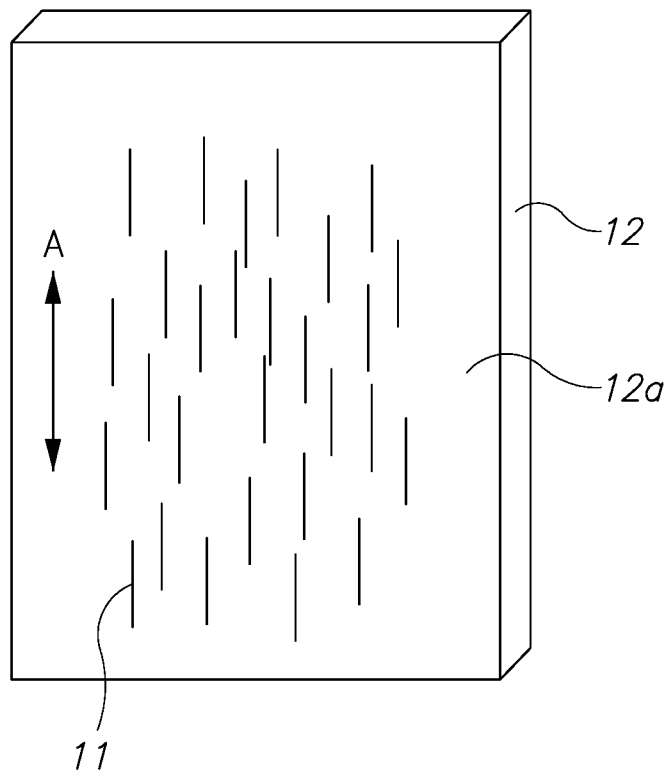


FIG.1C

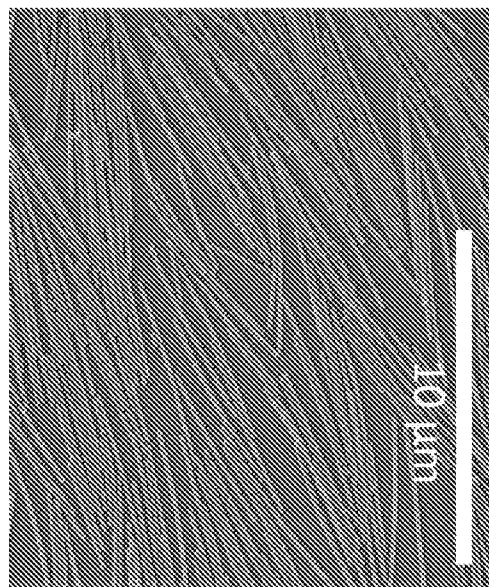


FIG.1D

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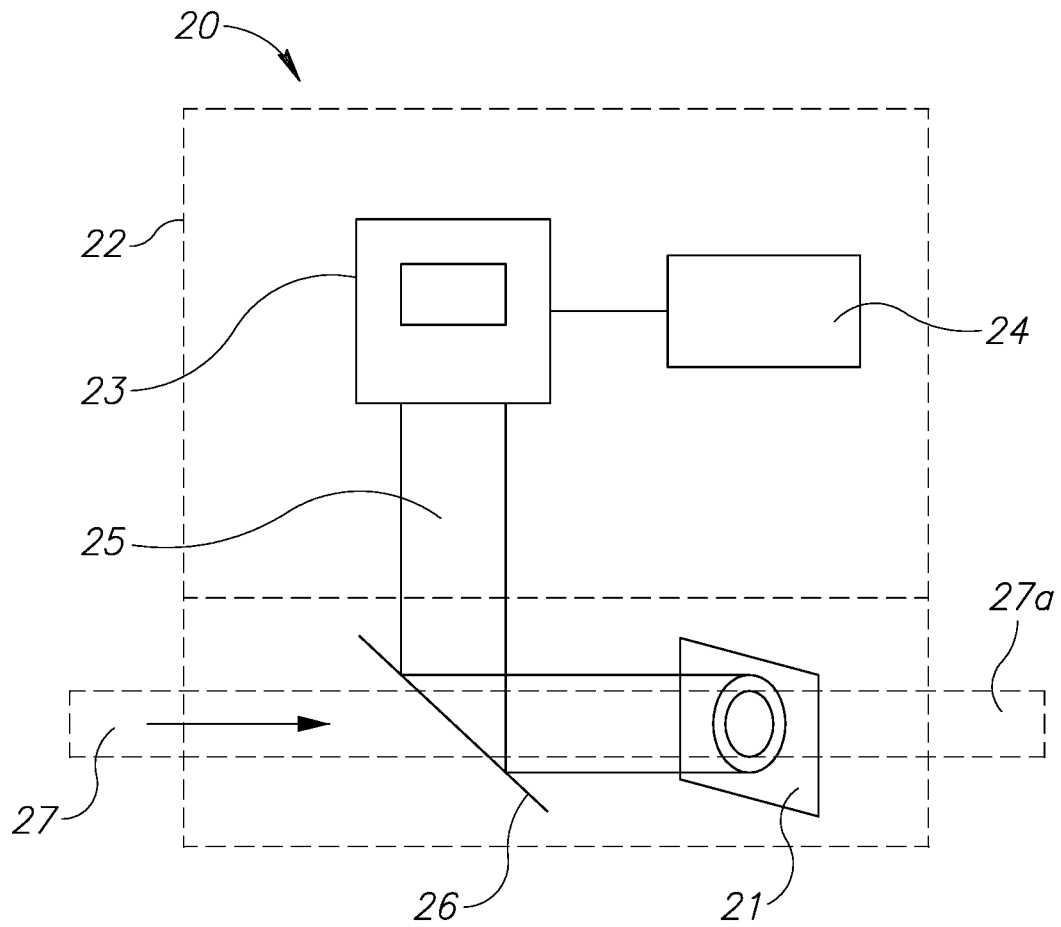


FIG.2

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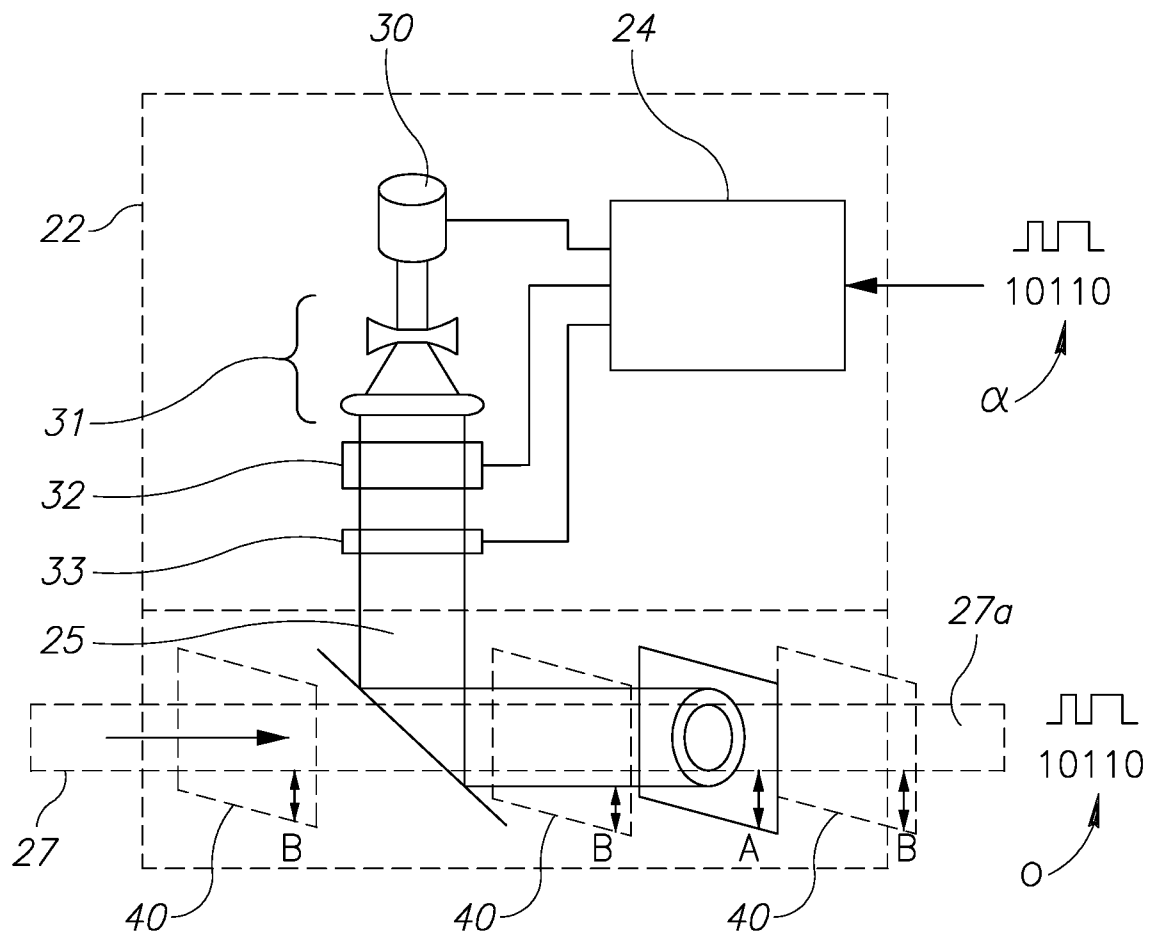


FIG.3

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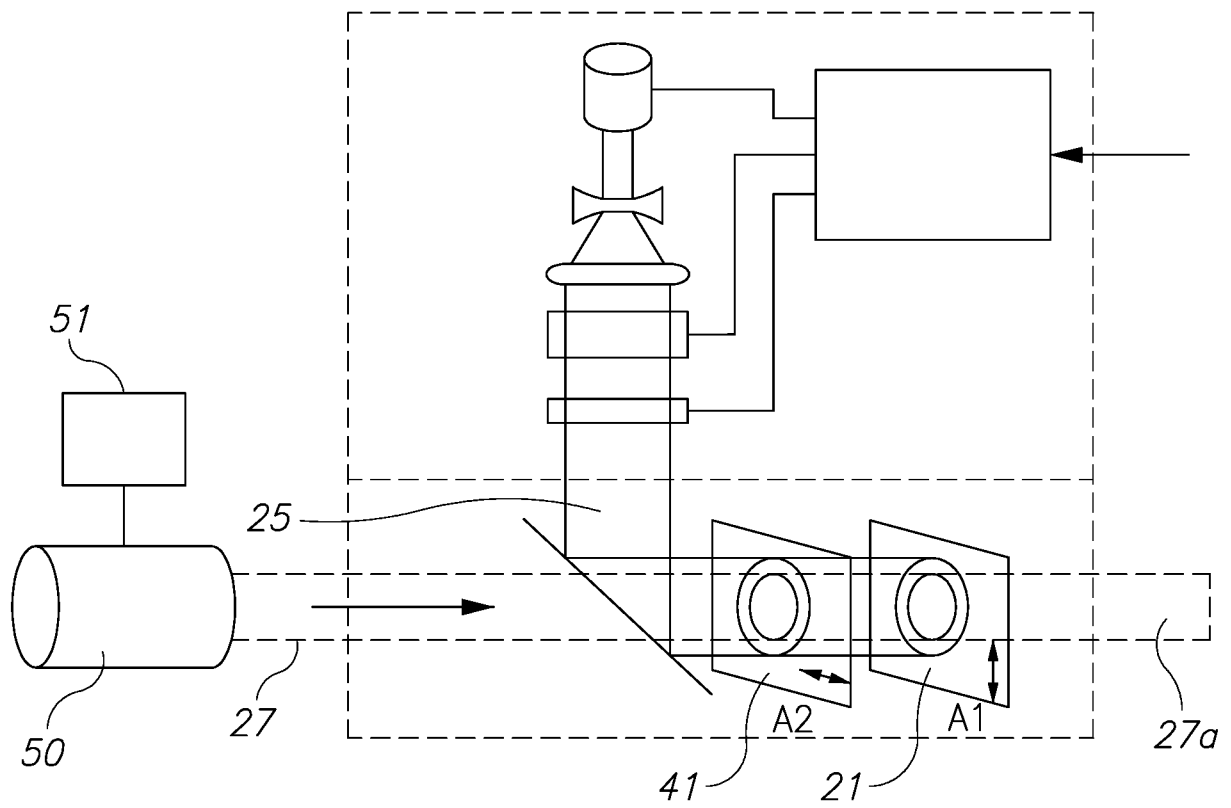


FIG.4

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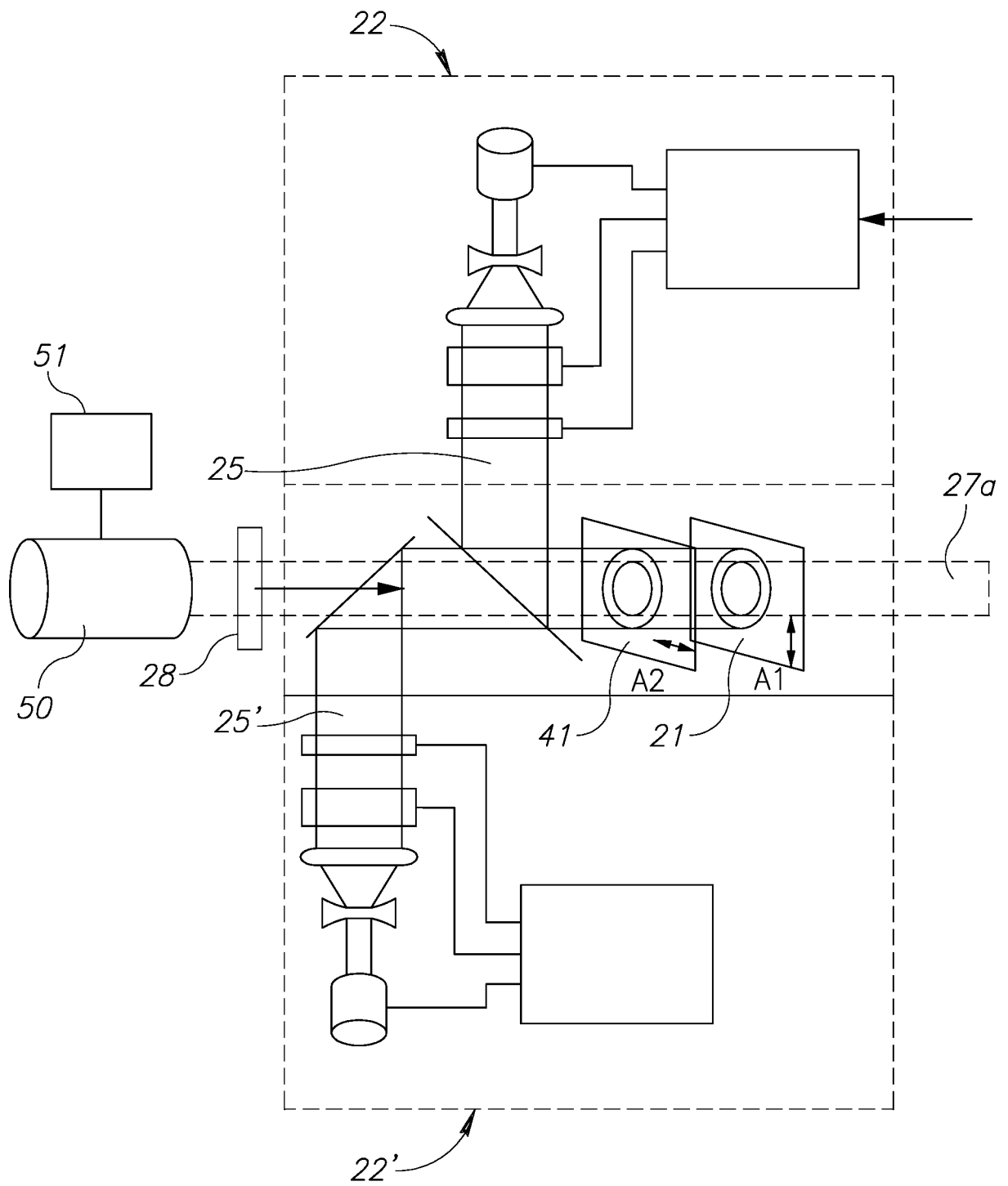


FIG.5

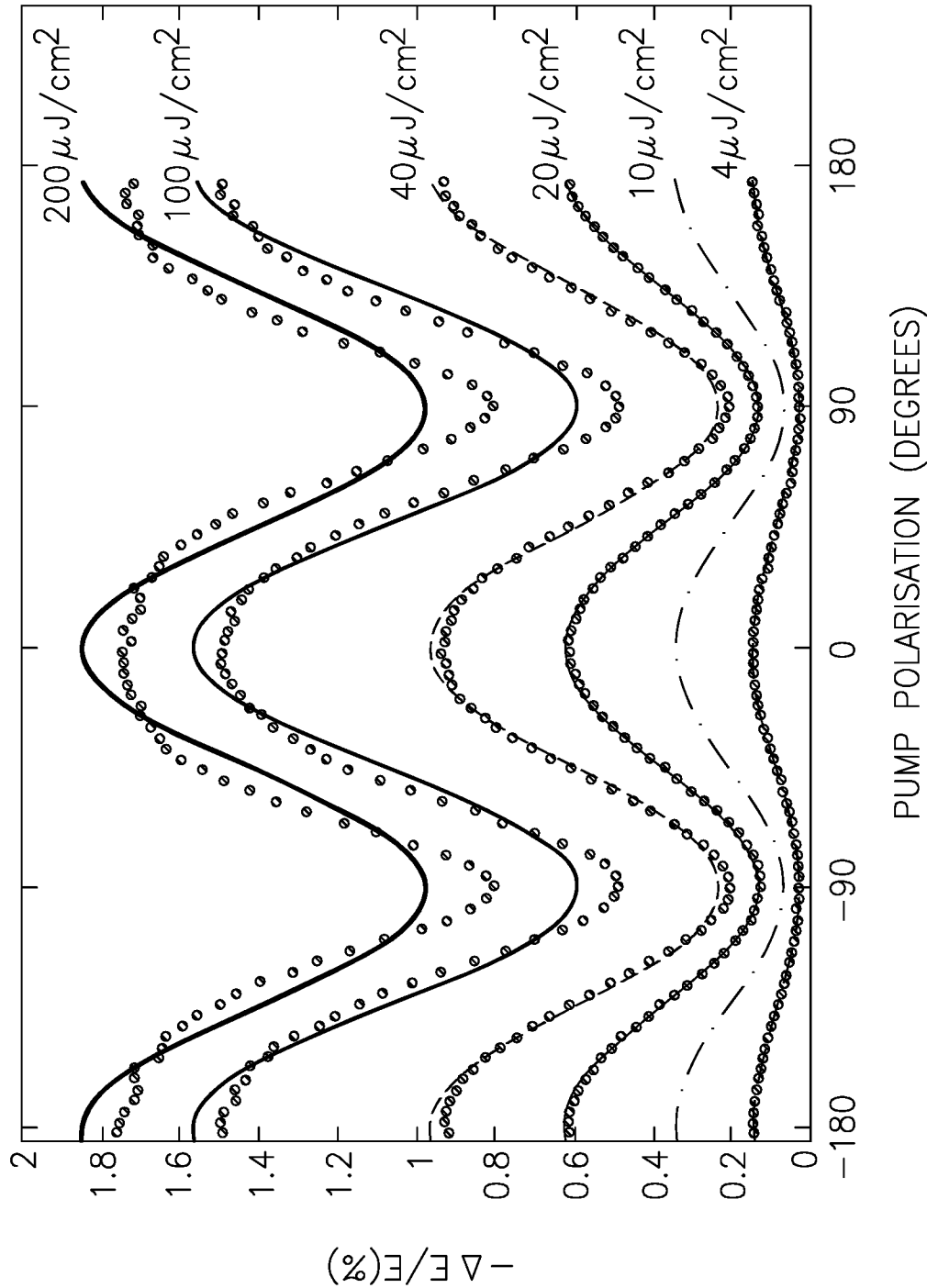


FIG.6

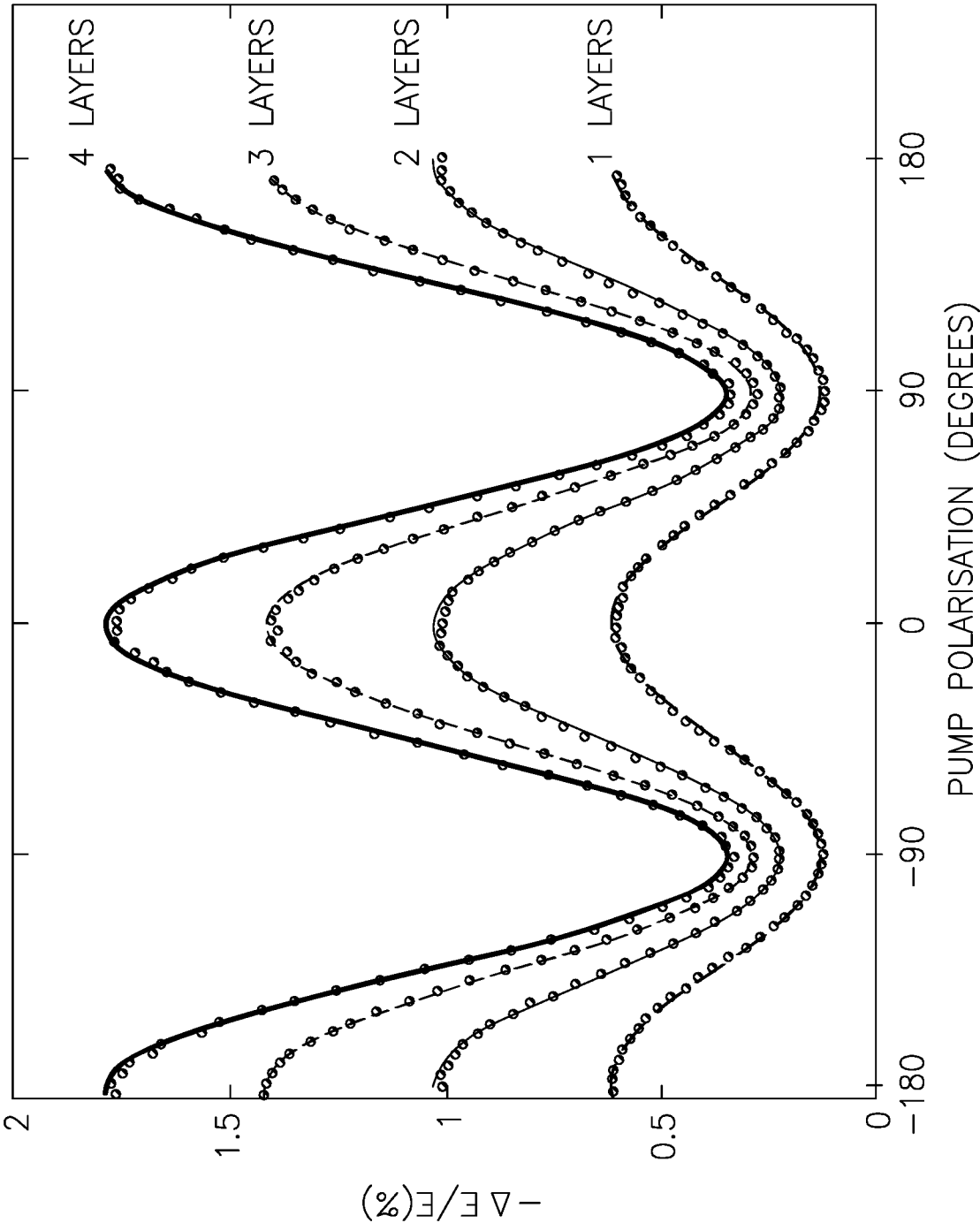


FIG.7

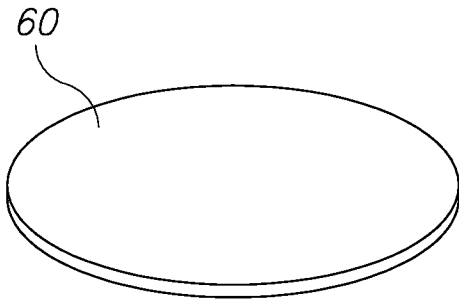


FIG. 8A

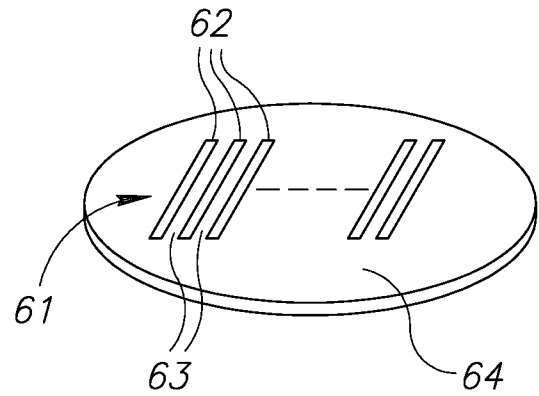


FIG. 8B

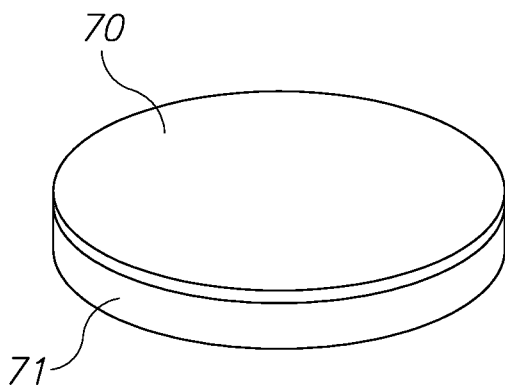


FIG. 9A

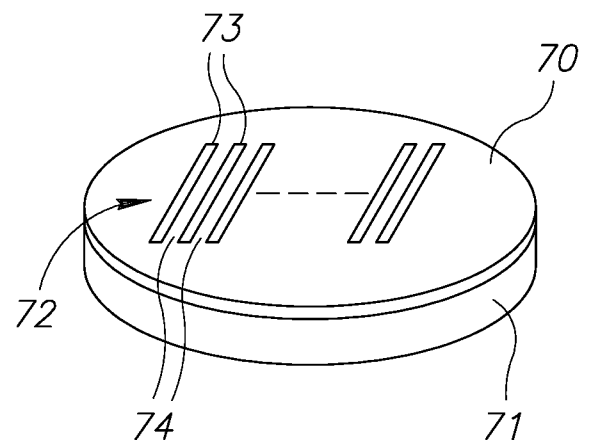


FIG. 9B

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/050779

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B5/30 G02F1/01 H01L29/06 B82Y20/00
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 G02F H01L B82Y

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	HONG LU ET AL: "Self-Assembled ErSb Nanostructures with Optical Applications in Infrared and Terahertz", NANO LETTERS, vol. 14, no. 3, 8 November 2013 (2013-11-08), pages 1107-1112, XP055180324, ISSN: 1530-6984, DOI: 10.1021/nl402436g page 1107, column 1, paragraph 1 - page 1111, column 2, paragraph 1 ----- -/--	1-22



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)

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"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

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Date of the actual completion of the international search

31 March 2015

Date of mailing of the international search report

09/04/2015

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Authorized officer

Szachowicz, Marta

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2015/050779

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LEI REN ET AL: "Broadband Terahertz Polarizers with Ideal Performance Based on Aligned Carbon Nanotube Stacks", NANO LETTERS, vol. 12, no. 2, 8 February 2012 (2012-02-08), pages 787-790, XP055180250, ISSN: 1530-6984, DOI: 10.1021/nl203783q page 787, column 1, paragraph 1 - page 789, column 2, paragraph 2 -----	1-22
X	QIAOQIANG GAN ET AL: "Wavelength-Independent Optical Polarizer Based on Metallic Nanowire Arrays", IEEE PHOTONICS JOURNAL, IEEE, USA, vol. 3, no. 6, 1 December 2011 (2011-12-01), pages 1083-1092, XP011485154, ISSN: 1943-0655, DOI: 10.1109/JPHOT.2011.2173478 page 1083, line 1 - page 1084, line 18 page 1088, paragraph 5 - page 1091, line 23 -----	1-16,22
A	US 2010/147674 A1 (KRIVOSHLYKOV SERGEI [US]) 17 June 2010 (2010-06-17) paragraph [0045] paragraph [0062] - paragraph [0081] claims 1, 16 -----	1-22
A	US 6 563 622 B2 (MUELLER ERIC R [US] ET AL) 13 May 2003 (2003-05-13) the whole document -----	1-22
A	AU 2012 201 641 A1 (NANOCOMP TECHNOLOGIES INC) 5 April 2012 (2012-04-05) paragraph [0074] - paragraph [0078] -----	1-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2015/050779

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010147674	A1	17-06-2010	NONE

US 6563622	B2	13-05-2003	US 2002036814 A1 28-03-2002
			WO 0215416 A2 21-02-2002

AU 2012201641	A1	05-04-2012	NONE
