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[Continued on next page]

(54) **Title:** DETECTION APPARATUS FOR DETECTING ELECTROMAGNETIC WAVE PASSED THROUGH OBJECT

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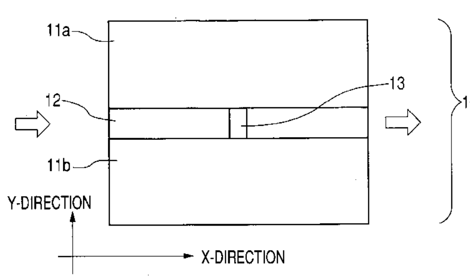

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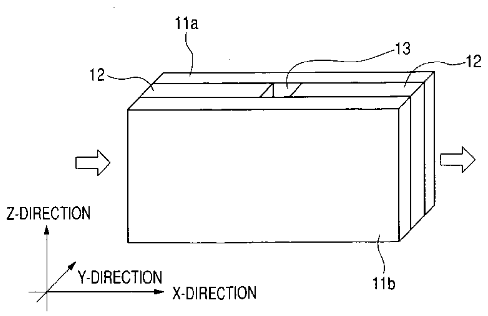

(57) Abstract: ABSTRACT A detection apparatus for detecting an electromagnetic wave passed through an object is provided which includes a transmission line for transmitting an electromagnetic wave therethrough and a detector for detecting an electromagnetic wave passed through an object, wherein the transmission line has a gap for disposing the object therein.

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DESCRIPTION

DETECTION APPARATUS FOR DETECTING ELECTROMAGNETIC WAVE PASSED THROUGH OBJECT

TECHNICAL FIELD

The present invention relates to a technique for detecting a change in propagation state of an electromagnetic wave passed through an object to be inspected or examined (hereinafter, simply referred to as "object"), and more particularly to a detection apparatus for detecting a change in propagation state of an electromagnetic wave passed through an object to perform measurement, sensing and/or analysis of the object.

BACKGROUND ART

In recent years, attention has been focused on a technique using the so-called terahertz-wave. A spectral analysis using the terahertz-wave, imaging using the terahertz-wave, and the like have been expected for industrial applications.

For example, techniques now under development in application fields of the terahertz-wave include an imaging technique using a safe fluoroscopic apparatus alternative to an X-ray apparatus, a spectral technique for obtaining an absorption spectrum or complex dielectric constant of a substance to examine a bonding state therein, a technique for analyzing biomolecules, a technique for estimating a carrier concentration or mobility.

Of the techniques, as a method of spectroscopically analyzing a substance using the terahertz-wave, there has been known a method of irradiating a substance to be analyzed with the terahertz-wave to obtain a spectrum of a transmitted or reflected terahertz-wave.

Meanwhile, water has a number of very strong absorption spectrums in a frequency range of 30 GHz to 30 THz. Therefore, the terahertz-wave is almost shielded by, for example, a container with a thickness of 1 mm containing liquid water. Thus, it is relatively difficult to obtain an information of a substance contained in water by means of a terahertz-wave passed through the water.

Therefore, as a method of determining an absorption spectrum or complex dielectric constant of a substance such as water having a strong absorption spectrum band within the terahertz range or molecules contained in such a substance, there has been known a method using an evanescent wave of a terahertz-wave which is generated in total reflection in a prism, as disclosed in "Extended Abstracts, The 51st Spring Meeting, 2004, The Japan Society of Applied Physics and Related Societies, 28p-YF-7". In this method, a terahertz-wave emitted from a terahertz-wave generator is made incident on a first surface of a prism and totally reflected by a second surface the prism. Then, a terahertz-wave exited from a third surface of the prism is detected by a detector, and a sample is disposed on the second surface so as to interact with an evanescent wave of the terahertz-wave which is generated upon the total reflection of the terahertz-wave by the second surface, thereby spectroscopically analyzing the sample. According to this method, it is possible to analyze a sample in a form of solid, powder, liquid, or the like. However, because the method disclosed in "Extended Abstracts, The 51st Spring Meeting, 2004, The Japan Society of Applied Physics and Related Societies, 28p-YF-7" uses a spatial optical system, system size reduction as well as optical adjustment is difficult.

DISCLOSURE OF INVENTION

It is, therefore, an object of the present invention to provide a detection apparatus which is capable of easy system size reduction and optical adjustment.

According to a first aspect of the present invention, there is provided a detection apparatus for detecting an electromagnetic wave passed through an object, comprising a transmission line for transmitting an electromagnetic wave therethrough; and a detector for detecting an electromagnetic wave passed through an object, wherein the transmission line has a gap for disposing the object therein.

According to a second aspect of the present invention, there is provided a detection method of detecting an electromagnetic wave passed through an object, comprising the steps of disposing an object in a gap of a transmission line for transmitting an electromagnetic wave therethrough; and detecting an electromagnetic wave passed through the object.

According to a third aspect of the present invention, there is provided a transmission line for transmitting an electromagnetic wave therethrough, for use in a detection apparatus for detecting an electromagnetic wave passed through an object, comprising a gap for disposing an object in the transmission line.

According to the present invention, system size reduction and easy optical adjustment can be realized.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIGS. 1A and 1B are schematic views showing a detection apparatus in accordance with a preferred embodiment of the present invention, and FIG. 1A is a plan view and FIG. 1B is a perspective view;

FIG. 2 is a schematic diagram showing a detection apparatus in accordance with a preferred embodiment of the present invention;

FIGS. 3A, 3B, and 3C are schematic graphical representations each showing a change in state of an electromagnetic wave obtained by a detection apparatus in accordance with a preferred embodiment of the present invention;

FIG. 4 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention;

FIG. 5 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention;

FIGS. 6A and 6B are schematic views showing a detection apparatus in accordance with a preferred embodiment of the present invention, and FIG. 6A is a plan view and FIG. 6B is a front view;

FIG. 7 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention;

FIG. 8 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention;

FIG. 9 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention; and

FIG. 10 is a schematic perspective view showing a detection apparatus in accordance with a preferred embodiment of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Hereinafter, preferred embodiments of the present invention will be more specifically described.

It is preferable that a transmission line for guiding a terahertz-wave have a flow path through which a flowable substance such as liquid or powder can be introduced. Any path capable of disposing an objective substance to be inspected or examined (hereinafter, simply referred to as "object substance") in the transmission line may be used. It is preferable that the flow path is not parallel to a propagation direction of an electromagnetic wave and is provided so as to pass through a region of the transmission line in which the electromagnetic wave is strongly distributed. By utilizing the phenomenon that the terahertz-wave guided through the transmission line and the flowable substance in the flow path interact with each other to change the propagation state of the terahertz-wave passed through the flowable substance, and by comparing propagation states of the terahertz-wave before and after introduction of the flowable substance into the flow path with each other, the physical properties of the flowable substance can be examined or the substance can be identified, for example.

Even for a substance having a terahertz-wave absorbing characteristic such as water, by designing such that the thickness of the flow path in the propagation direction of the terahertz-wave is small, the terahertz-wave can pass through a sample of such substance.

When a waveguide is used as the transmission line, a gap may be provided at a part of a cladding and a core which compose the waveguide to thereby form a flow path. When a metallic waveguide tube is used as the transmission line, a pipe-shaped hollow member made of a dielectric may be provided in a cavity of a waveguide tube composing the metallic waveguide tube to thereby form a flow path. When a waveguide tube used is filled with a dielectric, a gap may be provided in a portion of the dielectric to thereby form a flow path. When a transmission cable is used as the transmission line, a gap may be provided at a part of a dielectric portion between a ground cable and a signal cable which compose the transmission cable to thereby form a flow path.

When a metallic waveguide tube used as the transmission line has a cavity therein, a pipe-shaped hollow member made of a dielectric can be provided in the cavity to thereby form a flow path. In such a case, it is desirable that the pipe-shaped hollow member constituting the flow path is a dielectric with a low loss, a low dispersion and a low refractive index. Further, when a metallic waveguide tube is internally filled with a dielectric and a gap is provided in a portion of the dielectric to thereby form a flow path, it is desirable that the dielectric has a low loss, a low dispersion and a low refractive index. By forming such a flow path, even when only a small amount of sample is obtained, measurement can be performed. Further, by forming a flow path so as to be shielded from outside air, it is possible to sense a substance which is susceptive to outside air.

A terahertz-wave may be coupled from the outside into a transmission line, while a terahertz-wave generator may be integrated in a portion of a transmission line. For example, when a waveguide or a waveguide tube is used, a terahertz-wave generator may be integrated at an end surface of the waveguide or the waveguide tube. When a transmission cable is used, a terahertz-wave generator may be integrated on the transmission cable. Further, similarly, a terahertz-wave propagating through a transmission line may be radiated outside and detected by a terahertz-wave detector, while a terahertz-wave detector may be integrated in a portion of a transmission line. In such a case, there are advantages that the terahertz-wave is not influenced by moisture in air, optical adjustment is unnecessary, and size reduction can be realized.

Examples of the terahertz-wave generator and terahertz-wave generating method include a method of applying a voltage to a photoconductive antenna formed on gallium arsenide formed by a low-temperature growth method and irradiating a femtosecond laser light thereto. Examples of integration of a terahertz-wave generator include a method in which such a photoconductive antenna as mentioned above is provided on, for example, an end surface of a waveguide tube. Further, examples of the terahertz-wave detector include one utilizing a method of irradiating a femtosecond laser light to a photoconductive antenna without applying a voltage thereto and measuring a current. As another example of the integration of a terahertz-wave detector, the above-mentioned photoconductive antenna may be provided on an end surface of a waveguide tube from which a terahertz-wave is exited. Thereby, sensing can be performed with a terahertz-wave being not influenced by moisture in air.

Moreover, there may be employed a method in which an EO crystal having an electrooptic effect (such as ZnTe) is provided on an end surface from which a terahertz-wave is exited, and the crystal orientation of the EO crystal and the polarization direction of the terahertz-wave are suitably selected, thereby utilizing a phenomenon in which the reflectance and refractive index of the EO crystal are changed with polarization dependence.

In addition, as another example of integration method of a terahertz-wave generator, a nonlinear substance (such as DAST crystal) may be provided inside or at an end surface of a waveguide tube or waveguide.

Further, when it is necessary to take a sample at a separate position as in the case of, for example, blood, by connecting a sampling tool (such as a needle for syringe) as means for obtaining an object and the flow path as connecting means for connecting the obtained object to a path through another flow path (such as a tube), the sample can be set at a predetermined position simultaneously with sampling. In addition, because an area of the sample in the flow path which is in contact with outside air is small, such configuration is advantageous in the case where a sample susceptible to outside air is to be measured.

When specific (one or more kinds of) particles or molecules contained in a flowable sample is to be sensed, by introducing the flowable sample from one end of a flow path and providing on the other end thereof a filter (for example, a semipermeable membrane) which does not allow passing of the specific particles or molecules but allows passing of other flowable substances (such as water), sensing can be performed while increasing the concentration of the specific particles or molecules in a sensing portion. This method makes it possible to successively or simultaneously perform sample concentration and sensing, and is therefore advantageous for improving working efficiency.

Moreover, by disposing on a wall surface of a flow path a substance which absorbs or is bonded to specific (one or more kinds of) particles or molecules contained in a flowable substance, and by capturing the specific particles or molecules on the wall surface of the flow path, it is possible to sense a flowable sample and particles or molecules contained therein based on a change in the complex dielectric constant or absorption spectrum of the substance disposed on the wall surface of the flow path resulting from the absorption or bonding of the particles or molecules.

Moreover, as the electromagnetic wave, it is preferable to use an electromagnetic wave including an arbitrary component in a frequency range of 30 GHz to 30 THz.

Hereinafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings.

(First Embodiment)

A first embodiment of the present invention will be described with reference to FIGS. 1A, 1B, and FIG. 2. A parallel plate waveguide 10 has a structure in which a polystyrene plate 12 is interposed between metallic plates 11a, 11b. The polystyrene plate 12 has a gap 13 provided therein. The interval between the opposed surfaces of the metallic plates 11a, 11b is about 100 μm. A typical size of each of the metallic plates 11a, 11b is about 10 mm to 20 mm in each of x-direction and z-direction. The gap 13 is about 50 μm in x-direction. A flowable sample such as a fluid can be introduced into the gap 13. In this embodiment, the interval between the metallic plates 11a, 11b is set to 100 μm. However, the present invention is not limited thereto. Further, although polystyrene is used for the member interposed between the metallic plates 11a, 11b, the present invention is not limited thereto. For the member interposed between the metallic plates 11a, 11b, any other dielectric (resin or semiconductor) may be used as long as it is sufficiently small in absorption (loss) and dispersion with respect to the terahertz-wave. Moreover, it is desirable that the refraction index is close to 1. Further, a semiconductor having a high conductivity may be used instead of the metallic plates 11a, 11b.

In FIGS. 1A and 1B, a terahertz-wave enters the parallel plate waveguide 10 in a direction indicated by the left-hand arrow in the figures and exits from the parallel plate waveguide 10 in a direction indicated by the right-hand arrow in the figures. The terahertz-wave propagating through the parallel plate waveguide 10 interacts with a flowable sample introduced into the gap 13. By utilizing the phenomenon that the spectrum or propagation state of the terahertz-wave passed through the parallel plate waveguide 10 changes before and after the introduction of the flowable sample into the gap 13, the flowable substance can be measured, sensed, or analyzed.

Hereinafter, an entire sensing system will be described with reference to FIG. 2. A laser light having a pulse width of about 100 fs (femtoseconds) emitted from a femtosecond laser 20 is split by a beam splitter 21 into two optical paths, one of which is irradiated onto a biased gap portion of a photoconductive antenna 22a made of low-temperature grown GaAs (LT-GaAs) or the like to generate terahertz-wave pulses 27 (a hemispherical lens made of high-resistance Si or the like being in close contact with a rear surface of the photoconductive antenna). The terahertz-wave pulses 27 are reflected by a parabolic mirror 23a, pass through a semicylindrical lens 24a made of high-resistance Si (for example, 10 kΩ·cm) or the like and are coupled to the parallel plate waveguide 10 at a first end of the parallel plate waveguide 10. The terahertz-wave pulses interact with the sample (not shown) introduced into the gap 13 of the parallel plate waveguide 10 and are then exited from a second end of the parallel plate waveguide 10 and reach a photoconductive antenna 22b through a semicylindrical lens 24b and a parabolic mirror 23b. On the other hand, the other component of the laser light as split by the beam splitter 21 passes through a time delay device 26, is reflected by a mirror 25 and reaches the photoconductive antenna 22b simultaneously with the arrival of the terahertz-wave pulses. At this time, by shifting the timing of the laser light beam reaching the photoconductive antenna 22b through the time delay device 26 and the timing of the terahertz-wave pulses reaching the photoconductive antenna 22b through the parallel plate waveguide 10 from each other by use of the time delay device 26, the waveform of the terahertz-wave pulse can be obtained. When the femtosecond laser light beam passing through the time delay device 28 is irradiated to the photoconductive antenna 22b, a current flows through the photoconductive antenna 22b for a period which corresponds to the pulse time width of the femtosecond laser and a carrier life of a semiconductor film constituting the photoconductive antenna 22b. The magnitude of the current at this time reflects the magnitude of electric field amplitude of the terahertz-wave pulse 27 incident on the photoconductive antenna 22b. Therefore, measuring the current that flows through the photoconductive antenna makes it possible to obtain the waveform of the terahertz-wave pulse 27, which is then subjected to Fourier transform to give a spectrum of the terahertz-wave pulse 27.

The parallel plate waveguide can transmit an electromagnetic wave in a TEM mode. Therefore, when no sample exists in the gap 13, the terahertz-wave pulses 27 propagate through the parallel plate waveguide 10 without changing the pulse waveform before and after the parallel plate waveguide 10. That is, when no sample exists in the gap 13, the waveform of the terahertz-wave pulse 27 before incidence on the parallel plate waveguide 10 and the waveform of the terahertz-wave pulse 27 after passing through the parallel plate waveguide 10 are substantially similar to each other.

Because the gap 13 has such a sufficiently small thickness as about 50 μm in the x-direction, even when the gap 13 is filled with a sample which well absorbs the terahertz-wave, such as water, the terahertz-wave pulses propagating through the parallel plate waveguide 10 can pass through the gap 13 without being completely absorbed.

Next, a measurement example in this embodiment will be specifically described with reference to FIGS. 3A, 3B, and 3C. FIGS. 3A, 3B, and 3C are schematic graphical representations showing spectrums of the terahertz-wave which are obtained in the embodiment of the present invention. First, in a state in which a flowable sample is not introduced into the gap 13 as shown in FIGS. 1A and 1B, the waveform of the terahertz-wave passing through the parallel plate waveguide 10 is recorded and subjected to Fourier transform to obtain a power spectrum 30 (FIG. 3A). Next, in a state in which a flowable sample is introduced into the gap 13, the waveform of the terahertz-wave passed through the parallel plate waveguide 10 is recorded and subjected to Fourier transform to obtain a power spectrum 31 (FIG. 3B). By determining the ratio between the power spectrums 30 and 31, an absorption spectrum 32 of the flowable sample to the terahertz-wave is obtained (FIG. 3C).

In this method, the volume of the gap 13 is sufficiently small and only a slight amount of sample is required. Therefore, this method is advantageous in the case where an expensive sample (for example, a solution containing an antibody) is to be examined.

Further, in this embodiment, the terahertz-wave pulse generation has been described by taking as an example a method using a photoconductive antenna. However, there may also be used other methods such as a method of radiating a nonlinear crystal with a femtosecond laser light or a method using parametric oscillation. Moreover, as the detection method, there may also be used, for example, a known method using an electrooptic crystal.

(Second Embodiment)

A second embodiment of the present invention will be described with reference to FIGS. 4 and 5. In the second embodiment of the present invention, as shown in FIG. 4, photoconductive antennas 33a, 33b are provided in both ends of the parallel plate waveguide 10. However, in this embodiment, unlike the first embodiment, a hemispherical lens made of high-resistance Si or the like is not in close contact with the photoconductive antennas 33a, 33b. In this case, it is unnecessary to perform optical axis alignment of the terahertz-wave spatial propagation optical system, so that the size reduction of the system can be attained.

The photoconductive antennas 33a, 33b each typically has a substrate with a size of about several millimeters to one centimeter in each of the y- and z-directions and are each provided with an antenna pattern (not shown) on its outer surface. Typical sizes of the metallic plates 11a, 11b, the polystyrene plate 12, and the gap 13 are identical to those described in the first embodiment. When the length (thickness) of each of the metallic plates 11a, 11b in the y-direction is set to about 5 or more millimeters, the photoconductive antennas 22a, 22b can be provided in both ends of the parallel plate waveguide 10.

Alternatively, as shown in FIG. 5, a photoconductive antenna 33a and an EO crystal 34 which is a substance having an electrooptic effect (such as ZnTe) may be provided in the respective ends of the parallel plate waveguide 10. In this case, the terahertz-wave is detected using a known technique of utilizing a phenomenon in which when a terahertz-wave generated by irradiating a femtosecond laser to the photoconductive antenna 33a passes through the gap 13 and then reaches the EO crystal 34, the reflectance of the EO crystal 34 to the laser light varies depending on a wave amplitude of the reached terahertz-wave, thereby obtaining the amplitude of the terahertz-wave.

Alternatively, a nonlinear optical crystal such as a DAST crystal or InP may be provided at an end of the parallel plate waveguide 10 instead of the photoconductive element 33a. In this case, irradiating such a nonlinear optical crystal directly with a femtosecond laser generates a terahertz-wave.

(Third Embodiment)

A third embodiment of the present invention will be described with reference to FIGS. 6A and 6B. The detection apparatus in accordance with this embodiment has a structure in which a hollow member 40 made of a substance with less absorption/loss and dispersion to the terahertz-wave, such as polystyrene is interposed between metallic plates 11a, 11b composing the parallel plate waveguide 10. With this structure, for example, when an end of the hollow member 40 is connected to a tube 41 and another end of the tube 41 is connected to a needle for syringe 42, blood is sampled from a human body and simultaneously introduced into the waveguide, so that a terahertz transmission spectrum of the blood can be easily obtained.

With this embodiment, it is possible to successively perform the sampling of a flowable sample and the measurement, sensing, and analysis of the sample.

(Fourth Embodiment)

A fourth embodiment of the present invention will be described with reference to FIGS. 7 and 8. In the fourth embodiment, a waveguide tube whose section is square or circular is used instead of the parallel plate waveguide. As shown in FIG. 7, a hollow member 40 for flowable sample introduction is provided in a waveguide tube 50 having a square section. A typical size of the section of the square waveguide tube is 100 μm to 200 μm in each of the y- and z-directions. When such a waveguide tube is used, there is an advantage that size reduction can be realized as compared with the case where the parallel plate waveguide is used.

Further, a gap capable of introducing a flowable sample may be provided between a signal cable and a ground cable of a transmission cable. As shown in FIG. 8, a flow path 63 is provided between a signal cable 61 and a ground cable 62 of a transmission cable 60 (microstrip line in the example shown in the figure). When the flow path is provided in the transmission cable, the sample introducing flow path and the terahertz-waveguide portion (transmission cable) can be integrally formed on the same substrate, so that further size reduction can be realized.

(Fifth Embodiment)

A fifth embodiment of the present invention will be described with reference to FIG. 9. In a parallel plate waveguide 10 having a gap 13 such as described in the first embodiment, a filter 14 is provided in a portion of the gap 13. In FIG. 9, a metallic plate 11b as illustrated in FIGS. 1A and 1B is omitted for convenience of description. In the figure, a terahertz-wave enters the parallel plate waveguide 10 in a direction indicated by the left-hand arrow and exits from the parallel plate waveguide 10 in a direction indicated by the right-hand arrow. Here, it is assumed that an end of the gap 13 at which the filter 14 is provided is a first end of the gap 13 and an end opposed to the first end is a second end of the gap 13. For example, when a certain type of protein contained in body fluid is to be sensed, a filter (for example, a semipermeable membrane) which allows passing of water but does not allow passing of the certain type of protein is provided. When the body fluid is continuously flown into the gap 13 from the second end, the concentration of the certain type of protein in the gap 13 increases, so that a transmission spectrum of the certain type of protein can be measured at a high sensitivity with a high precision.

With this structure, sample concentration increase and sensing can be performed in the same portion, so that it is possible to omit work such as sample transfer.

(Sixth Embodiment)

A sixth embodiment of the present invention will be described with reference to FIG. 10. In a parallel plate waveguide 10 having a gap 13 such as described in the first embodiment, a first substance 15 (e.g., biotin) which is specifically bonded to or absorbs a given substance in a solution is applied to the inner surface of the gap 13. In FIG. 10, a metallic plate 11b as illustrated in FIGS. 1A and 1B is omitted for convenience of description. In the figure, a terahertz-wave enters the parallel plate waveguide 10 in a direction indicated by the left-hand arrow and exits from the parallel plate waveguide 10 in a direction indicated by the right-hand arrow. A solution containing a second substance (e.g., avidin; not shown) which is specifically bonded to the first substance 15 is flown into the gap 13. The second substance in the solution is bonded to the first substance 15 applied to the inner surface of the gap 13, so that a complex dielectric constant and an absorption spectrum of the first substance 15 in the frequency range of the terahertz-wave are changed, based on which the second substance can be sensed at a high sensitivity. With this structure, in addition to the high-sensitivity sensing of a given substance, it is possible to distinguish between a substance which is non-specifically absorbed to the substance 15 and a substance which is specifically absorbed to the substance 15 based on the spectrum of the transmitted terahertz-wave.

As many apparently widely different embodiments of the present invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the claims.

This application claims priority from Japanese Patent Application No. 2004-376370 filed on December 27, 2004, the entire content of which is hereby incorporated by reference herein.

CLAIMS

1. A detection apparatus for detecting an electromagnetic wave passed through an object, comprising:

a transmission line for transmitting an electromagnetic wave therethrough; and

a detector for detecting an electromagnetic wave passed through an object,

wherein the transmission line has a gap for disposing the object therein.

2. The detection apparatus according to claim 1, wherein the transmission line comprises a waveguide, a waveguide tube, or a transmission cable.

3. The detection apparatus according to claim 1, wherein the gap comprises a flow path for introducing the object into the transmission line.

4. The detection apparatus according to claim 1, which comprises the detector in plurality.

5. The detection apparatus according to claim 1, further comprising means for obtaining the object.

6. The detection apparatus according to claim 1, further comprising a generating means for generating the electromagnetic wave.

7. The detection apparatus according to claim 1, wherein the electromagnetic wave includes an arbitrary component in a frequency range of 30 GHz to 30 THz.

8. A detection method of detecting an electromagnetic wave passed through an object, comprising the steps of:

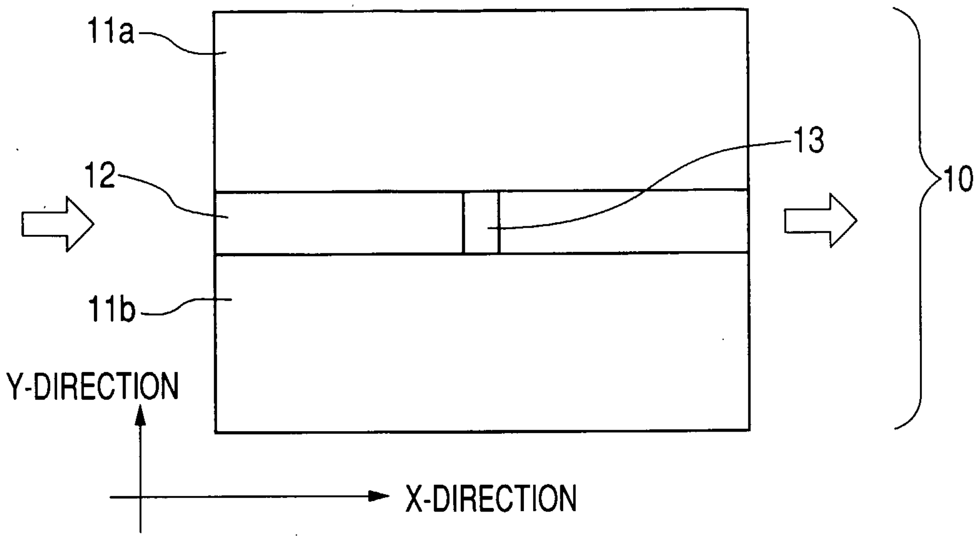
disposing an object in a gap of a transmission line for transmitting an electromagnetic wave therethrough; and

detecting an electromagnetic wave passed through the object.

9. The detection method according to claim 8, further comprising the step of generating an electromagnetic wave.

10. A transmission line for transmitting an electromagnetic wave therethrough, for use in a detection apparatus for detecting an electromagnetic wave passed through an object, the transmission line comprising a gap for disposing an object therein.

FIG. 1A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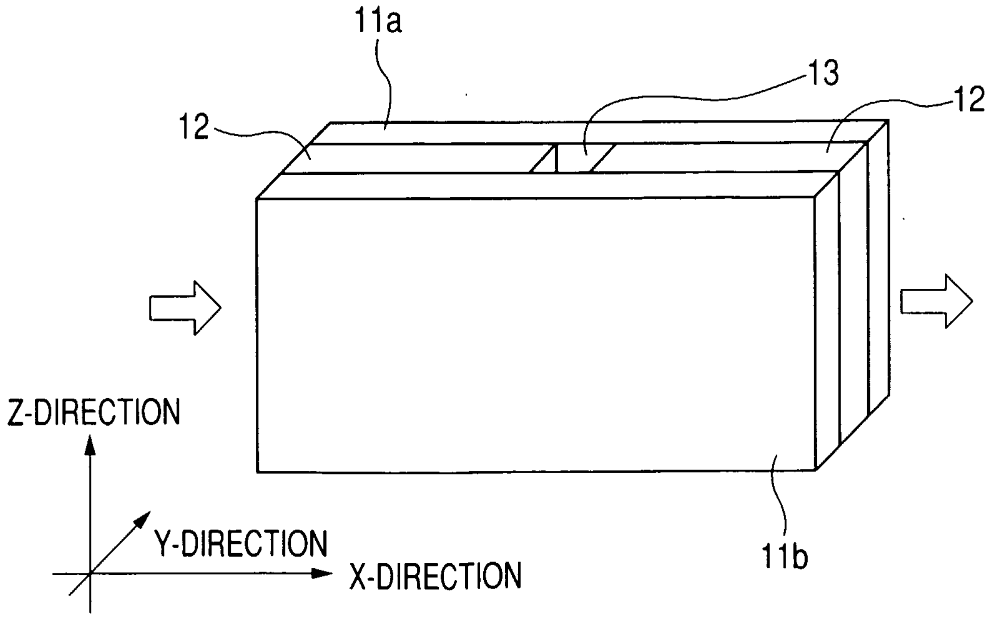
13
10
11b
Y-DIRECTION
X-DIRECTION

FIG. 1B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13
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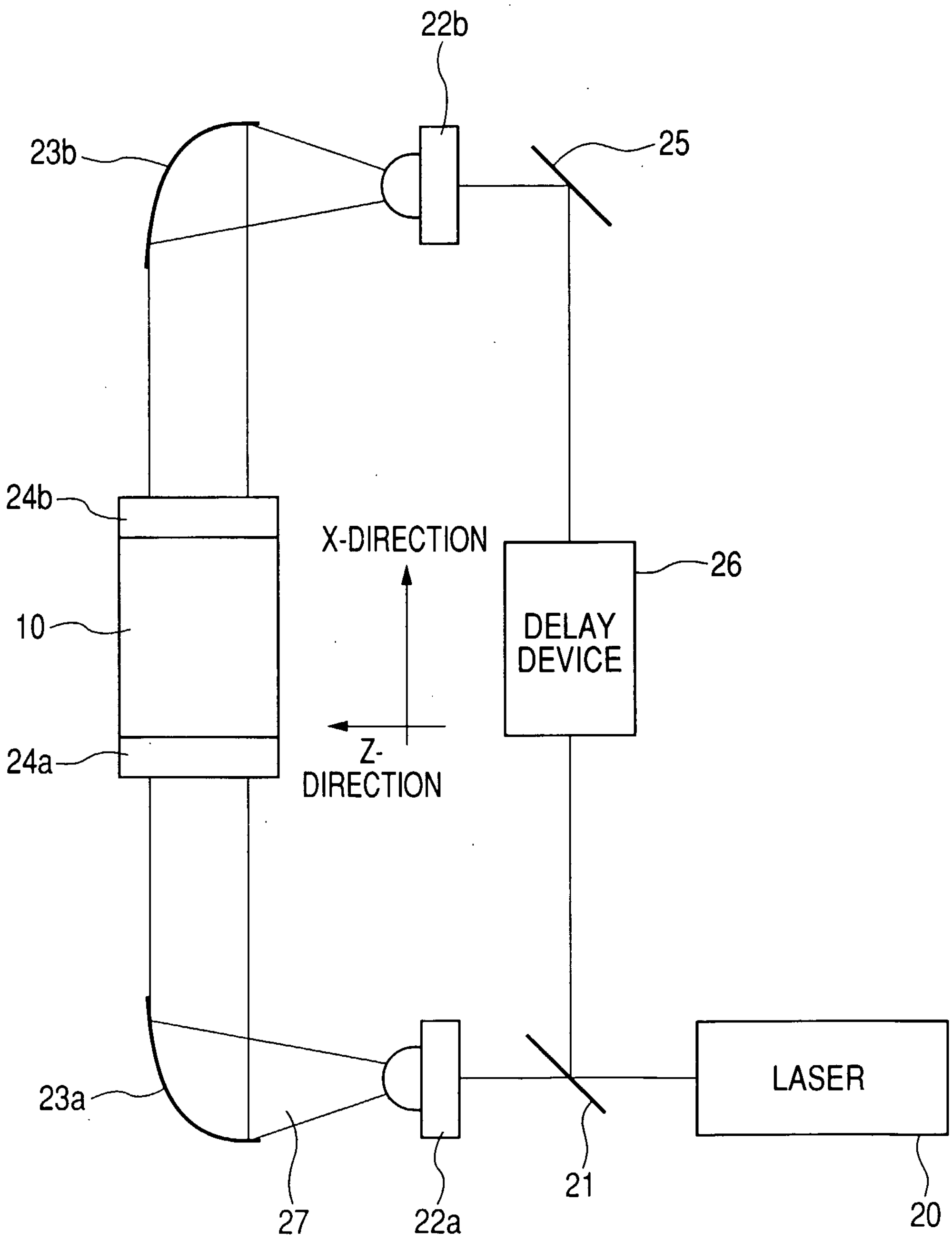
Y-DIRECTION
X-DIRECTION
11b

FIG. 2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DELAY
DEVICE
24a
Z-
DIRECTION
23a
LASER
21
27
22a
20

FIG. 3A

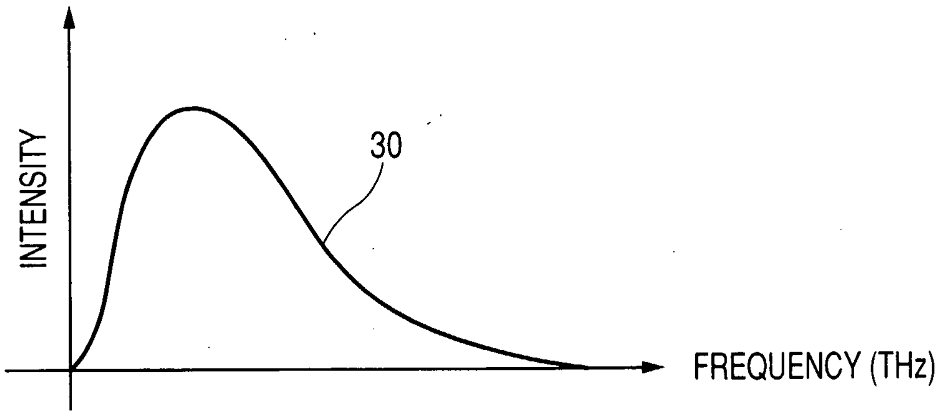


FIG. 3B

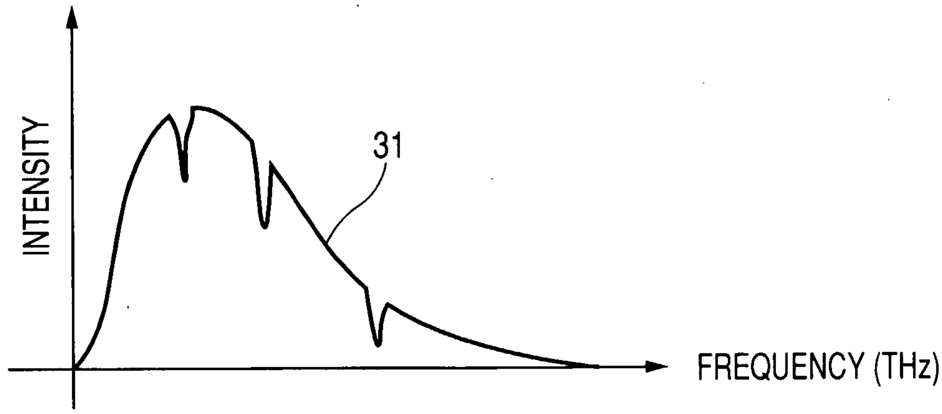


FIG. 3C

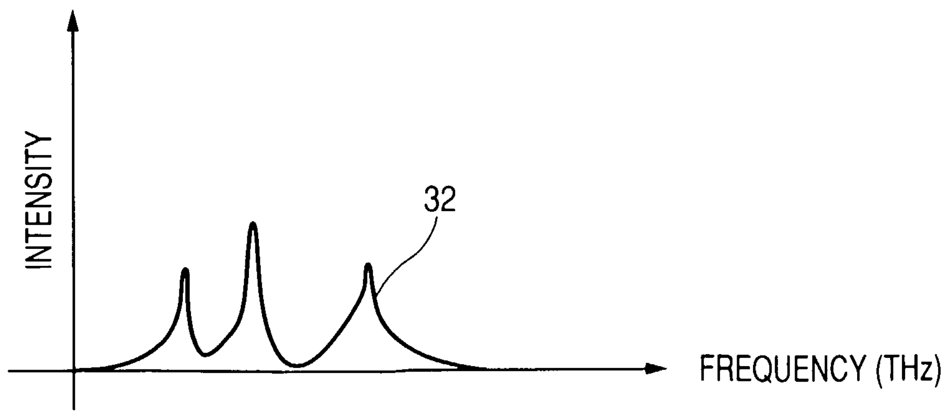


FIG. 4

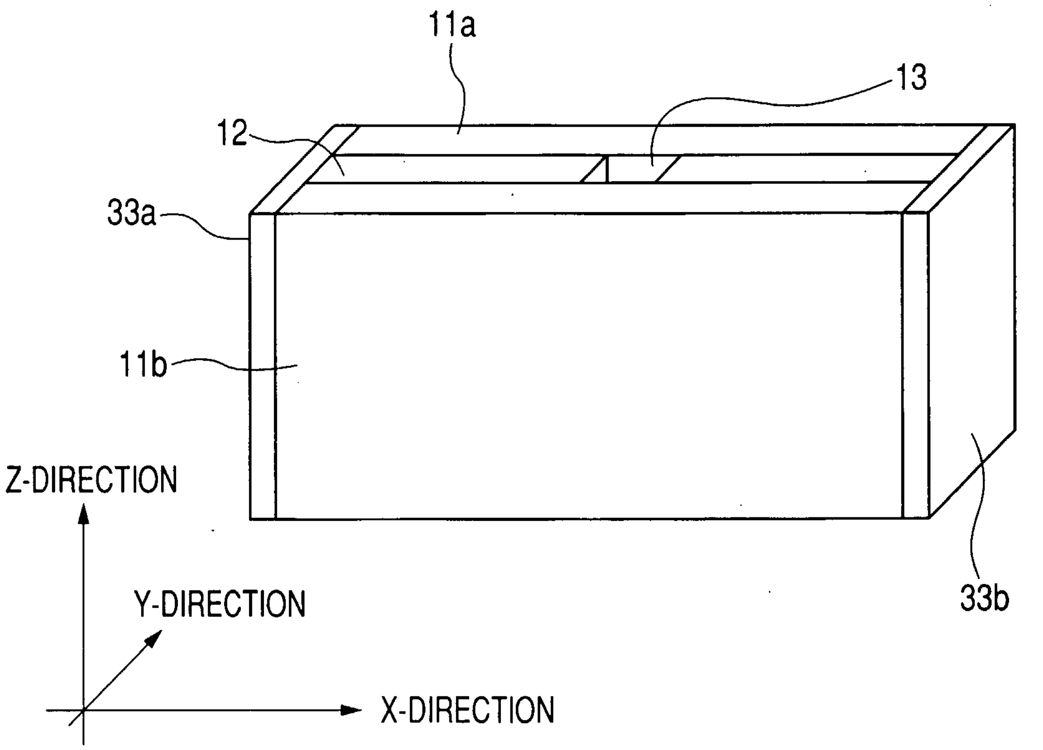


FIG. 5

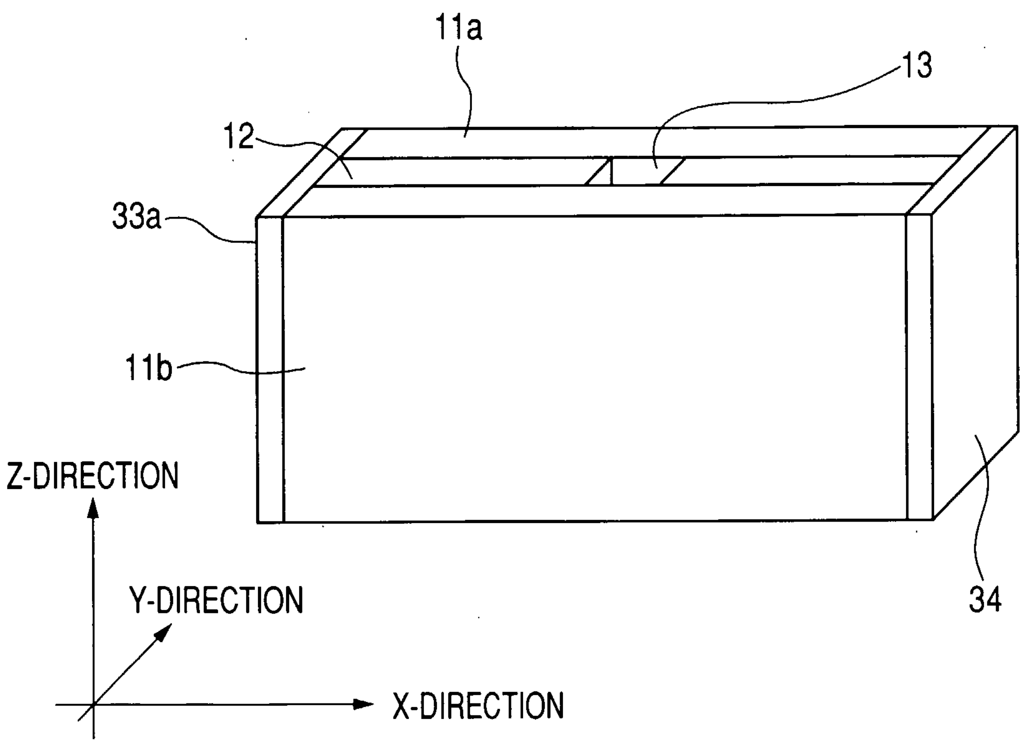


FIG. 6A

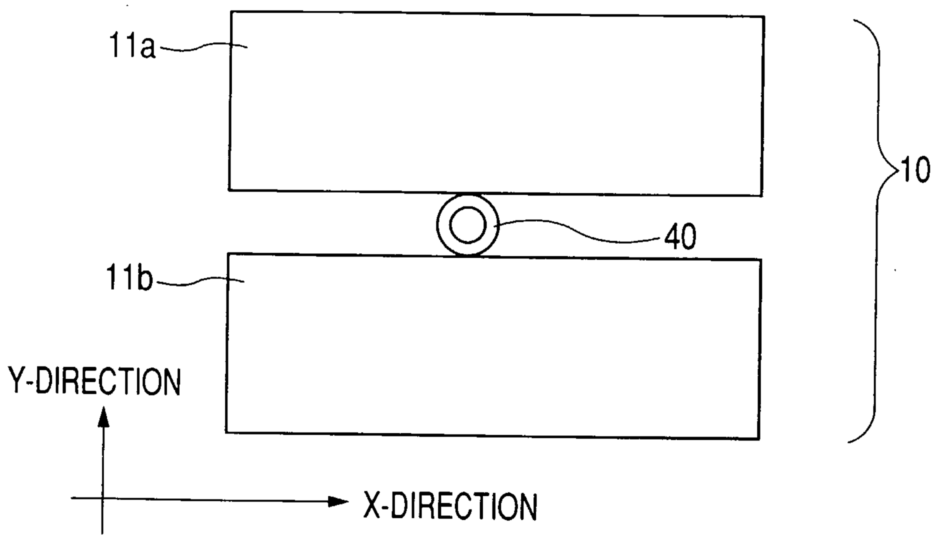

11a
10
40
11b
Y-DIRECTION
X-DIRECTION

FIG. 6B

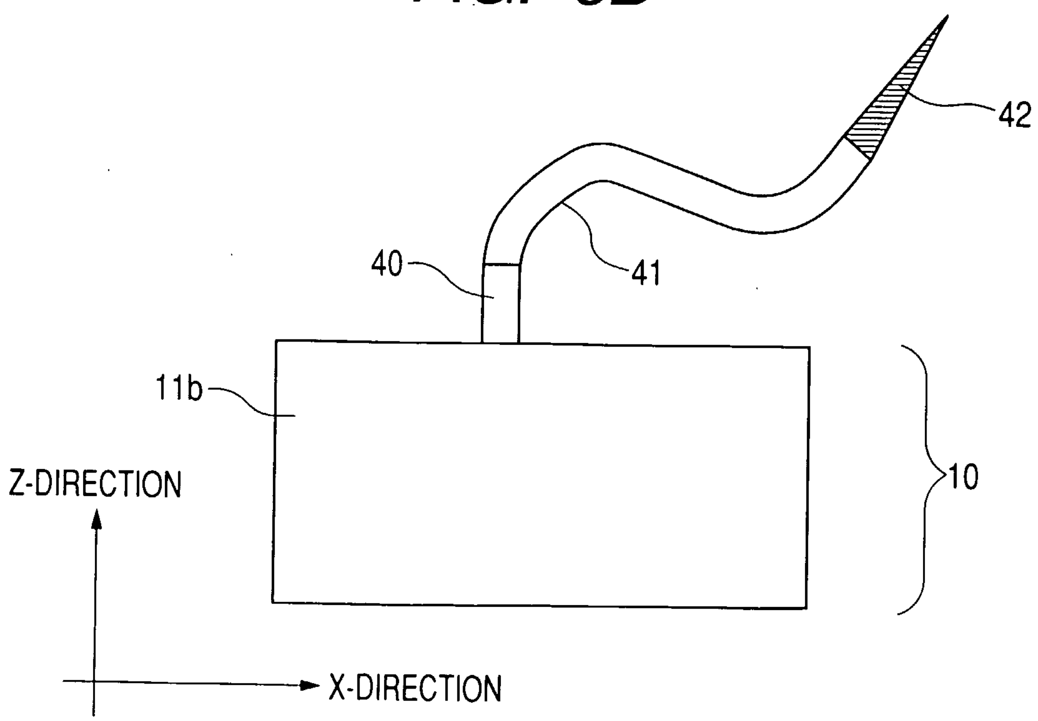

42
40
41
11b
10
Z-DIRECTION
X-DIRECTION

FIG. 7

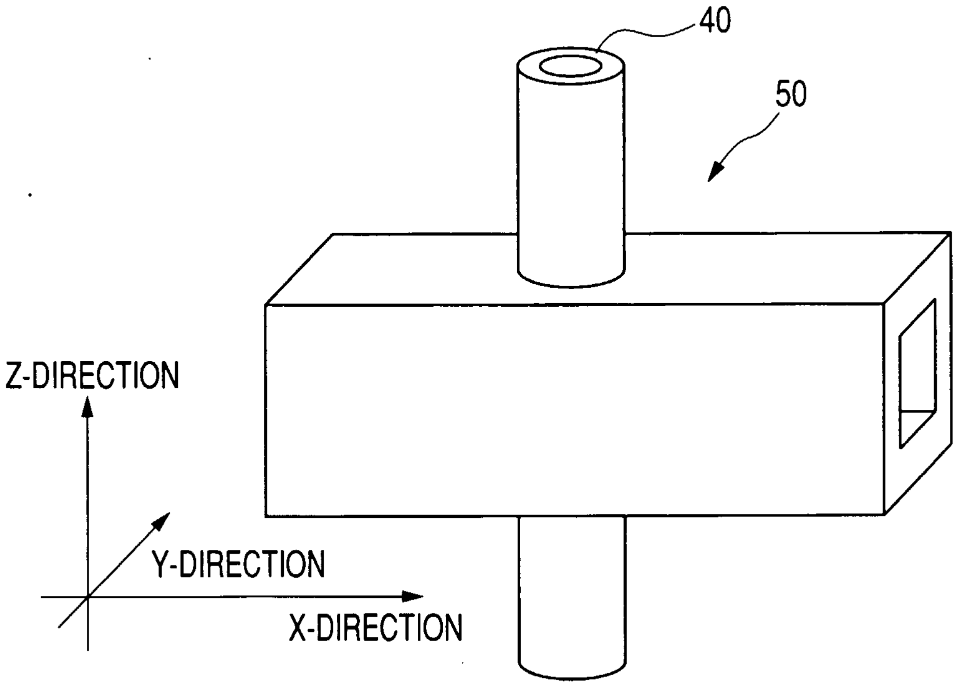


FIG. 8

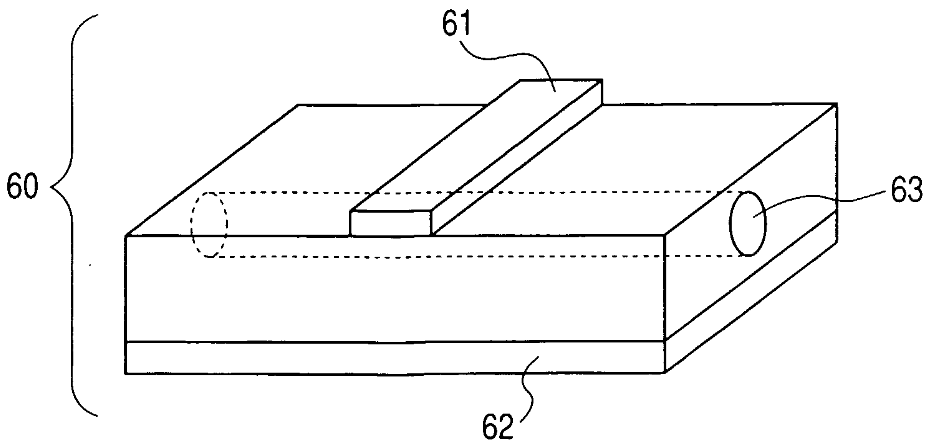


FIG. 9

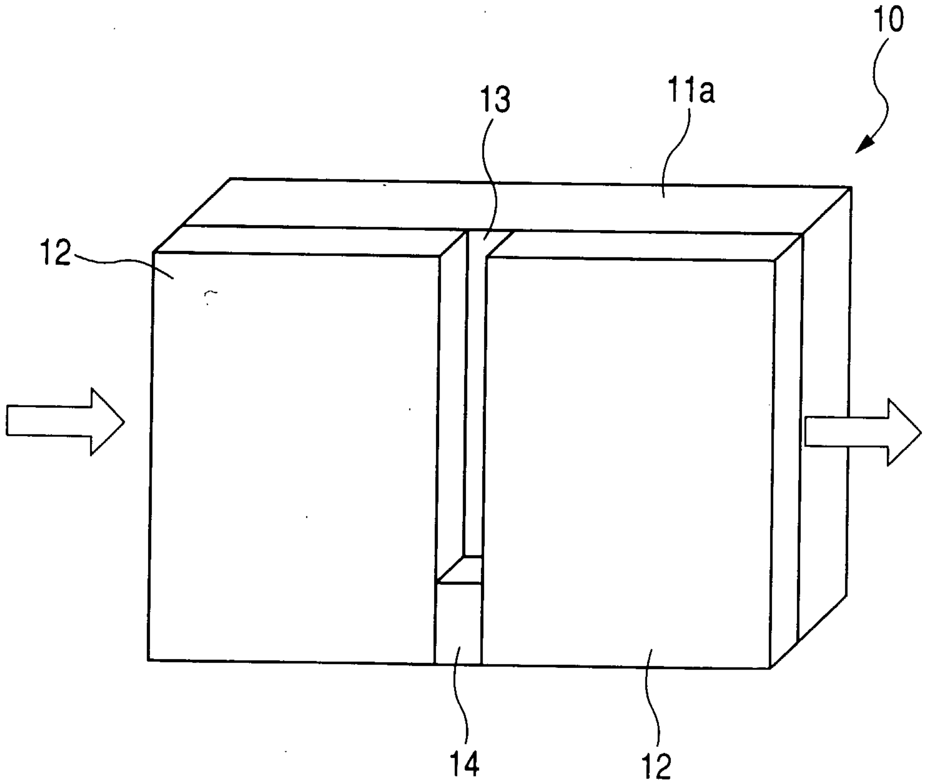
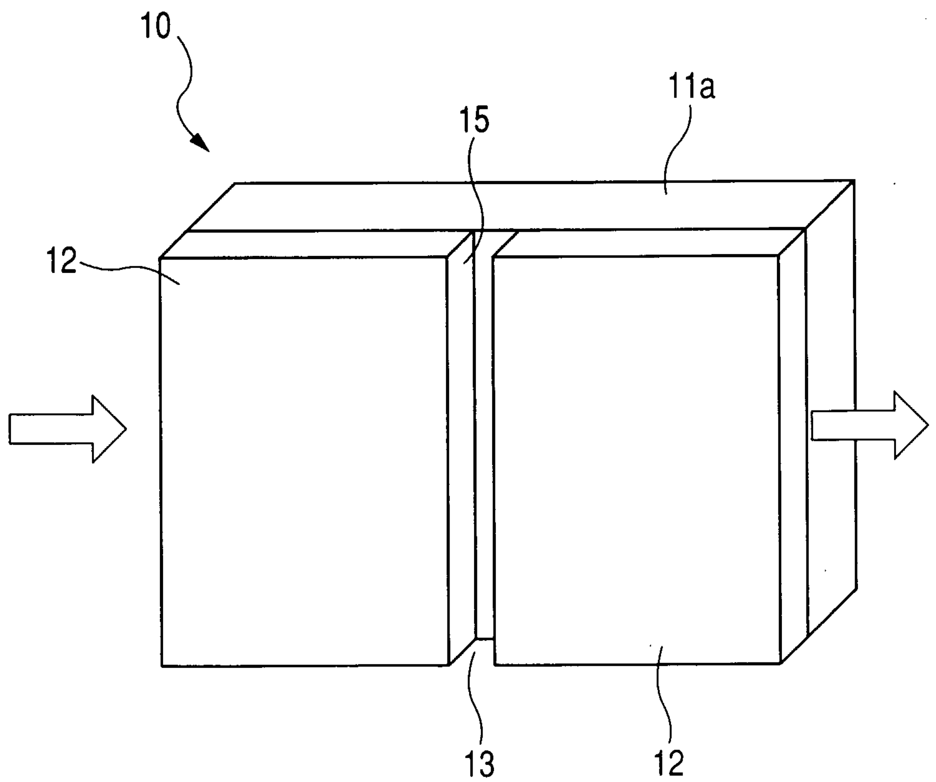


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/024017

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. *G01N21/35*(2006.01), *G01N22/00*(2006.01)

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)

Int.Cl. G01N21/00 - 21/61, G01N22/00 - 22/04

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2006
Registered utility model specifications of Japan 1996-2006
Published registered utility model applications of Japan 1994-2006

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

IEEE, Science Direct, JSTPlus(JOIS), Science Citation Index Expanded (Web of Science)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/50859 A1 (TOSHIBA RESEARCH EUROPE LTD.) 2000.08.31 p.23 Para.4 - p.24 Para.1, p.28 Para.4, p.33 Paras.1-4, Figs.19,20,22	1-2,4-10
Y	E.Knoesel, *et al.*, "Charge transport and carrier dynamics in liquids probed by THz time-domain spectroscopy", PHYSICAL REVIEW LETTERS, Vol.86, No.2, 2001.01.08, pp.340-343	1-10
Y	J.Zhang and D.Grischkowsky, "Waveguide terahertz time-domain spectroscopy of nanometer water layers", OPTICS LETTERS, Vol.29, No.14, 2004.07.15, pp.1617-1619	1-10

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27.01.2006	07.02.2006

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INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2005/024017

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	R.Mendis and D.Grischkowsky, "Plastic ribbon THz waveguides", JOURNAL OF APPLIED PHYSICS, Vol.88, No.7, 2000.10.01, pp.4449-4451	1-10
Y	R.Mendis and D.Grischkowsky, "THz Interconnect With Low-Loss and Low Group Velocity Dispersion", IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, Vol.11, No.11, Nov. 2001, pp.444-446	1-10
Y	K.Wang and D.M.Mittleman, "Metal wire waveguides for broadband terahertz pulses", LEOS 2004, Vol. 1, Nov. 2004, pp.372-373	1-10

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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		GB 2347835 A	2000.09.13
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		JP 2002-538423 A	2002.11.12
		US 6957099 B1	2005.10.18