US 20160246158A1

(19) **United States**
(12) **Patent Application Publication**
Kajiki

(10) **Pub. No.: US 2016/0246158 A1**
(43) **Pub. Date: Aug. 25, 2016**

(54) TERAHERTZ WAVE GENERATING ELEMENT AND TERAHERTZ WAVE DETECTING ELEMENT

(71) Applicant: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(72) Inventor: **Kousuke Kajiki**, Tokyo (JP)

(21) Appl. No.: **15/027,361**

(22) PCT Filed: **Sep. 24, 2014**

(86) PCT No.: **PCT/JP2014/076232**
§ 371 (c)(1),
(2) Date: **Apr. 5, 2016**

(30) **Foreign Application Priority Data**

Oct. 9, 2013 (JP) 2013-212295
Sep. 8, 2014 (JP) 2014-182737

Publication Classification

(51) **Int. Cl.**
G02F 1/37 (2006.01)
G02F 1/365 (2006.01)
G01N 21/55 (2006.01)

(52) **U.S. Cl.**
CPC ***G02F 1/37*** (2013.01); ***G01N 21/55*** (2013.01); ***G02F 1/365*** (2013.01); *G02F 2001/3503* (2013.01)

(57) ABSTRACT

A terahertz wave generating element includes a nonlinear optical crystal generating terahertz waves by propagating light, and a coupling member propagating the generated terahertz waves. The coupling member includes a reflecting face reflecting at least part of the generated terahertz waves. The reflecting face is convex in a propagation direction of the generated terahertz waves. An angle at the coupling member side between the reflecting face and the propagation direction of the light is greater than 90 degrees−$\cos^{-1}(n_g/n_{THz})$ but smaller than 90 degrees at a plane including the light propagation direction. n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, n_{THz} the refractive index of the coupling member at a wavelength of the generated terahertz waves. A curvature radius of the reflecting face, in a reflection region reflecting the radius terahertz waves, is smaller the farther downstream in the light propagation direction.

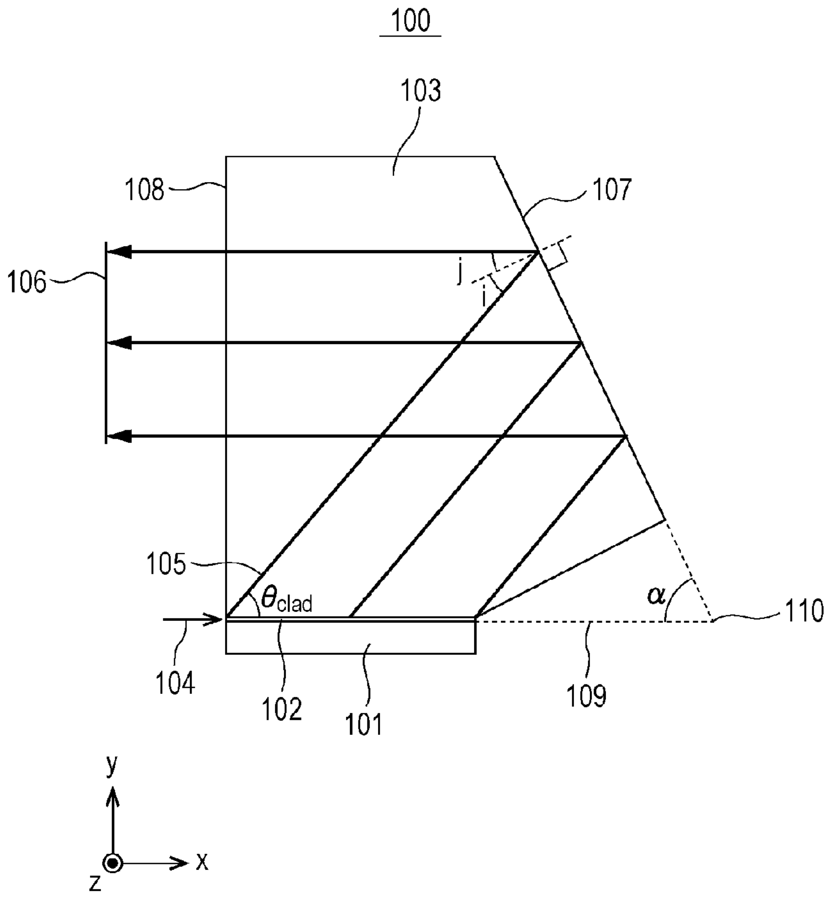


FIG. 1

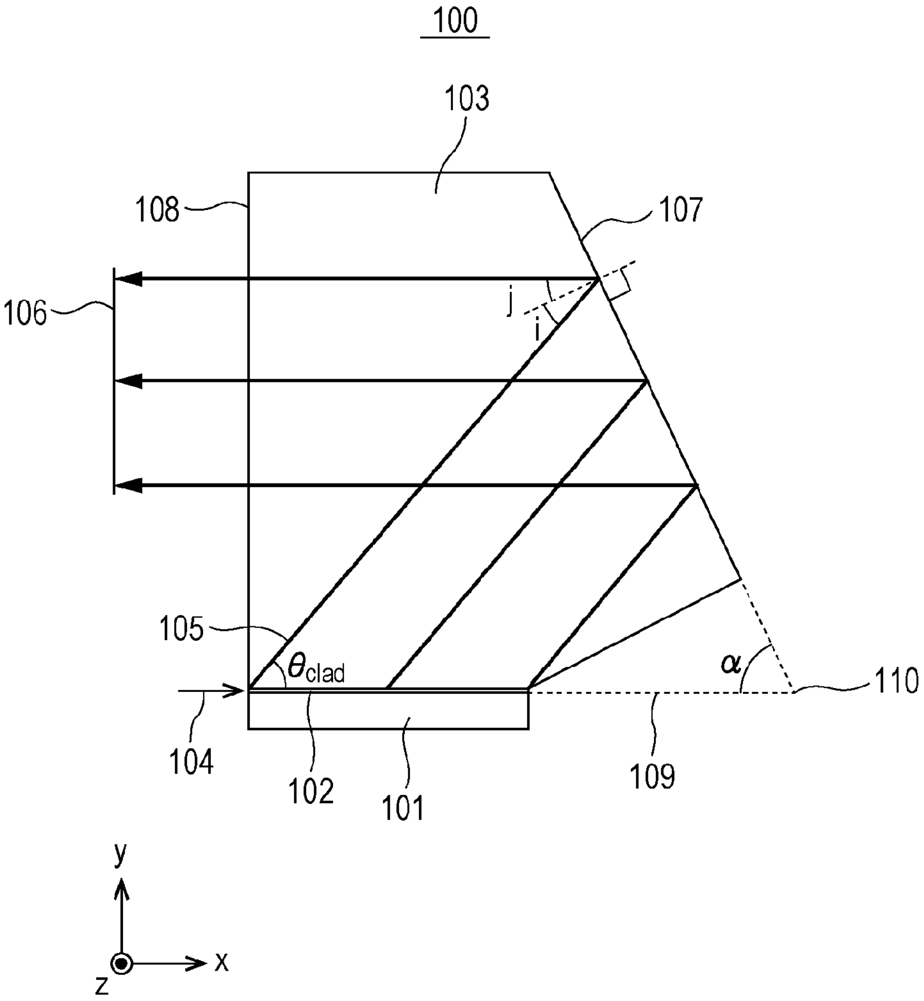

100
103
108
107
106
j
i
105
θ_{clad}
α
110
104
102
101
109
y
x
z

FIG. 2

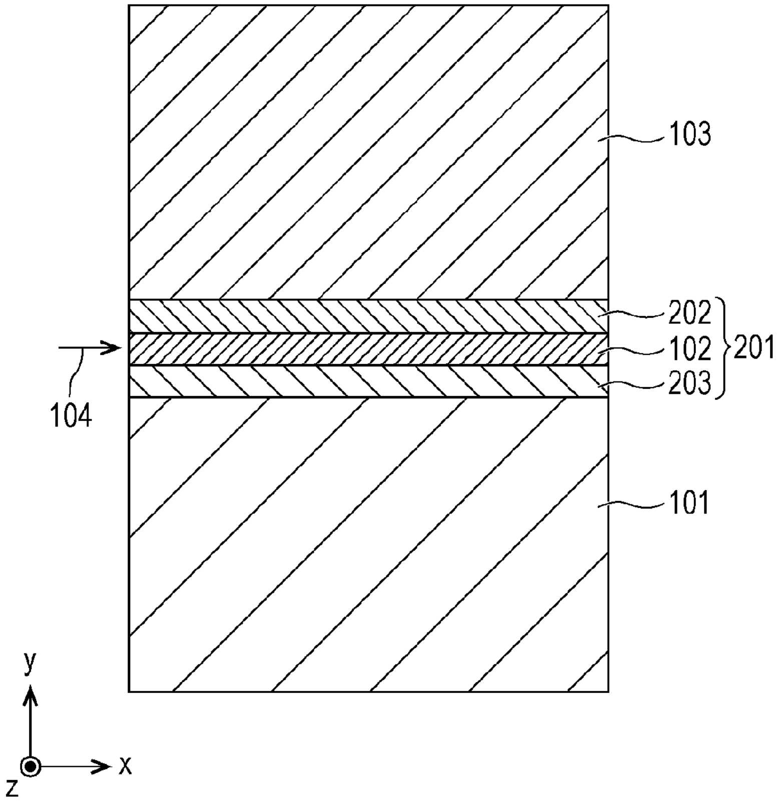


FIG. 3A

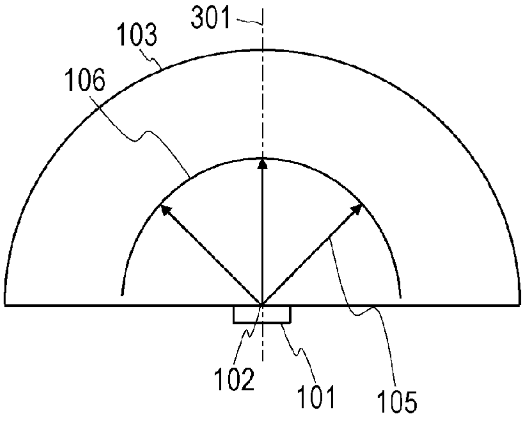


FIG. 3B

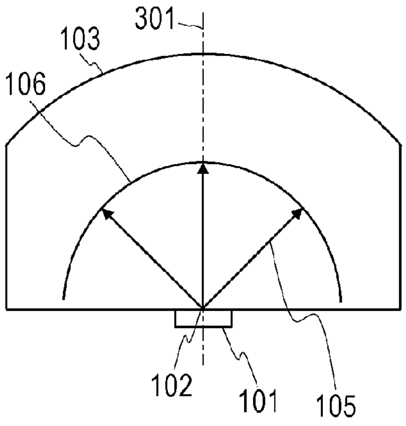


FIG. 3C

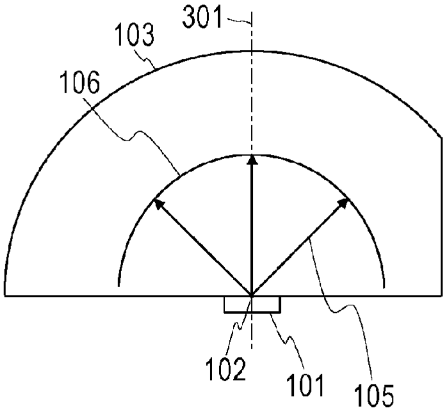


FIG. 3D

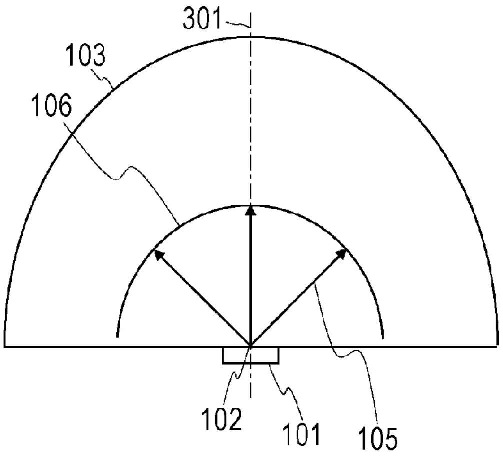


FIG. 4A

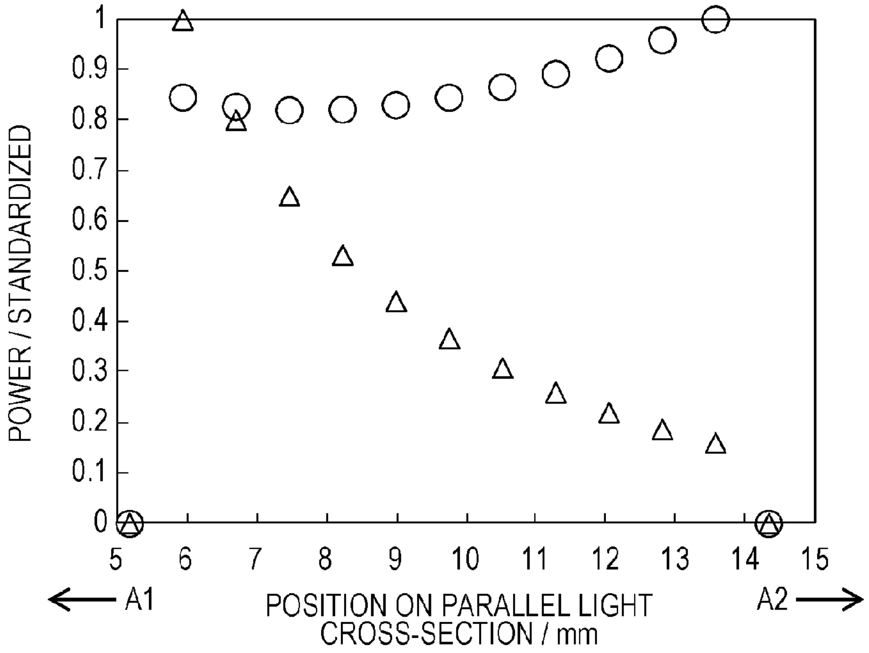

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
POWER / STANDARDIZED
5
6
7
8
9
10
11
12
13
14
15
A1
POSITION ON PARALLEL LIGHT CROSS-SECTION / mm
A2

FIG. 4B

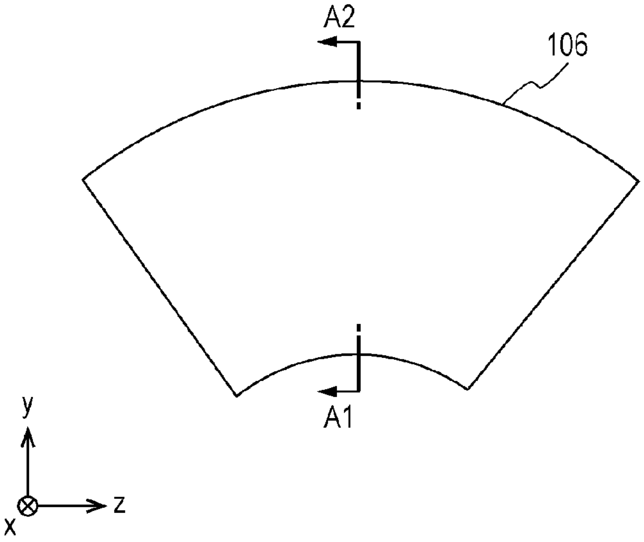

A2
106
A1
y
z
x

FIG. 5

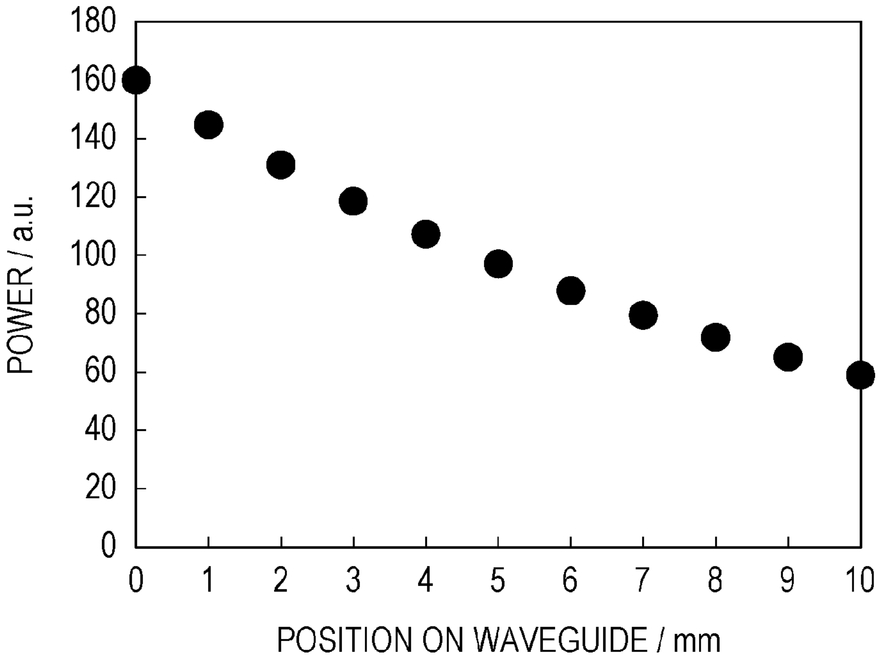

180
160
140
120
100
80
60
40
20
0
POWER / a.u.
0
1
2
3
4
5
6
7
8
9
10
POSITION ON WAVEGUIDE / mm

FIG. 6

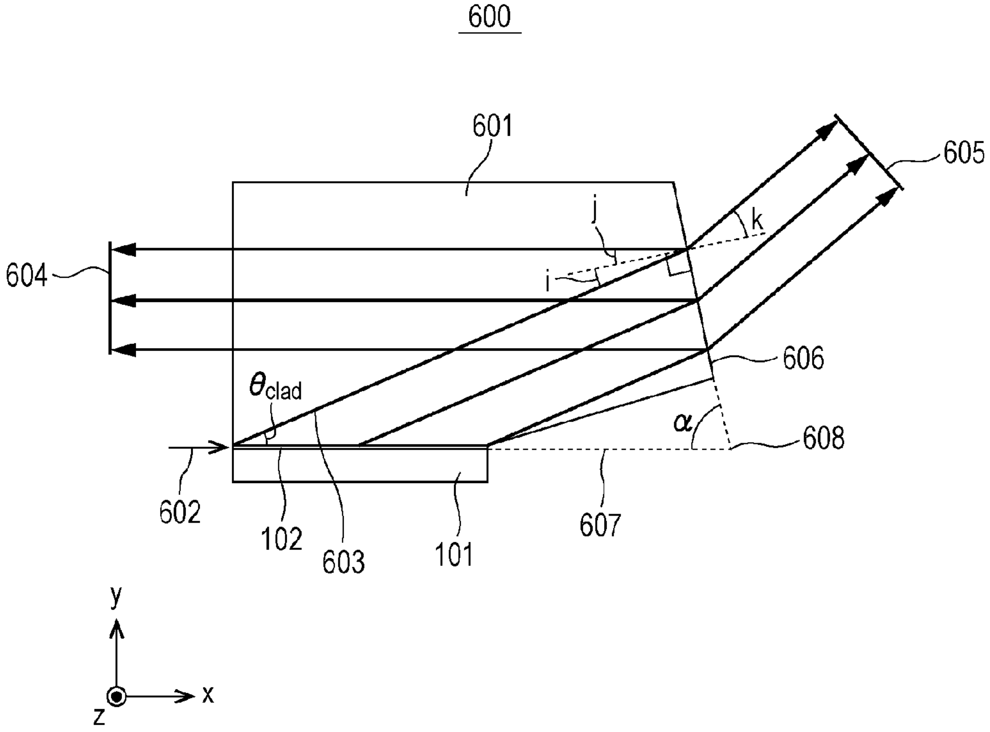

600
601
605
604
j
k
i
606
θ_{clad}
α
608
602
102
603
101
607
y
x
z

FIG. 7A

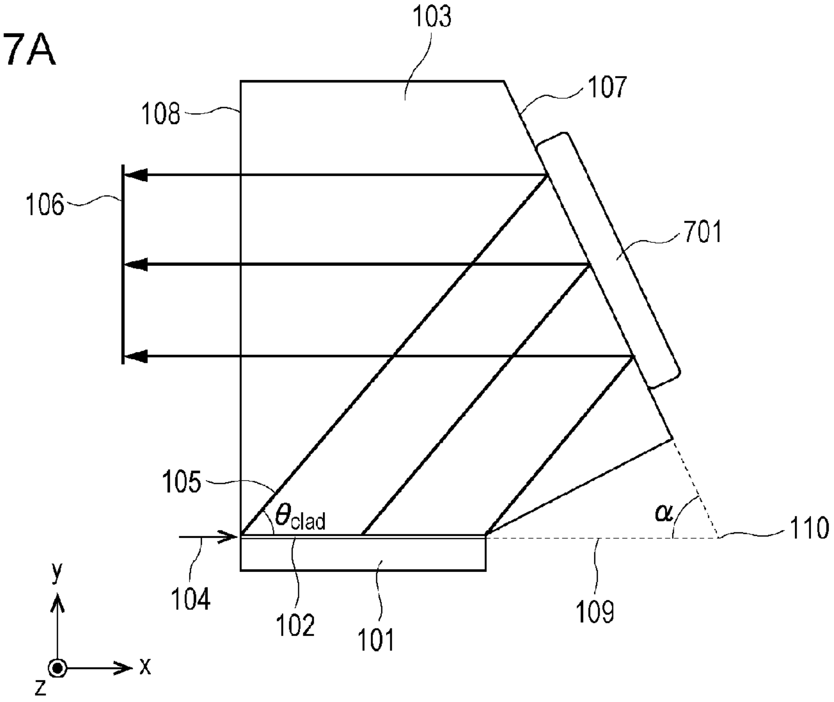

103
107
108
106
701
105
θ_{clad}
α
110
104
102
101
109
y
x
z

FIG. 7B

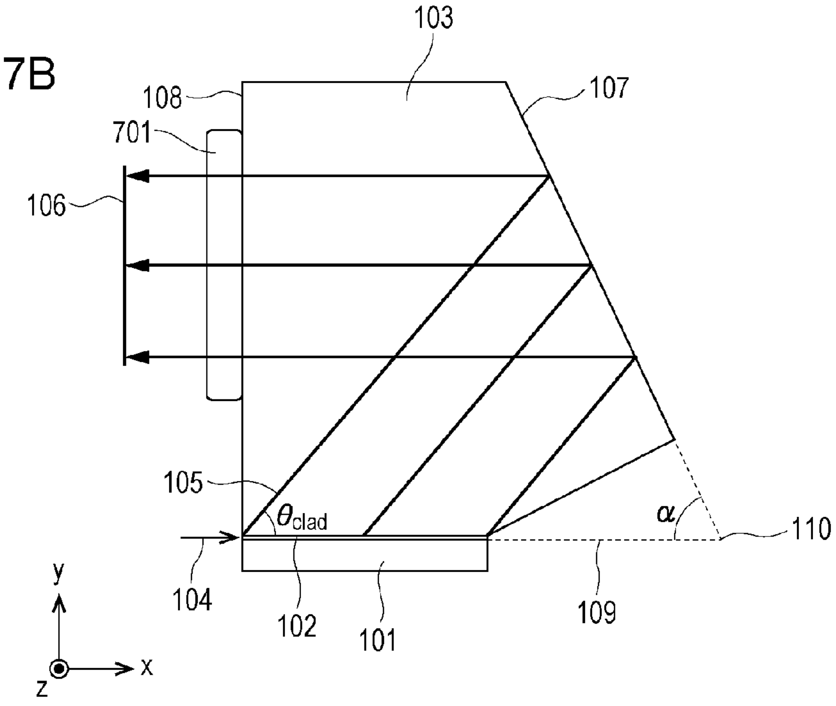

103
108
107
701
106
105
θ_{clad}
α
110
104
102
101
109
y
x
z

FIG. 8

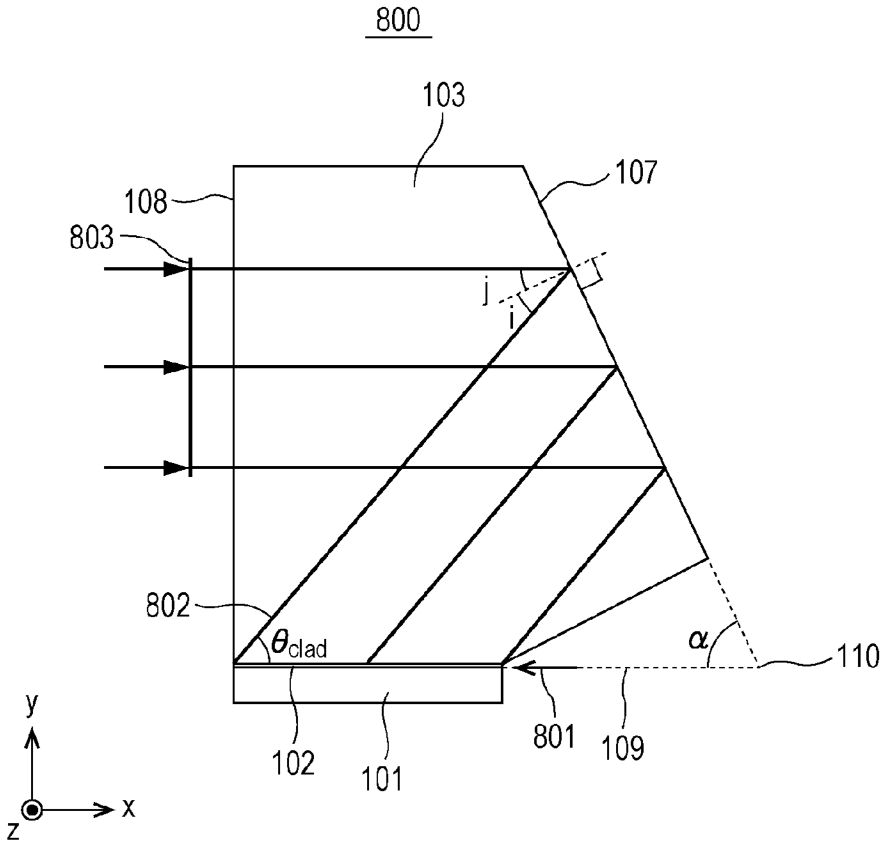

800
103
107
108
803
j
i
802
θ_{clad}
α
110
102
101
801
109
y
x
z

FIG. 9A

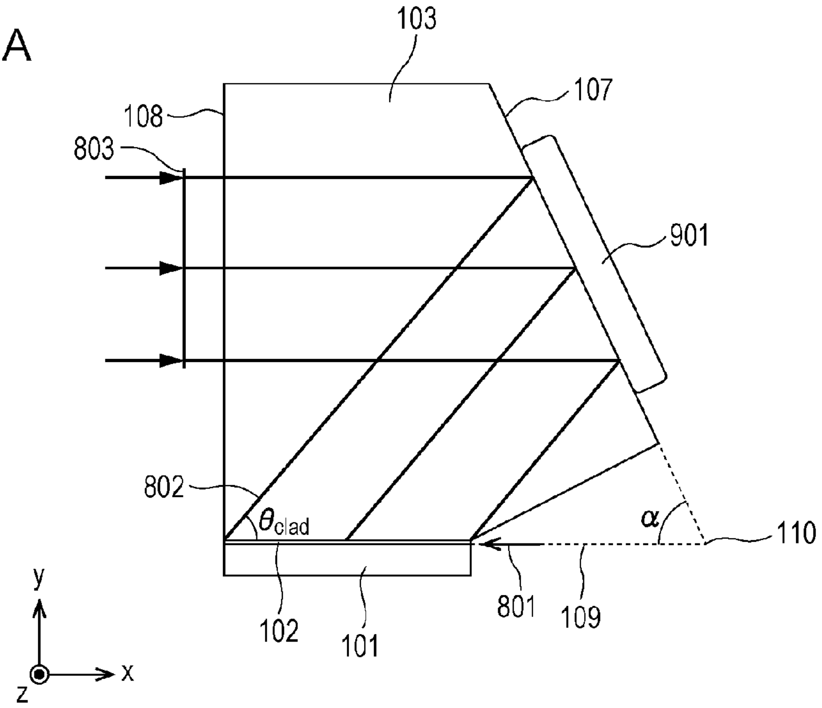

103
107
108
803
901
802
θ_{clad}
α
110
102
101
801
109
y
x
z

FIG. 9B

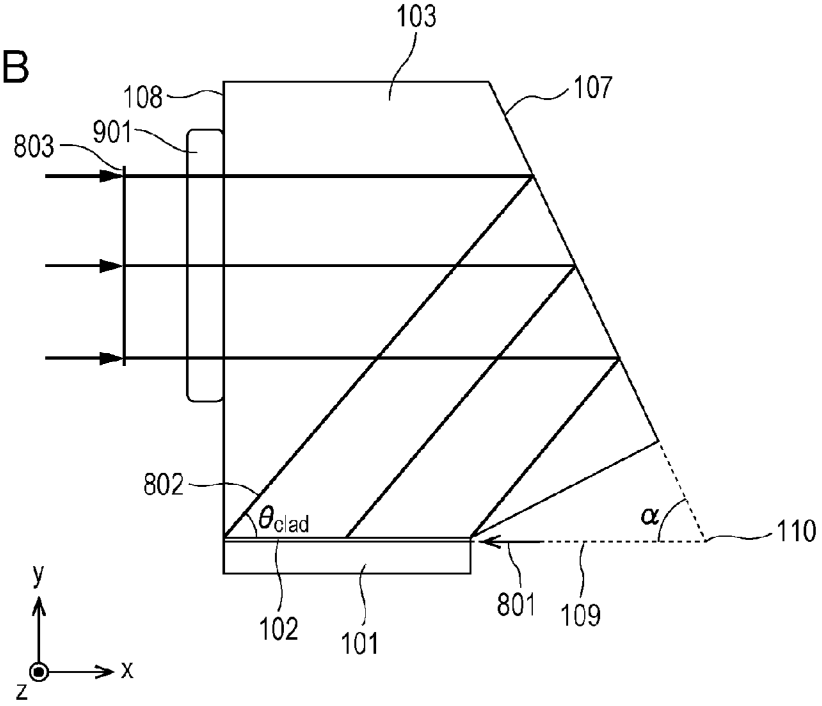

103
107
108
901
803
802
θ_{clad}
α
110
102
101
801
109
y
x
z

FIG. 10A

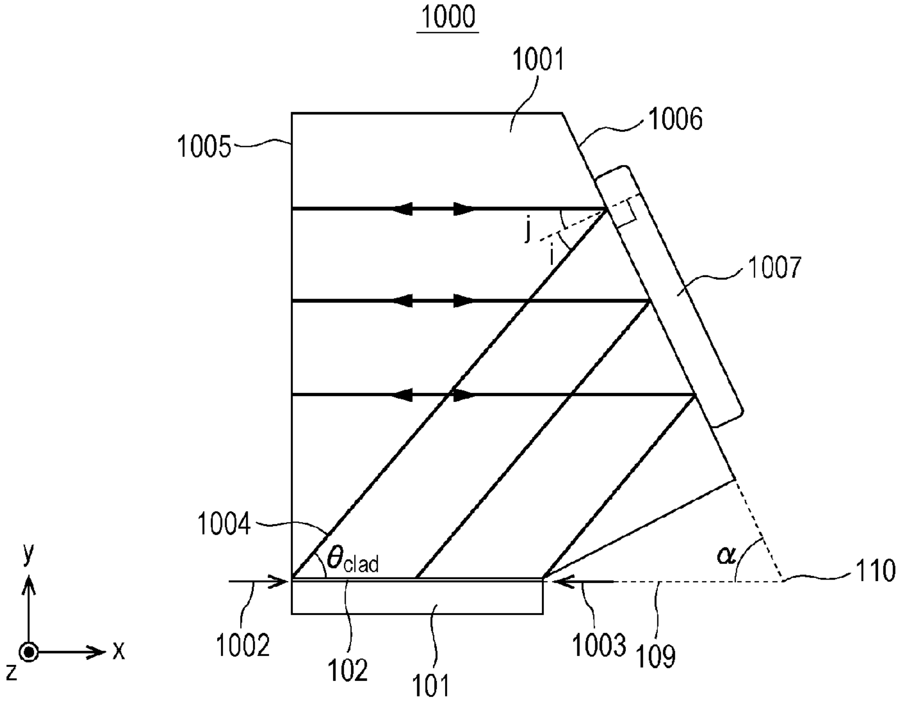


FIG. 10B

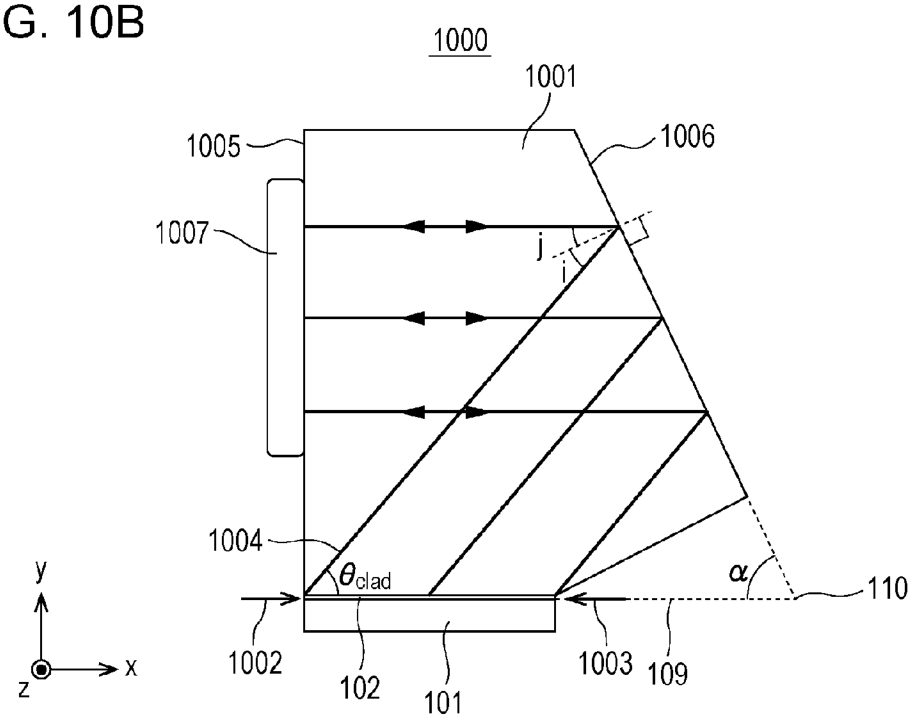


FIG. 11

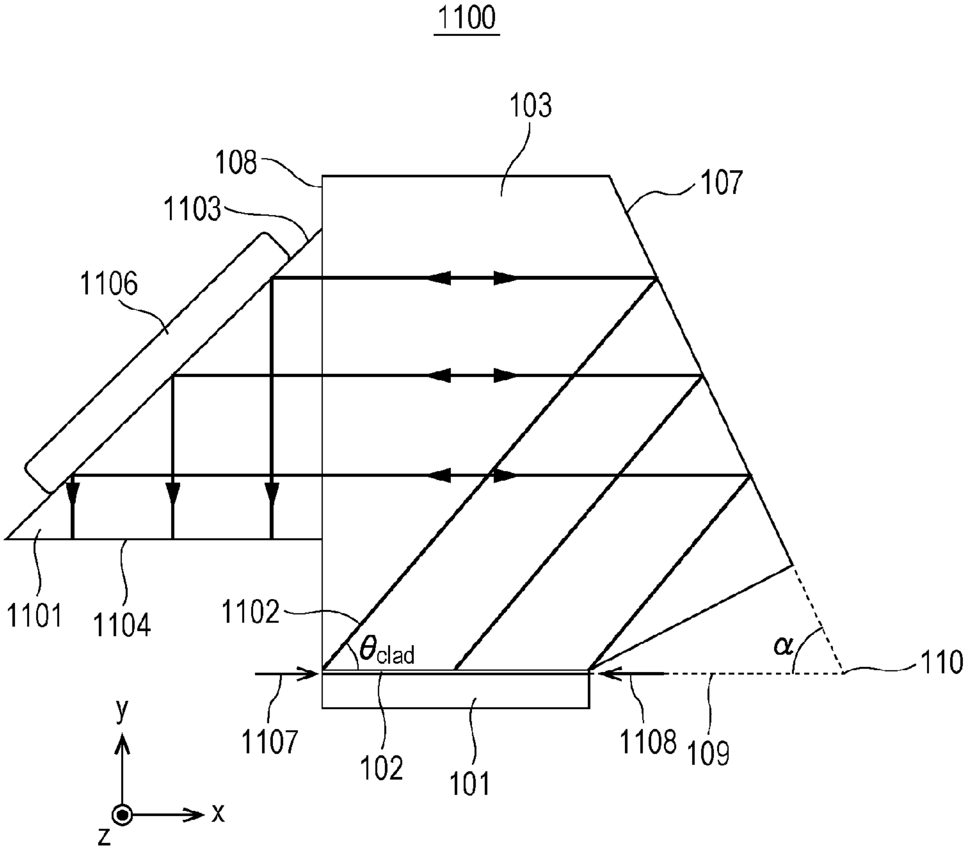

1100
103
108
107
1103
1106
1101
1104
1102
θ_{clad}
α
110
1107
102
101
1108
109
y
x
z

FIG. 12A

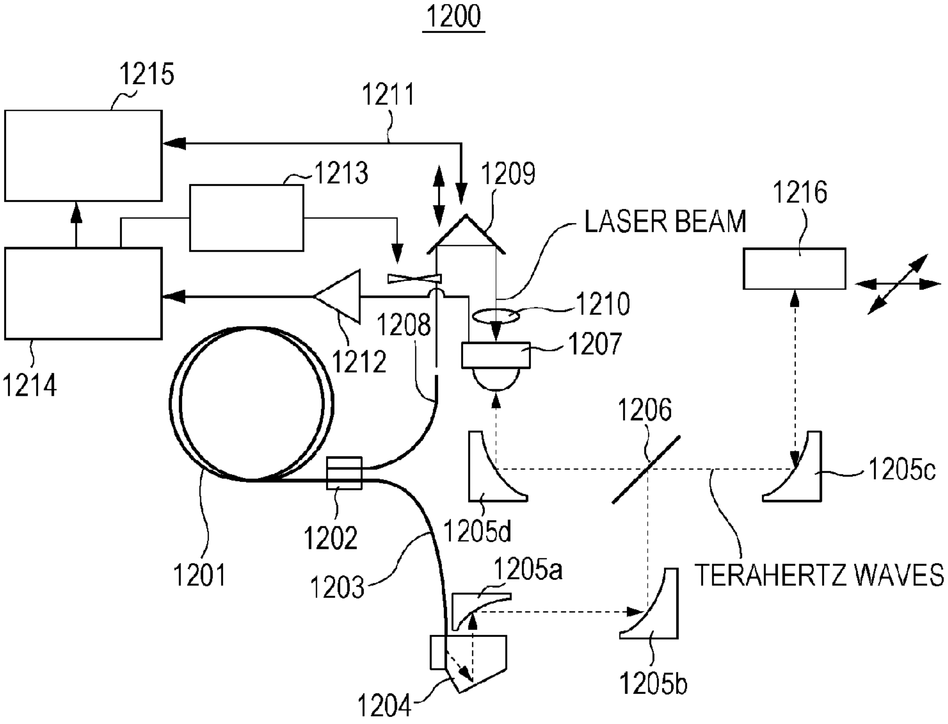


FIG. 12B

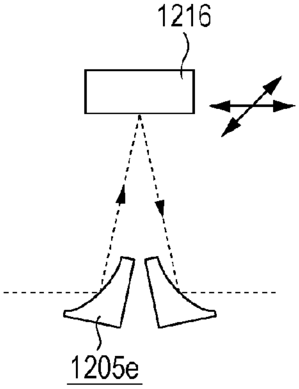


FIG. 13

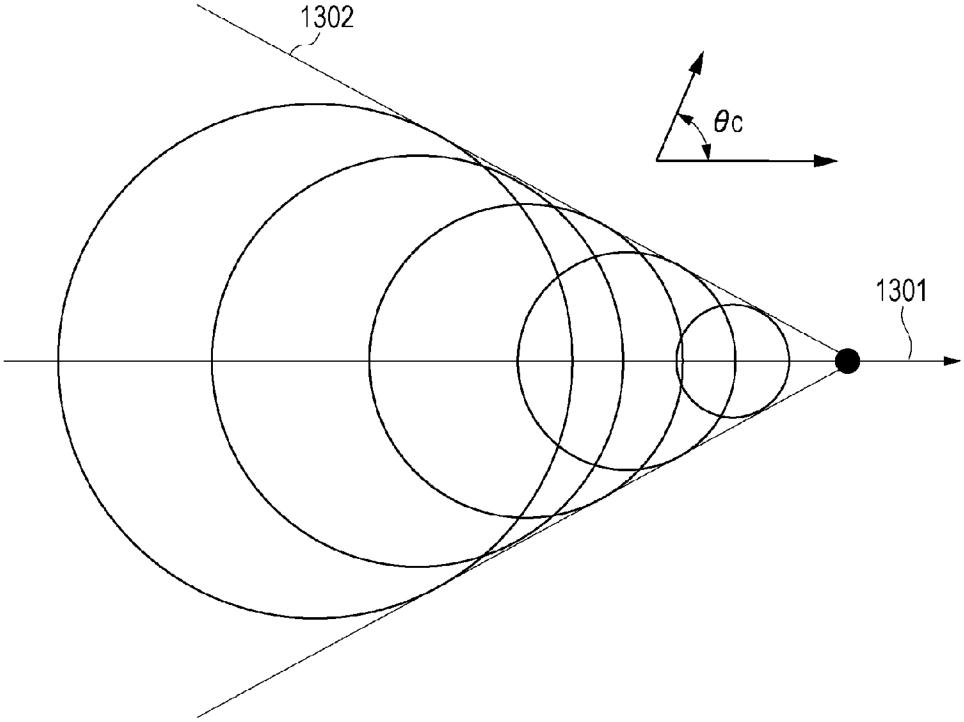
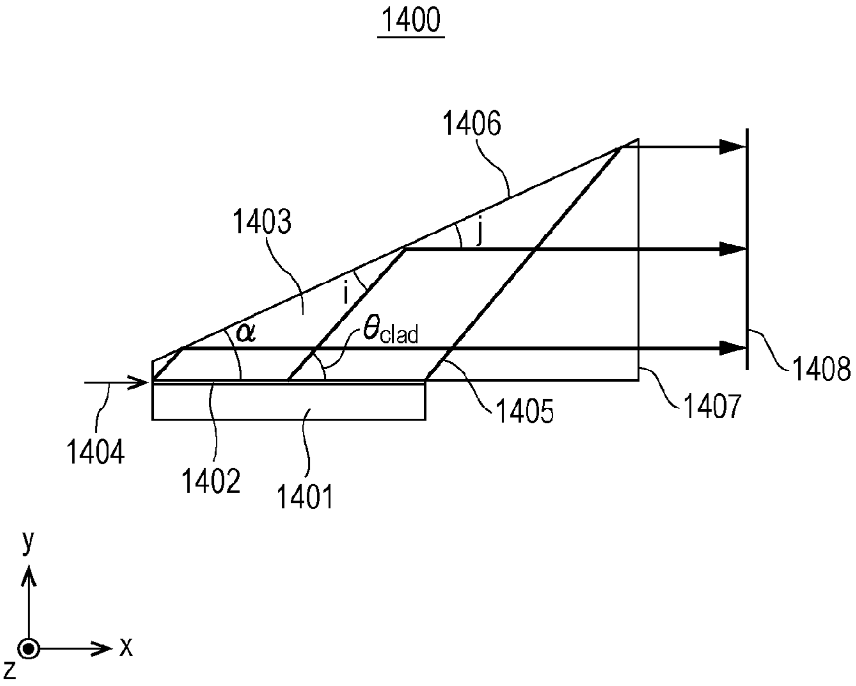


FIG. 14


1400
1406
1403
j
i
α
θ_{clad}
1408
1405
1407
1404
1402
1401
y
x
z

TERAHERTZ WAVE GENERATING ELEMENT AND TERAHERTZ WAVE DETECTING ELEMENT

TECHNICAL FIELD

[0001] The present invention relates to a terahertz wave generating element which generates terahertz waves, and a terahertz wave detecting element which detects terahertz waves.

BACKGROUND ART

[0002] Terahertz waves are electromagnetic waves, having a frequency band component anywhere between 0.03 THz to 30 THz. There are methods to generate terahertz waves using a secondary nonlinear phenomenon by a nonlinear optical crystal. Of these, a technique using electro-optical Cherenkov radiation phenomenon (hereinafter, "Cherenkov radiation") is capable of generating intense and relatively wide bandwidth terahertz waves, which is described in PTL 1.

[0003] Cherenkov radiation is a phenomenon where generated terahertz waves **1302** are conically emitted like shock waves, as illustrated in FIG. **13**. Cherenkov radiation occurs in a case where the propagating group velocity of light **1301** propagating through a nonlinear optical crystal is faster than the propagating phase velocity of the terahertz waves **1302**. Now, an angle θ_c between the propagation direction of the generated terahertz waves **1302** and the propagation direction of the light **1301** propagating through the nonlinear optical crystal (hereinafter referred to as "Cherenkov angle") can be expressed as

$$\cos\theta_c = n_g/n_{THz} \tag{1}$$

where n_g is the group refractive index of the nonlinear optical crystal as to light, and n_{THz} is the refractive index of the medium through which the terahertz waves propagate as to the terahertz waves.

[0004] In cases of using such a terahertz wave generating element employing Cherenkov radiation as a terahertz wave generating source in an information acquiring apparatus to acquire information regarding a specimen using terahertz waves, or the like, wavefront shaping may be necessary. PTL 2 discloses a method for second harmonic generation of light propagating through a nonlinear optical crystal, and shaping and externally extracting the generated second harmonic waves using a collimator, as illustrated in FIG. **14**.

[0005] Second harmonic waves **1405** generated by light **1404** propagating through the nonlinear optical crystal **1402** is emitted in a conical form, and reflected at a reflecting face **1406** of a coupling member **1403**. At this time, the wavefront **1408** of the reflected second harmonic waves **1405** is collimated to a high level of planarity. This configuration shapes the wavefront **1408** of second harmonic waves **1405** to be planar, making the second harmonic waves **1405** easier to handle.

CITATION LIST

Patent Literature

[0006] PTL 1 Japanese Patent Laid-Open No. 2010-204488

[0007] PTL 2 Japanese Patent Laid-Open No. 02-081035

[0008] In a case of applying the configuration according to PTL 2 to a terahertz wave generating element, shaping of the generated terahertz waves can be realized, but distortion in power distribution of the terahertz waves at the wavefront **1408** may increase in some cases. Increased distortion in power distribution results in the effective beam diameter being small even if the terahertz waves are converged, so this is not suitable for transmission or measurement.

SUMMARY OF INVENTION

Solution to Problem

[0009] A terahertz wave generating element includes a nonlinear optical crystal configured to generate terahertz waves by light propagating therethrough, and a coupling member through which the terahertz waves generated by the nonlinear optical crystal propagate. The coupling member includes a reflecting face configured to reflect at least a part of the terahertz waves generated by the nonlinear optical crystal. The reflecting face is convex in a propagation direction of the terahertz waves generated by the nonlinear optical crystal. An angle at the coupling member side between the reflecting face and a propagation direction of the light is greater than 90 degrees-$\cos^{-1}(n_g/n_{THz})$ but smaller than 90 degrees at a plane including the propagation direction of the light, where n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, and n_{THz} represents the refractive index of the coupling member at a wavelength of the terahertz waves generated by the nonlinear optical crystal. A radius of curvature of the reflecting face, in a reflection region where the terahertz waves generated by the nonlinear optical crystal are reflected, is smaller the farther downstream in the propagation direction of the light.

[0010] Further aspects of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a diagram for describing the configuration of a terahertz wave generating element according to a first embodiment.

[0012] FIG. **2** is a diagram for describing the configuration of waveguide of a terahertz wave generating element according to the first embodiment.

[0013] FIGS. **3**A through **3**D are cross-sectional views taken along a plane orthogonal to the propagation direction of light in the terahertz wave generating element according to the first embodiment.

[0014] FIGS. **4**A and **4**B are diagrams illustrating terahertz wave power distribution on a parallel light cross-section.

[0015] FIG. **5** is a diagram illustrating terahertz wave power distribution on a waveguide.

[0016] FIG. **6** is a diagram for describing the configuration of a terahertz wave generating element according to a second embodiment.

[0017] FIGS. **7**A and **7**B are diagrams for describing the configuration of a terahertz wave generating element according to a third embodiment.

[0018] FIG. **8** is a diagram for describing the configuration of a terahertz wave detecting element according to a fourth embodiment.

[0019] FIGS. **9**A and **9**B are diagrams for describing another configuration of the terahertz wave detecting element according to the fourth embodiment.

[0020] FIGS. **10**A and **10**B are diagrams for describing the configuration of a terahertz wave detecting element according to a fifth embodiment.

[0021] FIG. **11** is a diagram for describing the configuration of a terahertz wave detecting element according to a sixth embodiment.

[0022] FIGS. **12**A and **12**B are diagrams for describing the configuration of an information acquiring apparatus according to a seventh embodiment.

[0023] FIG. **13** is a diagram for describing the electro-optical Cherenkov radiation phenomenon.

[0024] FIG. **14** is a diagram for describing the configuration of a second harmonic generation element according to the related art.

DESCRIPTION OF EMBODIMENTS

First Embodiment

[0025] The configuration of a terahertz wave generating element **100** (hereinafter, also referred to as "element **100**") according to a first embodiment will be described with reference to FIG. **1**. FIG. **1** is a cross-sectional view of the element **100** with regard to a plane (first plane) including the propagation direction of light **104**. Specifically, FIG. **1** is a cross-sectional view at a face including the propagation direction of the light **104** and also perpendicular to the surface of a nonlinear optical crystal. Note that the "propagation direction of the light **104**" as used in the present specification refers to a direction in which incident light **104** to the nonlinear optical crystal is substantially propagated, and is defined as a straight line connecting the center of gravity of the input face and the center of gravity of the output face of the nonlinear optical crystal.

[0026] The element **100** includes a substrate **101**, a nonlinear optical crystal **102** (hereinafter, also referred to as "crystal **102**"), and a coupling member **103**. The substrate **101** includes a Y-cut lithium niobate (LiNbOx, hereinafter referred to as "LN crystal").

[0027] A waveguide **201** including the crystal **102** is formed on the substrate **101**. Terahertz waves are generated when light **104** is input to the crystal **102**. An ultrashort pulse laser having a pulse width in the range of 1 fs to 100 fs is used as the light **104** input to the crystal **102**. More specifically, femtosecond laser is input to the crystal **102**. Note that the term "femtosecond laser" as used in the present specification is ultrashort pulse laser having a pulse width in the range of 1 fs to 100 fs.

[0028] The wavelength of the light **104** is preferably included in a range of 0.2 μm to 10 μm. Light having a wavelength shorter than 0.2 μm is vacuum ultraviolet light, and is not suitable for use in atmosphere conditions. 10 μm is the wavelength of light obtained with a common carbon dioxide laser. The configuration of the waveguide **201** will be described in detail later.

[0029] The coupling member **103** is a member to externally extract generated terahertz waves **105** from the element **100**, and includes a reflecting face **107**. Details of the configuration of the coupling member **103** will be described later.

[0030] The element **100** according to the present embodiment generates terahertz waves **105** by inputting light **104** from the edge face of the crystal **102** and propagating the light **104**. The generating terahertz waves **105** are conically emitted by Cherenkov radiation (electro-optical Cherenkov radiation phenomenon), propagate through the coupling member **103**, and are externally extracted. While the terahertz waves **105** emitted from the crystal **102** are drawn as straight lines, in reality the terahertz waves **105** are refracted at the time of entering the coupling member **103** from the waveguide **201**.

[0031] The configuration of the waveguide **201** will now be described with reference to FIG. **2**. FIG. **2** is a diagram for describing the configuration of the waveguide **201** according to the present embodiment, and is an enlarged view of around the crystal **102** in FIG. **1**. The waveguide **201** includes the crystal **102** serving as a core layer, an upper clad layer **202** formed upon the core layer **102**, and a lower clad layer **203** formed below the core layer **102**. Note that in the present specification, the upper side of the core layer **102** is the side thereof toward the coupling member **103**, and the lower side of the core layer **102** is the side thereof toward the substrate **101**.

[0032] The core layer **102** is the portion where terahertz waves are generated, and includes an LN crystal which is a nonlinear optical crystal. The type of nonlinear optical crystal is not restricted to an LN crystal, rather, a variety of nonlinear optical crystals may be used, including $LiTaO_x$, $NbTaO_x$, KTP, DAST, ZnTe, GaSe, GaAs, and the like. The thickness of the core layer **102** is preferably half or less the equivalent wavelength of the highest frequency terahertz waves **105** externally emitted, at the core layer **102**.

[0033] The x axis of the LN crystal of the core layer **102** is configured to correspond to the propagation direction of the light **104**, and the y axis to a direction perpendicular to the nonlinear optical crystal. The light **104** has z-axial direction linearly-polarized waves orthogonal to the x axis and y axis.

[0034] This configuration improves generation of terahertz waves by the secondary nonlinear phenomenon, and improves efficiency of Cherenkov radiation. That is to say, the crystal axis settings of the LN crystal are chosen such that phase matching is realized between the light **104** and terahertz waves **105**, and the phase matching condition is satisfied regarding wave vectors of the light **104** and terahertz waves **105**.

[0035] The upper clad layer **202** and lower clad layer **203** are layers having lower refractive indices than the core layer **102**. Incident light **104** to the core layer **102** is trapped within the core layer **102** between the upper clad layer **202** and lower clad layer **203**. Accordingly, the light **104** propagates through the core layer **102** without exiting the waveguide **201**.

[0036] The substrate **101** and an MgO-doped LN crystal serving as the core layer **102** are bonded by an adhesive agent, such that the adhesive agent functions as the lower clad layer **203** in the present embodiment. The upper clad layer **202** is an adhesive agent for bonding the core layer **102** and the coupling member **103**. Note that the configuration of the waveguide **201** is not restricted to this configuration, and clad layers may be provided around the core layer **102** by bonding thereto other materials, having lower refractive indices than the core layer **102**, instead of the adhesive agent, for example.

[0037] The upper clad layer **202** is suitably formed of thin film of derivatives such as SiO_x or SiN_x or the like, or thin film of resins such as polyethylene terephthalate (PET), and so forth, having lower refractive indices than the LN crystal. The upper clad layer **202** is preferably thick enough to function as a clad layer but sufficiently thin to where the effects of multiple reflection and loss is negligible when externally extracting the terahertz waves from the coupling member **103**.

[0038] Specifically, in a case where part of the light **104** propagating through the core layer **102** leaks out into the upper clad layer **202**, it is sufficient for the intensity of light at the interface of the upper clad layer **202** and coupling member **103** to be $1/e^2$ or less that of the intensity of light at the core layer **102**. The thickness of the upper clad layer **202** is preferably around 1/10 or less the equivalent wavelength of the highest frequency terahertz waves **105** to be externally emitted, at the upper clad layer **202**. The reason is that generally, if the thickness of this structure is 1/10 or less the wavelength of the electromagnetic waves, the effects of reflection, scattering, refraction, and so forth can be considered to be negligible with regard to the electromagnetic waves.

[0039] That is to say, the thickness d of the upper clad layer **202** preferably satisfies $a<d<\lambda_{eq}/10$, where a represents a thickness where the intensity of light at the interface of the upper clad layer **202** and coupling member **103** is $1/e^2$ or less that of the intensity of light at the core layer **102**, and λ_{eq} represents equivalent wavelength of a wavelength equivalent to the maximum frequency of the terahertz waves **105** at the upper clad layer **202**. It should be noted, however, that terahertz waves can be generated using thicknesses other that that described above.

[0040] Also, $a<d$ is preferably satisfied regarding the lower clad layer **203**, so that the lower clad layer **203** functions as a clad layer regarding the light **104**. In a case of a configuration where the terahertz waves **105** are emitted to the lower portion of the core layer **102**, the thickness of the lower clad layer **203** also preferably satisfies the condition of $a<d<\lambda_{eq}/10$, in the same way as with the upper clad layer **202**.

[0041] The waveguide **201** can be formed by regions having lower refractive indices than the core layer **102** being formed above and below the core layer **102**, and the techniques for forming the waveguide **201** and the configurations thereof are not restricted in particular. That is to say, the technique is not restricted to bonding together members having different refractive indices using adhesive agent, and for example a technique for forming the waveguide **201** by diffusion or the like on a part of the substrate **101** using an LN crystal, may be used.

[0042] The width of the core layer **102** in the lateral direction (z-axial direction) is preferably small, taking into consideration generation of terahertz waves by the nonlinear effect. The reason is that in principle, the power density of generated terahertz waves **105** is proportionate to the square of the power density of the light **104** (the peak power density in a case where the light is a pulsed laser).

[0043] The waveguide **201** according to the present embodiment is a ridged waveguide where the lateral width of the core layer **102** is smaller than the wavelength of the terahertz waves to be generated, formed by a method where the portion to serve as the core layer **102** is imparted a high refractive index so as to have a difference in refractive index with the surrounding regions, a method where resin or the like is embedded around the core layer **102**, or the like. Moreover, an arrangement may be made where, instead of providing different clad layers around the core layer **102** as in the present embodiment, clad layers above, below, and to the sides, may be formed as an integral configuration.

[0044] If the width of the core layer **102** is too small, this may result in reduced coupling efficiency at the time of the light **104** entering the core layer **102**, increased waveguide loss, and so forth. Accordingly, the width of the core layer **102** is preferably no less than the center wavelength of the light **104** and no more than ten times this figure. Note that the term "center wavelength" means a wavelength in the spectrum of the light **104** where the intensity (amplitude) is the greatest.

[0045] The width of the core layer **102** is also preferably a width where the input light **104** can propagate through the core layer **102** in single mode. The reason is that if the light **104** propagates through the core layer **102** in multi-mode, the peak intensity of the light **104** decreases due to mode dispersion as the propagation proceeds, leading to lower efficiency in the conversion to terahertz waves **105**. Further, depending on the output of the light **104**, phenomena such as optical damage or the like may occur at the LN crystal, so the width of the core layer **102** has to be determined taking this point into consideration as well.

[0046] If optical damage occurs at the crystal **102** due to the output of the light **104** being strong, multiple waveguides may be provided so as to input the light **104** in a divided manner. An arrangement may also be made where multiple waveguides of different structures and materials are provided, and the light **104** is input to the waveguides so as to generate terahertz waves **105** having intended properties.

[0047] Further, interference may be caused among terahertz waves generated from multiple waveguides, so as to adjust the beam form and beam direction of the terahertz waves. Such a configuration should be made so that the terahertz waves to be extracted do not cancel each other out by interference. The way in which the multiple waveguides are arrayed is not restricted in particular; multiple waveguides may be arrayed in the z direction or y direction, or in a non-parallel manner. Further, a slab waveguide may be applied where the core layer **102** extends laterally in a uniform manner.

[0048] Next, the configuration of the coupling member **103** will be described. The material used for the coupling member **103** is one where the terahertz waves **105** are not totally reflected at the interface of the waveguide **201** and the coupling member **103**, but rather can be extracted as traveling waves within the coupling member **103**, and one where loss of the terahertz waves **105** is small. An example of a material which satisfies these conditions is high-resistance silicon (Si).

[0049] The coupling member **103** has a shape which is convex in the propagation direction of the terahertz waves **105** generated from the crystal **102**, and has a reflecting face **107** which reflects and corrects at least part of the generated terahertz waves. The expression to "collect" terahertz waves is defined as suppressing the dispersion of the terahertz waves as compared to before reflection, such as making the dispersing terahertz waves parallel, and so forth, in addition to converging the terahertz waves.

[0050] The reflecting face **107** is arranged such that the angle between the propagation direction of the light **104** and the reflecting face **107** of the coupling member **103** at a plane including the propagation direction of the light **104**, that is to say the magnitude of inclination a of the reflecting face **107** as to the direction of propagation of the light **104**, satisfies

$$90\text{ degrees}-\theta_{clad}<\alpha<90\text{ degrees} \qquad (2)$$

where θ_{clad} is the Cherenkov angle at the coupling member **103**, and from Expression (1), $\theta_{clad}=\cos^{-1}(n_g/n_{THz})$. Also, n_g is group refractive index of the crystal **102** with regard to light, and n_{THz} is the refractive index of the crystal **102** with regard to the terahertz waves.

[0051] Note that while the first plane includes the propagation direction of the light **104** and is perpendicular to the surface of the crystal **102** in the present embodiment, the present invention is not restricted to this, so it is sufficient for the first plane to include the propagation direction of the light **104**, and inclination as to the substrate **101** or waveguide **201** is not restricted in particular. This configuration results in the terahertz waves **105** reflecting at the reflecting face **107** and being emitted from a transmission face **108**.

[0052] Also, in a case where the reflecting face **107** is provided so as to satisfy Expression (3), the terahertz waves **105** do not transmit the reflecting face **107** but are totally reflected. Particularly, in a case where the reflecting face **107** satisfies Expression (4), the wavefront **106** of the terahertz waves **105** reflected at the reflecting face **107** can be shaped so as to be planar.

$$\alpha \geq \sin^{-1}(n_e/n_{THz}) + 90\text{ degrees} - \theta_{clad} \tag{3}$$

$$\alpha = 90\text{ degrees} - \theta_{clad}/2 \pm \lambda/8 \tag{4}$$

where n_e is the external refractive index of the coupling member **103**, and λ is the wavelength of the terahertz waves generated from the nonlinear optical crystal.

[0053] In this case, the incident angle i of the terahertz waves **105** to the reflecting face **107**, and the reflection angle j when reflecting, satisfy Expression (5). Note that the incident angle of terahertz waves in the present specification is the angle between the generated terahertz waves input to the reflecting face and a perpendicular to the reflecting face. The reflection angle is the angle between the terahertz waves reflected at the reflecting face and a perpendicular to the reflecting face.

$$i = j = \theta_{clad}/2 \tag{5}$$

[0054] An LN crystal is used for the crystal (core layer) **102** and high-resistance silicon (Si) is used for the coupling member **103** in the present embodiment, so according to Expression (1), the Cherenkov angle at the waveguide **201** is approximately 65 degrees. The terahertz waves **105** refract at the time of input to the coupling member **103** from the waveguide **201**, and the Cherenkov angle θ_{clad} at the coupling member **103** is approximately 50 degrees. The element **100** is configured such that the angle α between the propagation direction of the light **104** and the reflecting face **107** at the first plane is 65 degrees, which satisfies Expression (4).

[0055] FIGS. **3**A through **3**D are examples of cross-sectional views at a face (second plane) orthogonal to the propagation direction of the light **104** in the terahertz wave generating element **100** according to the present embodiment. At least part of the cross-section of the reflecting face **107** of the coupling member **103** at the second plane includes a curve which is concave at the crystal **102** side, i.e., a curve which is convex toward the propagation direction of the terahertz waves **105**, with the center of the curve being in the propagation direction of the light **104**.

[0056] The reflecting face **107** of the coupling member **103** is configured such that the length thereof at a cross-section orthogonal to the propagation direction of the light **104** is longer the farther upstream in the propagation direction of the light **104**, within a reflection region where the terahertz waves **105** are reflected. In other words, the radius of curvature of the reflecting face **107** in the reflection region where the terahertz waves **105** are reflected is smaller the farther downstream in the propagation direction of the light **104**.

[0057] Specifically, in the reflection region where the terahertz waves **105** are reflected, the radius of curvature at a cross-section which passes through a first position and is orthogonal to the propagation direction of the light **104**, is longer than the radius of curvature at a cross-section which passes through a second position and is orthogonal to the propagation direction of the light **104**. Accordingly, the length of the reflecting face **107**, at a cross-section which passes through the first position in the propagation direction of the light **104** and is orthogonal to the propagation direction of the light **104**, is longer than the length of the reflecting face **107** at a cross-section which passes through the second position which is downstream of the first position in the propagation direction of the light **104** and is orthogonal to the propagation direction of the light **104**.

[0058] That is to say, the reflecting face **107** is configured such that the optical power at the reflecting region, reflecting the terahertz waves generated downstream in the propagation direction of the light **104**, is greater than the optical power at the reflecting region reflecting the terahertz waves generated upstream in the propagation direction of the light **104**. This configuration enables distortion in power distribution of the terahertz waves **105** generated at the crystal **102** to be reduced.

[0059] One example is a configuration where a cross-section at the second plane has a curve such as an arc or the like, as illustrated in FIG. **3**A. In this case, the wavefront of the terahertz waves **105** emitted to the coupling member **103** is emitted conically with the first plane **301** as a plane of symmetry, the terahertz waves **105** can be shaped by reflection at the reflecting face **107**.

[0060] The present invention is not restricted to the above example, and a configuration where a part of the arc which is the curve is missing, or the like, such as illustrated in FIGS. **3**B and **3**C, can be applied as well. In this case, an arrangement is made where a region where the power of the generated terahertz waves **105** is small corresponds to the missing portion, is terahertz waves with substantially greater power can be formed and extracted. Also, a configuration including an ellipse such as illustrated in FIG. **3**D enables forming a beam converging in the z-axial direction of the crystal **102**. These and various other forms may be made.

[0061] Note that the reflecting face **107** may be symmetrical with the first plane **301** as a plane of symmetry, in cross-section at a plane orthogonal to the propagation direction of the light **104**, or may be asymmetric as illustrated in FIG. **3**C.

[0062] The reflecting face **107** according to the present embodiment is a shape including a part of a conical face of which the propagation direction of the light **104** is the axis. The propagation direction of the light **104** and the axis of the conical face preferably match at a precision of equivalent wavelength of the terahertz waves **105** or finer. The present invention is not restricted to this arrangement though, and a shape including a part of a curved face obtained by rotating any straight line or curve on the propagation direction of the light **104** as the axis thereof, or the like, is applicable.

[0063] The terahertz waves **105** reflected at the reflecting face **107** are transmitted through the transmission face **108** of the coupling member **103** and externally emitted. While the present embodiment describes the terahertz waves **105** as perpendicularly entering the transmission face **108**, this is not restrictive. For example, Fresnel loss due to reflection can be reduced by causing the terahertz waves **105** to be transmitted through the transmission face **108** at Brewster's angle (16.3 degrees in a case where the coupling member **103** is formed of silicon). The coupling member **103** may further include another reflecting face, separate from the reflecting face **107**.

[0064] Power distribution of the terahertz waves **105** generated using the element **100** will be described. Power distribution in a terahertz wave generating element **1400** (hereinafter referred to as "element **1400**") using the collimator according to PTL 2 as a coupling member **103** will be described for the sake of comparison.

[0065] The configuration of the element **1400** to which PTL 2 has been applied is illustrated in FIG. **14**. Note that while PTL 2 generates second harmonic waves from light **1404** entering a nonlinear optical crystal **1402** (hereinafter referred to as "crystal **1402**"), this is replaced with a configuration to generate terahertz waves in accordance with the present embodiment, in the following description. While the generation principles of second harmonic waves and terahertz waves in a nonlinear optical crystal are different as such, these are the same with regard to the fact that electromagnetic waves are omitted from a waveguide by Cherenkov phase matching.

[0066] The element **1400** to which the related art has been applied includes a substrate **1401** having the crystal **1402** and a coupling member **1403**, and the coupling member **1403** has a reflecting face **1406**. A member which functions as a clad layer is interposed between the crystal **1402** and the coupling member **1403**. At least a part of a primary portion of the reflecting face **1406** which reflects the terahertz waves **1405** generated from the crystal **1402** includes a conical face, the axis of the conical face matching the propagation direction of the light **1404** propagating through the crystal **1402**.

[0067] Setting the Cherenkov angle θ_{clad} to 50 degrees, and the refractive index of the coupling member **1403** at the wavelength of the terahertz waves **1405** to 3.42, the half apex angle α of the conical face is 25 degrees, in accordance to the expression ($r=i=j=\theta_{clad}/2$) described in PTL 2. The incident angle i of terahertz waves **1405** to the reflecting face **1406** is 25 degrees, and the reflection angle j is 25 degrees.

[0068] Upon the light **1404** entering the crystal **1402**, the terahertz waves **1405** generated from the crystal **1402** are reflected at the reflecting face **1406** of the coupling member **1403** and shaped, and travel in the same direction as the propagation direction of the light **1404** through the crystal **1402**. The terahertz waves **1405** reflected at the reflecting face **1406** are then emitted externally from the coupling member **1403** by perpendicularly transmitting through the transmission face **1407**. The wavefront **1408** of the conically-emitted terahertz waves **1405** is shaped as a plane and externally emitted by this configuration.

[0069] Power distribution of terahertz waves will be described with reference to FIGS. **4**A and **4**B. FIG. **4**B is a diagram viewing the wavefronts **106** and **1408** of the terahertz waves emitted from the respective coupling members **103** and **1403** of the two elements **100** and **1400**, from the upstream side in the propagation direction of the light **104** and **1404**. FIG. **4**A is a power distribution diagram of terahertz waves at various positions on an A**1**-A**2** cross-section in FIG. **4**B. The power of the terahertz waves **105** from the element **100** are represented by circles, and the power of the terahertz waves **1405** from the element **1400** are represented by triangles. The horizontal axis in FIG. **4**A represents the positions on the A**1**-A**2** cross-section, with the smaller values toward the A**1** side and the and larger values toward the A**2** side.

[0070] It can be seen from FIG. **4**A that the power distribution of the terahertz waves **1405** generated at the element **1400** is such that the power of terahertz waves markedly deteriorates toward the A**2** side of the A**1**-A**2** cross-section. In comparison, there is little difference in power at any position in the power distribution of the terahertz waves **105** generated by the element **100** according to the present embodiment, so it can be seen that distortion in power distribution is reduced.

[0071] When light is input to a waveguide including a nonlinear optical crystal, the power of the light on the waveguide is smaller the farther from the input end of the waveguide. This is due to the pulse width of the light spreading as being propagated over the waveguide. It is known that other varying factors include dispersion due to material, waveguide loss, non-uniformity of the crystal, phase properties of light input to the waveguide, and so forth.

[0072] As the lower of light becomes weaker, the power of terahertz waves generated from the nonlinear optical crystal also becomes weaker as the light propagates through the waveguide. That is to say, the power of terahertz waves becomes smaller toward the downstream side in the propagation direction of the light, exhibiting a power distribution such as illustrated in FIG. **5**.

[0073] On the other hand, both the reflecting faces **107** and **1406** are part of a conical face, so the length of the reflecting face at a cross-section orthogonal to the propagation direction of the light (hereinafter may be referred to simply as "length of reflecting face") may differ depending on the position where the terahertz waves are reflected. If terahertz waves which have uniform power are input to all positions of the reflecting face, the terahertz waves reflected at positions where the length of the reflecting face is longer will be dispersed and the power will be lower. On the other hand, the terahertz waves reflected at positions where the length of the reflecting face is shorter will have higher density, and the power will be greater than terahertz waves reflected at positions where the length of the reflecting face is longer.

[0074] In the case of the element **1400** to which the PTL 2 has been applied, the closer toward the input end side of the crystal **1402** where the light **1404** is input (the upstream side in the propagation direction of the light) the terahertz waves **1405** are generated, the greater the power of these terahertz waves **1405** is, and these are reflected at the shorter-length portions of the reflecting face **1406**. The further downstream in the propagation direction of the light **1404** the terahertz waves **1405** are generated, the weaker the power of these terahertz waves **1405** is, and these are reflected at the longer-length portions of the reflecting face **1406**. That is to say, the weaker the power of terahertz waves **1405** is, the greater the dispersion at the reflecting face **1406** and deterioration of power density is, so the greater the distortion of power distribution at the A**1**-A**2** cross-section is.

[0075] On the other hand, the element **100** according to the present embodiment is configured such that the terahertz waves **105** of which the power is weaker are reflected at portions where the length of the reflecting face **107** is short, and the terahertz waves **105** of which the power is greater are reflected at portions where the length of the reflecting face **107** is long. That is to say, the effect which change in power of the light **104** propagating through the crystal **102** has on the power distribution of the terahertz waves **105**, and the effect which the length of the reflecting face **107** has on the power distribution of the terahertz waves **105**, are opposite. Thus, the distortion in power distribution of the generated terahertz waves **105** can be reduced.

Second Embodiment

[0076] A terahertz wave generating element **600** (hereinafter referred to as "element **600**") according to a second embodiment will be described with reference to FIG. **6**. While total reflection of the terahertz waves **105** was performed at the reflecting face **107** of the coupling member **103** in the first embodiment, a reflecting face **606** of a coupling member **601** of the present embodiment transmits part of the generated terahertz waves **603**.

[0077] The element **600** includes a substrate **101**, a waveguide **201** which has a crystal (core layer) **102**, and a coupling member **601**. The substrate **101** and waveguide **201** are of the same configuration as the first embodiment. Light **602** propagates through the crystal **102** to generate terahertz waves **603**.

[0078] A diamond material is used for the coupling member **601**. Assuming the refractive index of diamond as to terahertz waves around a frequency of 1 THz to be 2.38, according to Expression (1), the Cherenkov angle θ_{clad} in a case of the generated terahertz waves **605** being emitted at the coupling member **603** is 24 degrees.

[0079] Setting the angle α between the reflecting face **606** and the propagation direction of the light so as to satisfy Expression (4) yields an incident angle i of the terahertz waves **603** as to the reflecting face **606** of 12 degrees, and a reflection angle j of 12 degrees from Expression (5). An angle k between the terahertz waves **603** which have transmitted through the reflecting face **606** and a perpendicular to the reflecting face **606** (output angle) is 29 degrees.

[0080] The total reflection angle emitted from diamond to the atmosphere is 25 degrees, so total reflection of the terahertz waves **603** at the reflecting face **606** does not occur, and a part is transmitted. Calculation by the Fresnel equations with the polarization of the terahertz waves **603** as linearly polarized light in the z direction yields that the power transmittance of the terahertz waves **603** at the reflecting face **606** is 79%. This transmittance can be optionally adjusted by coating the reflecting face **606** with resin or the like.

[0081] The length of the reflecting face **606** at a cross-section which passes through a first position in the propagation direction of the light **602** and is orthogonal to the propagation direction of the light **602**, is longer than the length of the reflecting face **606** at a cross-section which passes through a second position downstream from the first position in the propagation direction of the light **602** and is orthogonal to the propagation direction of the light **602**. It is sufficient for this condition to be satisfied at reflection regions where the terahertz waves **603** generated from the crystal **102** are reflected. That is to say, the radius of curvature of the reflecting face **606** at reflection regions where the terahertz waves **603** generated from the crystal **102** are reflected is smaller toward the downstream side in the propagation direction of the light **602**.

[0082] The terahertz waves **603** which have been reflected at the reflecting face **606** or transmitted through the reflecting face **606** are both emitted externally with distortion of power distribution having been reduced. The configuration of the element **600** according to the present embodiment where the coupling member is configured such that part of the generated terahertz waves **603** are transmitted allows terahertz waves **603** which have been shaped and distortion in power distribution reduced, to be branched into two.

[0083] The angle α between the propagation direction of the light **602** and the reflecting face **606** of the coupling member **601** is configured so as to satisfy the above-described Expression (4) in the present embodiment. Accordingly, the terahertz waves **603** reflected at the reflecting face **606** are shaped so that the wavefront **605** is planar, and externally emitted. The terahertz waves **603** which have transmitted through the reflecting face **606** are also shaped so that the wavefront **604** is planar, and externally emitted. Thus, according to the present embodiment, multiple outputs of terahertz waves, which have been shaped and power distribution distortion reduced, can be obtained.

[0084] The terahertz waves **603** split into two at the reflecting face **606** may be used separately, or the two outputs of terahertz waves **603** may be coaxially joined again after each being emitted form the coupling member **601**, subjected to interference and used for detection. This can be used with various types of known interferometers, such as the Michelson interferometer.

Third Embodiment

[0085] A third embodiment will now be described. In the first and second embodiments, the terahertz waves **105** generated from the crystal **102** have been described as being externally extracted through the coupling member **103**. In a case of use as a terahertz waves generating source in an information acquiring apparatus using terahertz waves, the extracted terahertz waves are guided to a specimen by an optical system and measurement is performed. In comparison, in the present embodiment a specimen **701** is placed at an optional face of the coupling member **103** of an element **100**, and the specimen **701** is measured. A configuration where the specimen **701** is disposed on the reflecting face **107** is exemplarily illustrated in FIG. **7**A, and a configuration where the specimen **701** is disposed on the transmission face **108** is exemplarily illustrated in FIG. **7**B.

[0086] The terahertz wave generating element according to the present embodiment has the same configuration as the element **100** according to the first embodiment. That is to say, the element **100** has a substrate **101**, crystal **102**, and coupling member **103**, with light **104** being propagated through the crystal **102** to generate terahertz waves **105**, which are emitted to the coupling member **103**. The emitted terahertz waves **105** are reflected at the reflecting face **107** of the coupling member **103**.

[0087] The generated terahertz waves **105** are reflected at the interface of the specimen **701** disposed on the reflecting face **107** and the coupling member **103**, and externally emitted, as illustrated in FIG. **7**A. Alternatively, a configuration may be made such as illustrated in FIG. **7**B, where the specimen **701** is disposed on the transmission face **108**, so that the terahertz waves **105** are reflected at the reflecting face **107**, and then transmitted through the transmission face **108** and specimen **701** to be externally emitted. Accordingly, the externally emitted terahertz waves **105** are affected by optical properties and the like of the specimen **701**, which can be detected and studied to obtain information regarding the specimen **701**.

[0088] According to the present embodiment, a specimen can be measured using terahertz waves with little distortion in power distribution. This configuration also does away with the need to provide an external optical system and space to irradiate the specimen by the terahertz waves, which can contribute to reduction in size of the information acquiring apparatus.

Fourth Embodiment

[0089] A terahertz wave generating element **800** (hereinafter referred to as "element **800**") according to a fourth embodiment will now be described with reference to FIG. **8**. FIG. **8** is a diagram for describing the configuration of the element **800**. The element **800** has the same configuration as the element **100** according to the first embodiment. That is to say, the element **800** has a substrate **101**, crystal (core layer) **102**, and coupling member **103**. While the embodiments described above have been with regard to terahertz wave generating elements, the element **800** according to the present embodiment detects terahertz waves **802** which have passed through the coupling member **103** and reached the crystal **102**.

[0090] Linearly-polarized light **801** is input to the crystal **102** with the polarization thereof at an optionally inclined angle from the z-axis direction of the crystal **102** toward the y-axis direction (e.g., 45 degrees). At this time, the light **801** is input to the crystal **102** from a face facing the face which was used in the first through third embodiments for input of light **104**.

[0091] Phase difference occurs between the z-axis component and y-axis component in the electric field of the light **801** propagated through the crystal **102** and emitted, due to the birefringent properties of the crystal **102**, so the light **801** is elliptically polarized. Such phase difference due to birefringence differs depending on the type of nonlinear optical crystal used as the crystal **102**, the direction of incident polarization, the length of the waveguide **201**, and so forth. The phase difference can be negated to zero depending on the configuration.

[0092] The terahertz waves **802** are input from the transmission face **108** of the coupling member **103** in a state where the wavefront **803** is planar, reflected at the reflecting face **107**, and then collected at the crystal **102**. The light **801** is being propagated through the crystal **102**, there is interaction between the terahertz waves **802** and the light **801** within the crystal **102**, according to a process opposite to that of generating terahertz waves **802**.

[0093] Note that the light **801** is input from the face facing the face from which the light **104** is input in the crystal **102** of the element **100**, so the upstream side and downstream side in the propagation direction of the light is opposite to that in the first through third embodiments. The reflecting face is convex in a direction opposite to the propagation direction of the terahertz waves **802** input to the nonlinear optical crystal. The length of the reflecting face **107** at a cross-section which passes through a first position in the propagation direction of the light **801** and is orthogonal to the propagation direction of the light **801**, is longer than the length of the reflecting face **107** at a cross-section which passes through a second position upstream from the first position in the propagation direction of the light **801** and is orthogonal to the propagation direction of the light **801**. It is sufficient for this configuration to be established at reflection regions where the terahertz waves **802** generated from the crystal **102** are reflected. That is to say, the radius of curvature of the reflecting face **107** at reflection regions where the terahertz waves **802** entering from the transmission face **108** are reflected is greater toward the downstream side in the propagation direction of the light **801**.

[0094] Upon terahertz waves **802** being input while the light **801** is propagating through the crystal **102**, linear electro-optic effect (Pockels effect, a type of secondary nonlinear process) occurs at the crystal **102** due to the electric field of the terahertz waves **802**. Accordingly, the refractive index of the z axis of the crystal **102** changes, and the polarization state of the light **801** changes.

[0095] AS a result, in addition to the phase difference occurring due to birefringent properties of the crystal **102**, phase difference also occurs regarding the z-axis component of the light **801** under the influence of the electric field of the terahertz waves **802**. On the other hand, the phase difference occurring regarding the y-axis component of the electric field of the light **801** is only phase difference due to the birefringent properties of the crystal **102**. The phase difference occurring regarding the z-axis component of the light **801** and the phase difference occurring regarding the y-axis component differ, so the propagation state of the light **801** omitted from the crystal **102**, such as the ellipticity of the elliptic polarization, the direction of the primary axis, and so forth, changes. If this change can be detected by an external polarization element (omitted from illustration) and light detector (omitted from illustration) and so forth, the intensity of the magnetic field of the terahertz waves **802** can be detected.

[0096] The light **801** emitted from the crystal **102** may be detected by splitting into two polarized rays using a Wollaston prism, and improving the S/N ratio by differential amplification of two light detectors (omitted from illustration). This improving of the S/N ratio by differential amplification is not essential, so one light detector alone may be employed, using a polarization plate. A phase compensation plate (e.g., quarter wave plate) may be added between the output end of the crystal **102** and a polarizer that is omitted from illustration, for compensation for inductive birefringence.

[0097] While the face facing the face used of input of light **104** in the first through third embodiments is used for input of light to the crystal **102** in the present embodiment, light **801** may be input from the same face (end). In this case, the matching length is shorter so signal intensity is weaker.

[0098] Also, the present embodiment investigates the effects of terahertz waves **802** using the phenomenon in which the polarization state of light **801** is changed by the linear electro-optic effect by the terahertz waves **802**, but the present invention is not restricted to this. Other methods may be used, such as detecting phase change of light **801** propagating through the crystal **102**, or detecting light signals of difference frequency of the frequency of the light **801** propagating through the crystal **102** and frequency of the terahertz waves **802**, i.e., detecting beat signals of the light, and so forth.

[0099] The detection sensitivity of the terahertz waves **802** is dependent on the state of the light **801** and the intensity of the terahertz waves **802**. Even if terahertz waves **802** with little distortion in power distribution are input to the coupling member **103** of the element **800**, the distortion in power distribution increases by the terahertz waves **802** reflecting off of the reflecting face **107**. Accordingly, detection sensitivity can be improved by adjusting the propagation state of the light **801** so that the light **801** is at a suitable state for detection at the position where the power of the terahertz waves **802** is great.

[0100] In the present embodiment, the terahertz waves **802** which have transmitted the specimen or reflected at the specimen are guided to the coupling member **103** of the element **800**, and input to the crystal **102** via the reflecting face **107**. However, this arrangement is not restrictive, and an arrangement may be made where the specimen **901** is situated on any face of the coupling member **103** of the element **800**, as illustrated in FIGS. **9**A and **9**B.

[0101] In the arrangement illustrated in FIG. **9**A, the terahertz waves **802** which have transmitted through the transmission face **108** from the outside and entered the coupling member **103** are reflected at the interface of the specimen **901** positioned at the reflecting face **107** and the coupling member **103**, and then enter the crystal **102**. In the arrangement illustrated in FIG. **9**B, the terahertz waves **802** which have transmitted through the specimen **901** and transmission face **108** from the outside and entered the coupling member **103** are reflected at the reflecting face **107** and enter the crystal **102**. These configurations do away with the need to provide an external optical system and space to guide terahertz waves reflected at or transmitted through the specimen to the detector, which can contribute to reduction in size of the information acquiring apparatus.

Fifth Embodiment

[0102] A fifth embodiment will be described with reference to FIG. **10**A. FIG. **10**A illustrates an example of the configuration of a terahertz wave generating/detecting element **1000** (hereinafter referred to as "element **1000**") according to the present embodiment. The elements **100** in the first through third embodiments have been described as having functions to generate terahertz waves, and the element **800** in the fourth embodiment has been described as having functions to detect terahertz waves generated at a separate generating element. On the other hand, the element **1000** according to the present embodiment both generates and detects terahertz waves with a single element.

[0103] The element **1000** has a substrate **101**, a crystal **102**, and a coupling member **1001**. The substrate **101** and the waveguide **201** including the crystal **102** are of the same configuration as with the first embodiment. the coupling member **1001** is the same as the coupling member **103** according to the first embodiment with regard to material and shape, but the coupling member **1001** has two reflecting faces **1005** and **1006**, whereas the coupling member **103** has the reflecting face **107** and transmission face **108**.

[0104] Describing the element **1000** in more detail, generating light **1002** propagating through the crystal **102** generates terahertz waves **1004**. The generated terahertz waves **1004** propagate through the coupling member **1001**, and reflect at the reflecting face **1006** and thus are shaped.

[0105] Thereafter, the terahertz waves **1004** are reflected at the reflecting face **1005**, reflected again at the reflecting face **1006**, and input to the crystal **102**. Detection light **1003** for detecting the terahertz waves **1004** is input from a face facing the face from which the light **1002** of the crystal **102** has been input, so the terahertz waves **1004** can be detected in the same way as with the fourth embodiment.

[0106] In this case, placing the specimen **1007** at the reflecting face **1006** as illustrated in FIG. **10**A allows information of the specimen **1007** to be obtained by detecting the terahertz waves **1004** reflected at the specimen **1007**. Alternately, the specimen **1007** may be positioned on the reflecting face **1005**, as illustrated in FIG. **10**B.

[0107] While the configuration of the present embodiment involves providing one waveguide **201** including the crystal **102**, a separate waveguide may be provided, so that the generation light **1002** and detection light **1003** are each input from different waveguides. The light source of the generation light **1002** and detection light **1003** may be the same or may be different. In a case where the same light source is to be used, the light from the light source is first split into two by a beam splitter or the like before input to the crystal **102**, and then the two are input to the crystal **102**. Also, generation light **1002** that was emitted from the crystal **102** without being converted into terahertz waves may be used as detection light **1003**.

[0108] The element **1000** according to the present embodiment can measure the specimen **1007** with reduced distortion in the power distribution of the generated terahertz waves. The detected terahertz waves **1004** have distortion in power distribution, so detection sensitivity can be improved by adjusting so that the detection light **1003** is in a suitable state for detection at a position where the power of the terahertz waves **1004** input to the crystal **102** is strong.

[0109] Further, there is no need to externally provide peripheral optical systems to handle the terahertz waves **1004**, so a small-sized generating/detecting element can be provided. Such a terahertz wave generating/detecting element may be applied to small-sized probes, such as endoscopes or the like, and so forth.

Sixth Embodiment

[0110] A modification of the terahertz wave generating element according to the fifth embodiment will be described in the sixth embodiment, with reference to FIG. **11**. FIG. **11** is a diagram for describing the configuration of a terahertz wave generating/detecting element **1100** (hereinafter referred to as "element **1100**"). The element **1100** is a configuration which further has a triangular prism **1101** added to the configuration of the element **100** according to the first embodiment.

[0111] The triangular prism **1101** is disposed in contact with the transmission face **108** of the coupling member **103**, and a specimen **1106** is disposed on a total-reflection face **1103** of the triangular prism **1101**. The triangular prism **1101** is a prims including Si, and a face **1104** is coated with a conductive material such as metal or the like which reflects terahertz waves well.

[0112] The total-reflection face **1103** of the triangular prism **1101** is a face which totally reflects the terahertz waves **1102**. If the refractive index of the specimen **1106** is assumed to be 2, the total reflection angle in a case of terahertz waves **1102** being input from the triangular prism **1101** to the specimen **1106** is 36 degrees. The refractive index of the specimen **1106** is assumed to be 2 in the present embodiment, and the incident angle of the terahertz waves **1102** as to the total-reflection face **1103** is set to be 45 degrees, thus making a configuration where there is total reflection of the terahertz waves **1102** at the total-reflection face **1103**. Note that the reflection of terahertz waves **1102** at the interface between the coupling member **103** and the triangular prism **1101** is preferably as close to zero as possible.

[0113] The element **1100** generates terahertz waves **1102** upon generation light **1107** being input to the crystal **102**. The generated terahertz waves **1102** are reflected at the reflecting face **107**, upon which power distribution distortion of the terahertz waves **1102** is reduced. Thereafter, the terahertz waves **1102** are transmitted through the transmission face **108** and input to the triangular prism **1101**.

[0114] The terahertz waves **1102** are propagated through the triangular prism **1101**, totally reflected at the interface of the total-reflection face **1103** and the specimen **1106**, perpendicularly reflected at the face **1104**, and retraces its own path to be input to the crystal **102**. Analyzing the detection light **1108** emitted from the crystal **102** enables detection of terahertz waves and information of the specimen **1106** to be obtained, in the same way as with the fourth embodiment.

[0115] While the transmission face **108** of the coupling member **103** and the triangular prism **1101** are disposed adjacently in the present embodiment, this is not restrictive, and the coupling member **103** and the triangular prism **1101** may be integrated. Also, the form of the triangular prism **1101** used in the present embodiment is not restricted in particular, as long as the configuration is such that there is total reflection of the terahertz waves **1102** at the total-reflection face **1103** where the specimen **1106** is disposed, and the totally reflected terahertz waves **1102** are input to the crystal **102**.

[0116] According to the element **1100** of the present embodiment, distortion in power distribution of generated terahertz waves can be reduced. Specimen measurement can also be performed using the terahertz waves with reduced power distribution distortion. Further, there is no need to externally provide peripheral optical systems to handle the terahertz waves, so a small-sized generating/detecting element can be provided.

Seventh Embodiment

[0117] Generating single-frequency terahertz waves will be described as a seventh embodiment. In the present embodiment, single-frequency terahertz waves are generated using the element **100** according to the first embodiment. The first embodiment uses ultrashort pulse laser for the light to be input to the crystal **102**. Conversely, the terahertz wave generating element according to the present embodiment generates single-frequency terahertz waves by inputting two lights with different oscillation frequencies to the crystal **102**.

[0118] Examples of light sources which output light of two different oscillation frequencies include neodymium-doped yttrium aluminum garnet (Nd:YAG)-excited potassium titanyl phosphate optical parametric oscillator (KTP-OPO), two wavelength-variable laser diodes, and so forth. Hereinafter, the two light oscillation frequencies will be referred to as v**1** and v**2**.

[0119] Upon the light of the two different oscillation frequencies v**1** and v**2** being input to the crystal **102**, single-frequency terahertz waves **105**, equivalent to the differential wave between the oscillation frequency v**1** and the oscillation frequency v**2**, are generated. The generated terahertz waves **105** are reflected at the reflecting face **107**, reducing distortion in power distribution thereof, in the same way as with the above-described embodiments.

[0120] Such a single-frequency terahertz wave generating method can be applied to cases of performing testing or imaging using terahertz waves of a particular frequency, such as testing an inclusion amount of a particular substance in a pharmaceutical product by matching the frequency to the absorption spectrum of that particular substance.

[0121] The method for generating single-frequency terahertz waves is not restricted to application to the first embodiment, but rather can be applied the terahertz wave generating devices, detecting devices, and generating/detecting devices according to the second through sixth embodiments. In a case where light having two different oscillation frequencies is input to a nonlinear optical crystal of a terahertz wave detecting element or terahertz wave generating/detecting element, single-frequency terahertz waves, equivalent to the differential wave between the oscillation frequencies v**1** and v**2**, can be detected. Changing the frequency difference of the two lights enables detection of amplitude of terahertz waves at a desired frequency.

Eighth Embodiment

[0122] Description will be made in an information acquiring apparatus **1200** (hereinafter referred to as "apparatus **1200**") using terahertz waves, in an eight embodiment. The apparatus **1200** is a terahertz time-domain spectroscopy (THz-TDS) apparatus which uses the THz-TDS principle to acquire the time waveform of terahertz waves. The apparatus **1200** acquires time waveforms of terahertz waves **1230** reflected at a specimen **1216**, as information of the specimen **1216**. The optical properties, shape, and other such information of the specimen **1216** can be acquired using the acquired time waveform. An arrangement may also be made where an image is formed based on the obtained information of the specimen **1216**.

[0123] FIG. **12**A is a configuration diagram of the apparatus **1200**. The apparatus **1200** includes a light source **1201**, a branching unit **1202**, a generating unit **1204**, parabolic mirrors **1205***a* through **1205***d*, a beam splitter **1206**, a detecting unit **1207**, an optical delay **1209**, an amplifying unit **1212**, a modulating unit **1213**, a signal acquiring unit **1214**, and a processing unit **1215**.

[0124] The light source **1201** generates light, and includes an optical fiber. The light source **1201** according to the present embodiment outputs femtosecond laser (hereinafter referred to as "laser light").

[0125] The laser light output from the light source **1201** is branched into two at the branching unit **1202**, with one output thereof passing through an optical fiber **1203** and being input to the generating unit **1204**, while the other passes through an optical fiber **1208** and reaches the detecting unit **1207**. Note that the optical fibers **1203** and **1208** may include highly nonlinear optical fibers to perform higher soliton compression, dispersion optical fiber for pre-chirping to reduce the effects of laser light dispersion from the generating unit **1204** to the detecting unit **1207**, or the like. There are also preferably polarization maintaining optical fibers.

[0126] The generating unit **1204** is a unit which generates terahertz waves, and includes the element **100** according to the first embodiment. The terahertz waves **1230** are generated by laser light passing through the optical fiber **1203** and entering the crystal **102** of the element **100** serving as the generating unit **1204**. The generated terahertz waves **1203** are propagated through the coupling member **103** and externally extracted.

[0127] The optical fiber **1203** is preferably configured such that the output of the laser light is no greater than the numerical aperture (NA) of the crystal **102**. This can be realized by a method where the tip of the optical fiber **1203** is formed to be a pigtail, or the like. This is to raise the coupling efficiency of input laser light from the optical fiber **1203** to the crystal **102**. Space coupling may also be performed using a lens. In these cases, applying a non-reflective coating to the ends of the optical fiber **1203** and crystal **102** enables reduction of Fresnel loss and unnecessary interference noise. The optical fiber **2013** may be bonded to the crystal **102** by direct coupling (butt-coupling) with the NA and mode field diameter being designed to be close to the Na and mode field diameter of the crystal **102**. Reflection can be reduced in this case by selecting a suitable adhesive agent.

[0128] Note that in a case where a non-polarization-maintaining optical fiber is included in the optical fiber **1203**, light source **1201**, or the like, the polarization of the laser light input to the generating unit **1204** is preferably stabilized by an inline polarization controller.

[0129] The specimen **1216** is irradiated by the terahertz waves **1230** from the generating unit **1204** which pass through an optical system including parabolic mirrors **1205***a* and **1205***b*, the beam splitter **1206**, and a parabolic mirror **1205***c*. the terahertz waves **1230** which have reflected at the specimen **1216** are collected at a parabolic mirror **1205***d* and input to the detecting unit **1207**.

[0130] On the other hand, the laser light passing through the optical fiber **1208** passes through the optical delay **1209** and lens **1210** and is input to the detecting unit **1207** from the opposite side as to the terahertz waves **1230** reflected at the specimen **1216**. Hereinafter in the present specification, the laser light entering the detecting unit **1207** will be referred to as "probe light".

[0131] The optical delay **1209** is a portion where the timing of detection of the terahertz waves **1230** is adjusted by appropriately changing the difference in the length of the optical paths over which the terahertz waves **1230** and the probe light travel to enter the detecting unit **1207**. A loopback optical system for loopback of the probe light, and a movable portion which moves the loopback optical system, are used in the present embodiment to change the length of the optical path over which the probe light travels to be input to the detecting unit **1207**.

[0132] The optical delay **1209** is not restricted to the above-described configuration. A rotating system may be applied to the moving portion. Alternatively, a method where the refractive index along the propagation path of the probe light is adjusted to change the optical path length, or the like, may be applied as well. On the other hand, the length of the optical path over which the laser light travels from the light source **1201** to the generating unit **1204** may be changed instead of the path over which the probe light travels, using a method such as described above.

[0133] The detecting unit **1207** is the part where the terahertz waves **1230** are detected, and uses a photoconductive element which has been fabricated by forming a dipole antenna on low-temperature-grown gallium arsenide (GaAs). In a case where the wavelength of the laser light output from the light source **1201** is 1.55 μm, a second harmonic generation (SHG) crystal, which is omitted from illustration, may be disposed on the propagation path of the probe light. Generating second order harmonics using an SHG crystal enables probe light suitable for GaAs excitation to be obtained, thereby enabling highly precise detection.

[0134] The SHG crystal used preferably is a crystal of periodically poled lithium niobate (PPLN), around 0.1 mm thick, to maintain the pulse forms of the laser light. Note in that a case where the pulse width is sufficiently small, as in the case of the present embodiment, the fundamental wave may be used as the probe light as it is.

[0135] The signals detected at the detecting unit **1207** are subjected to phase-sensitive detection, and the output signals thereof are amplified at the amplifying unit **1212** and forwarded to the signal acquiring unit **1214**. An optical chopper **1211** is a part which modulates the probe light so as to perform phase-sensitive detection, and is controlled by the modulating unit **1213**.

[0136] The signal acquiring unit **1214** is a part which acquires output signals from the detecting unit **1207**. The processing unit acquires the time waveform based on the output signals acquired by the signal acquiring unit **1214**, and inspects the time waveform, thereby acquiring information regarding the specimen **1216**. An image of the internal structure of the specimen **1216** may also be obtained based on the acquired information of the specimen **1216**.

[0137] If there are portions within the specimen **1216** where the refractive index differs (interfaces), time waveforms of the terahertz waves reflected at the interfaces appear at different positions on the time waveforms in the imaging of the internal structure of the specimen **1216**, depending on the depth of the interfaces. Accordingly, one-dimensional scanning of the specimen **1216** enables a tomographic image to be obtained, and two-dimensional scanning of the specimen **1216** enables a three-dimensional image to be obtained.

[0138] Note that the terahertz waves **1230** collected at the parabolic mirror **1205***c*, by which the specimen **1216** is irradiated, and the terahertz waves **1230** reflected at the specimen **1216** and traveling toward the parabolic mirror **1205***c*, are generally coaxial. Thus, the power of the terahertz waves **1230** decreases due to two terahertz waves **1230** being branched at the beam splitter **1206**. Accordingly, an arrangement may be made such as illustrated in FIG. **12**B, where one or more parabolic mirrors **1205***e* are additionally provided to form a non-coaxial configuration. In this case, the incident angle of the terahertz waves **1230** by which the specimen **1216** is irradiated is not 90 degrees, but the output of the detected terahertz waves **1230** can be increased.

[0139] While the element **100** according to the first embodiment has been used as the generating unit **1204** in the present embodiment, Any of the terahertz wave generating elements or the like in the first through third embodiments may be used. In a case of using the element according to the third embodiment, there is no need to provide an optical system to guide the terahertz waves **1230** from the generating unit **1204** to the specimen **1216**.

[0140] While the detecting unit **1207** is used as a photoconductor in the present embodiment, this may be replaced by a terahertz waves detecting element according to the fourth and fifth embodiments, or another terahertz waves detecting element. In a case of using a terahertz waves detecting element according to the fourth and fifth embodiments as the detecting unit **1207**, the configuration of the generating unit **1204** is not restricted and a terahertz waves detecting element according to the above-described embodiments may be used, or a known terahertz waves generating element such as a photoconductor may be used. In a case of using the element **1000** according to the fifth embodiment, an optical system to guide the terahertz waves **1230** reflected at the specimen **1216** to the detecting unit **1207** can be omitted.

[0141] The generating unit **1204** and detecting unit **1207** may also be replaced by a generating/detecting element such as described in the fifth and sixth embodiments, so as to have a single generating/detecting unit. In this case, the optical system to guide terahertz waves **1230** from the generating unit **1204** to the specimen **1216**, and the optical system to guide the terahertz waves **1230** from the specimen **1216** to the detecting unit **1207**, can be omitted. Further, while the apparatus **1200** has been described as the terahertz waves **1230** reflected at the specimen **1216** being detected, the terahertz waves **1230** transmitted through the specimen **1216** may be detected instead.

[0142] Further, application of the terahertz wave generating elements, terahertz wave detecting elements, and terahertz wave generating/detecting elements, according to the first through seventh embodiments is not restricted to the THz-

TDS apparatus according to the present embodiment, and may be applied to other information acquiring apparatuses as well.

[0143] Using the element **100** as the generating unit **1204** enables the apparatus **1200** according to the present embodiment to measure the specimen **1216** using terahertz waves with reduced power distribution distortion, which enables measurement with high resolution. Reduction in power distribution distortion means that the power of the terahertz waves by which the specimen **1216** is irradiated is greater, so improved S/N ratio can be expected. Further, the optical system is configured using optical fibers in the present embodiment, so reduction in the size of the apparatus **1200** can be expected.

First Exemplary Embodiment

[0144] A more detailed configuration example of the element **100** according to the first embodiment will be described, as a first exemplary embodiment. The length of the waveguide **201** is 10 mm. The core layer **102** included in the waveguide **201** is formed of an MgO-doped LN crystal layer which is 5 μm wide and 3.8 μm thick. An upper clad layer **202** which is 5 μm wide and 2 μm thick is formed upon the core layer **102**. The upper clad layer **202** is an optical adhesive agent for bonding the core layer **102** and the coupling member **103** together.

[0145] The thickness of the upper clad layer **202** is determined from the wavelength of the generated terahertz waves **105**. In a case where the maximum frequency of the terahertz waves **105** is 7 THz, the wavelength of the terahertz waves **105** in free space is approximately 43 μm. AS described above, the thickness of the upper clad layer **202** is preferably $\lambda_{eq}/10$ or less, as described earlier. In a case where the refractive index of a buffer layer is 1.5, $\lambda_{eq}/10=2.85$, so the thickness of the upper clad layer **202** is set to 2 μm so as to be within this thickness range.

[0146] High-resistance Si is used for the coupling member **103**. The reflecting face **107** of the coupling member **103** has a shape like a conical face with part thereof cut off, and is configured such that the axis **109** of the conical face and the propagation direction of the light **104** agree. At this time, the angle α formed between the propagation direction of the light **104** and the reflecting face **107** is 65 degrees. The size of the coupling member **103** from the input end of the waveguide **201** to an apex **110** of the conical face is 18 mm.

[0147] The Cherenkov angle θ_{clad} in the present embodiment is 50 degrees. The angle i between the terahertz waves **105** and the perpendicular of the reflection face **107** in a case where the terahertz waves **105** are input to the reflecting face **107** (incident angle) is 25 degrees, and the angle j between the terahertz waves **105** reflected at the reflection face **107** and the perpendicular of the reflection face **107** (reflection angle) is also 25 degrees.

[0148] The incident light **104** to the crystal **102** is an ultrashort pulse laser of which the peak wavelength is 1.6 μm, the pulse width is 20 fs, average power is 60 mW, and beam diameter (diameter of intensity portion no less than $1/e^2$ of maximum intensity) is 6 μm. Upon light **104** input from the end of the crystal **102** propagating in single mode through the crystal **102**, terahertz waves **105** are generated by conically emitted by Cherenkov radiation.

[0149] The emitted terahertz waves **105** are propagated through the coupling member **103**, and reflected at the reflecting face **107**. The total reflection angle at the interface of the high-resistance Si making up the coupling member **103** and the air is approximately 17 degrees, so the terahertz waves **105** are totally reflected at the reflecting face **107**. The terahertz waves **105** reflected at the reflecting face **107** are transmitted through the transmission face **108** and emitted to the space outside of the coupling member **103**.

[0150] According to the element **100** of the present embodiment, terahertz waves with little distortion in power distribution can be obtained while shaping the waveform of the terahertz waves to be almost planar.

[0151] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0152] For example, description has been made in the above embodiments regarding a case where the width of the nonlinear optical crystal **102** is small to the point that it can be considered to be a point light source with no width. However, the present invention is not restricted to this, and the present invention can be applied to a case where the nonlinear optical crystal **102** has a substantial width.

[0153] In this case, the shape of the reflecting face **107** of the coupling member **103** at a cross-section orthogonal to the propagation direction of light is preferably changed in accordance with the wavefront of the terahertz waves **105** at the face orthogonal to the propagation direction of light. One conceivable example is a form close to an elliptic shape, such as illustrated in FIG. **3**D. This shape enables the wavefront to be nearer to a plane, while reducing distortion in power distribution of the terahertz waves reflected at the reflecting face **107**.

[0154] Also, description has been made in the above embodiments regarding a case where the width of the reflecting face is a straight line in a plane including the propagation direction of light, but may be a curve rather than a straight line. In such a case, the angle α between the reflecting face and the propagation direction of light should be made to be the angle between the tangent of the curve making up the reflecting face and the propagation direction of light.

[0155] Also, description has been made in the above embodiments regarding a case where LN is used as the nonlinear optical crystal, but the present invention is not restricted to this, and other nonlinear optical crystals may be used as well. LN has a sufficiently great difference between the refractive index regarding terahertz waves and the refractive index regarding laser light, so terahertz waves generated non-collinearly can be extracted.

[0156] However, depending on the nonlinear optical crystal used, this refractive index difference may be so small that the generated terahertz waves are not readily extracted. Such a case can be handled by providing the waveguide **201** so that the nonlinear optical crystal **102** and the coupling member **103** are sufficiently close, and forming the coupling member **103** of a material which has a greater refractive index than the nonlinear optical crystal. This configuration enables conditions for Cherenkov radiation of generated electromagnetic waves ($V_{THz}<V_g$), so that the terahertz waves can be externally extracted.

[0157] The length of the waveguide **201** (length in the x direction) of the terahertz wave generating element may be extended to increase the output of terahertz waves. In this case, the size of the coupling member **103** is a so changed to match the length of the waveguide **201**, so that more generated terahertz waves can be used.

[0158] The substrate **101** also is not restricted to the above embodiments, and various change may be made. For example, the size of the substrate **101** may be reduce, within a range where the waveguide **201** can be meld. The rear face of the substrate **101**, which is the face opposite from the face on which the waveguide **201** is formed, can be changed. Specific examples include cutting obliquely so that light reflected on the rear face of the substrate **101** can be prevented from becoming stray light, and in a case where terahertz waves are also irradiated to the rear face of the substrate **101**, a prism or lens may be disposed thereat. Various materials may be used, such as Si, resin, and so forth. Further, an arrangement may be made where no substrate **101** is provided.

[0159] This application claims the benefit of Japanese Patent Application No. 2013-212295, filed Oct. 9, 2013 and No. 2014-182737, filed Sep. 8, 2014, which are hereby incorporated by reference herein in their entirety.

1. A terahertz wave generating element comprising:

a nonlinear optical crystal configured to generate terahertz waves by light propagating therethrough; and

a coupling member through which the terahertz waves generated by the nonlinear optical crystal propagate;

wherein the coupling member includes a reflecting face configured to reflect at least a part of the terahertz waves generated by the nonlinear optical crystal and a transmission face configured to transmit the terahertz waves reflected at the reflecting face;

wherein the reflecting face is convex in a propagation direction of the terahertz waves generated by the nonlinear optical crystal;

wherein an angle at the coupling member side between the reflecting face and a propagation direction of the light is greater than 90 degrees−$\cos^{-1}(n_g/n_{THz})$ and smaller than 90 degrees at a plane including the propagation direction of the light, where n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, and n_{THz} represents the refractive index of the coupling member at a wavelength of the terahertz waves generated by the nonlinear optical crystal;

and wherein a radius of curvature of the reflecting face, in a reflection region where the terahertz waves generated by the nonlinear optical crystal are reflected, is smaller the farther downstream in the propagation direction of the light.

2. The terahertz wave generating element according to claim **1**,

wherein the angle is not less than $\sin^{-1}(n_e/n_{THz})$+90 degrees-$\cos^{-1}(n_g/n_{THz})$ where n_e represents a refractive index of an external matter of the coupling member at the wavelength of the terahertz waves generated by the nonlinear optical crystal.

3. A terahertz wave generating element comprising:

a nonlinear optical crystal configured to generate terahertz waves by light propagating therethrough; and

a coupling member through which the terahertz waves generated by the nonlinear optical crystal propagate;

wherein the coupling member includes a reflecting face configured to reflect at least a part of the terahertz waves generated by the nonlinear optical crystal;

wherein the reflecting face is convex in a propagation direction of the terahertz waves generated by the nonlinear optical crystal;

wherein an angle at the coupling member side between the reflecting face and a propagation direction of the light is not less than $\sin^{-1}(n_e/n_{THz})$+90 degrees−$\cos^{-1}(n_g/n_{THz})$ and smaller than 90 degrees at a plane including the propagation direction of the light, where n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, n_e represents a refractive index of an external matter of the coupling member at the wavelength of the terahertz waves generated by the nonlinear optical crystal, and n_{THz} represents the refractive index of the coupling member at a wavelength of the terahertz waves generated by the nonlinear optical crystal;

and wherein a radius of curvature of the reflecting face, in a reflection region where the terahertz waves generated by the nonlinear optical crystal are reflected, is smaller the farther downstream in the propagation direction of the light.

4. The terahertz wave generating element according to claim **1**,

wherein the angle is 90 degrees−$\cos^{-1}(n_g/n_{THz})/2\pm\lambda/8$, where λ represents the wavelength of the terahertz waves generated by the nonlinear optical crystal.

5. The terahertz wave generating element according to claim **1**,

wherein the terahertz waves generated by the nonlinear optical crystal are totally reflected at the reflecting face.

6. The terahertz wave generating element according to claim **1**,

wherein the reflecting face includes a part of a curve formed by rotating a straight line or a curve of which the axis of rotation is the propagation direction of the light.

7. The terahertz wave generating element according to claim **1**,

wherein the reflecting face includes a part of a conical face of which the axis is the propagation direction of the light.

8. The terahertz wave generating element according to claim **1**,

wherein at least part of a cross-section of the reflecting face at a plane orthogonal to the propagation direction of the light through the coupling member is a part of a circle or ellipse.

9. The terahertz wave generating element according to claim **1**,

wherein the plane including the propagation direction of the light is perpendicular to the surface of the nonlinear optical crystal.

10. The terahertz wave generating element according to claim **1**, further comprising:

a waveguide;

wherein the waveguide includes the nonlinear optical crystal, and a clad layer which is disposed between the nonlinear optical crystal and the coupling member and which has a refractive index lower than the refractive index of the nonlinear optical crystal at the wavelength of the light.

11. The terahertz wave generating element according to claim **1**,

wherein the width of the nonlinear optical crystal is smaller than the wavelength of the terahertz waves generated by the nonlinear optical crystal.

12. The terahertz wave generating element according to claim **1**,

wherein the nonlinear optical crystal is configured so that the terahertz waves generated by the nonlinear optical crystal are input again, whereby a propagation state of light different from the light changes, whereby the terahertz waves generated by the nonlinear optical crystal are detected using the light of which the propagation state has changed.

13. A terahertz wave detecting element comprising:

a nonlinear optical crystal configured to change a propagation state of light by input of terahertz waves; and

a coupling member configured to guide the terahertz waves to the nonlinear optical crystal;

wherein the coupling member includes a transmission face configured to transmit the terahertz waves and a reflecting face configured to reflect at least a part of the terahertz waves transmitted through the transmission face;

wherein the reflecting face is convex in a direction opposite to the propagation direction of the terahertz waves input to the nonlinear optical crystal;

wherein an angle at the coupling member side between the reflecting face and a propagation direction of the light is greater than 90 degrees$-\cos^{-1}(n_g/n_{THz})$ and smaller than 90 degrees at a plane including the propagation direction of the light, where n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, and n_{THz} represents the refractive index of the coupling member at a wavelength of the terahertz waves generated by the nonlinear optical crystal;

and wherein a radius of curvature of the reflecting face, in a reflection region where the terahertz waves generated by the nonlinear optical crystal are reflected, is greater the farther downstream in the propagation direction of the light.

14. A terahertz wave detecting element comprising:

a nonlinear optical crystal configured to change a propagation state of light by input of terahertz waves; and

a coupling member configured to guide the terahertz waves to the nonlinear optical crystal;

wherein the coupling member includes a reflecting face configured to reflect at least a part of the terahertz waves input to the nonlinear optical crystal;

wherein the reflecting face is convex in a direction opposite to the propagation direction of the terahertz waves input to the nonlinear optical crystal;

wherein an angle at the coupling member side between the reflecting face and a propagation direction of the light is not less than $\sin^{-1}(n_e/n_{THz})$+90 degrees$-\cos^{-1}(n_g/n_{THz})$ and smaller than 90 degrees at a plane including the propagation direction of the light, where n_g represents a group refractive index of the nonlinear optical crystal at a wavelength of the light, and n_{THz} represents the refractive index of the coupling member at a wavelength of the terahertz waves generated by the nonlinear optical crystal;

and wherein a radius of curvature of the reflecting face, in a reflection region where the terahertz waves generated by the nonlinear optical crystal are reflected, is greater the farther downstream in the propagation direction of the light.

15. An information acquisition apparatus configured to irradiate a specimen with terahertz waves and acquire information of the specimen, the apparatus comprising:

a generating unit configured to generate terahertz waves; and

a detecting unit configured to detect the terahertz waves which have transmitted or reflected at the specimen;

wherein the generating unit includes the terahertz wave generating element according to claim **1**.

16. The information acquisition apparatus according to claim **15**,

wherein the generating unit and detecting unit are configured integrally, in which the terahertz wave generating element functions as the generating unit and the detecting unit.

17. An information acquisition apparatus configured to irradiate a specimen with terahertz waves and acquire information of the specimen, the apparatus comprising:

a generating unit configured to generate terahertz waves; and

a detecting unit configured to detect the terahertz waves from the specimen;

wherein the detecting unit includes the terahertz wave detecting element according to claim **13**.

* * * * *