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Matsui et al.

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(54) **OPTICAL MEMBER AND IMAGE READING DEVICE**

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(52) **U.S. Cl.**
CPC .... ***G02B 3/0062*** (2013.01); ***H04N 1/0306*** (2013.01); ***H04N 1/191*** (2013.01); (Continued)

(58) **Field of Classification Search**
USPC 358/475, 484, 482, 483, 474, 509, 505
See application file for complete search history.

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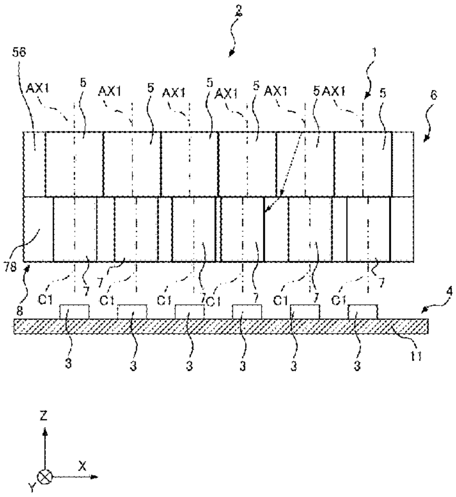
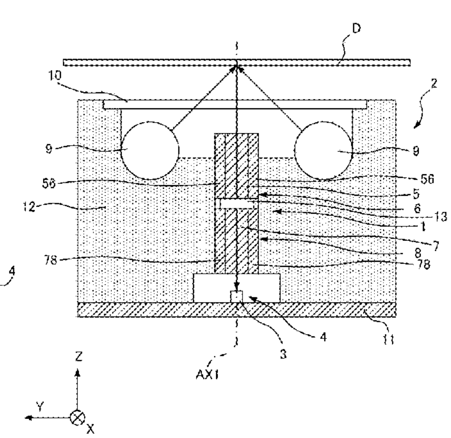
(74) *Attorney, Agent, or Firm* — XSENSUS LLP

(57) **ABSTRACT**

An optical member includes a lens array including lens bodies, and transmissive members. The transmissive members are made of a material having a uniform refractive index, and are disposed at positions nearer an object-to-be-read than the corresponding lens bodies are disposed or at positions farther from the object-to-be-read than the corresponding lens bodies are disposed. The transmissive members have a columnar shape extending along the optical axes of the lens bodies, and allow light incident through one end faces to exit through the other end faces. At least either ones of the lens bodies or the transmissive members are arranged with distances therebetween larger than errors in the arrangement of the lens bodies and the transmissive members.

7 Claims, 20 Drawing Sheets





(51) **Int. Cl.**
H04N 1/03 (2006.01)
H04N 1/191 (2006.01)

(52) **U.S. Cl.**
CPC *G02B 2003/0093* (2013.01); *H04N 2201/0081* (2013.01)

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FIG.1

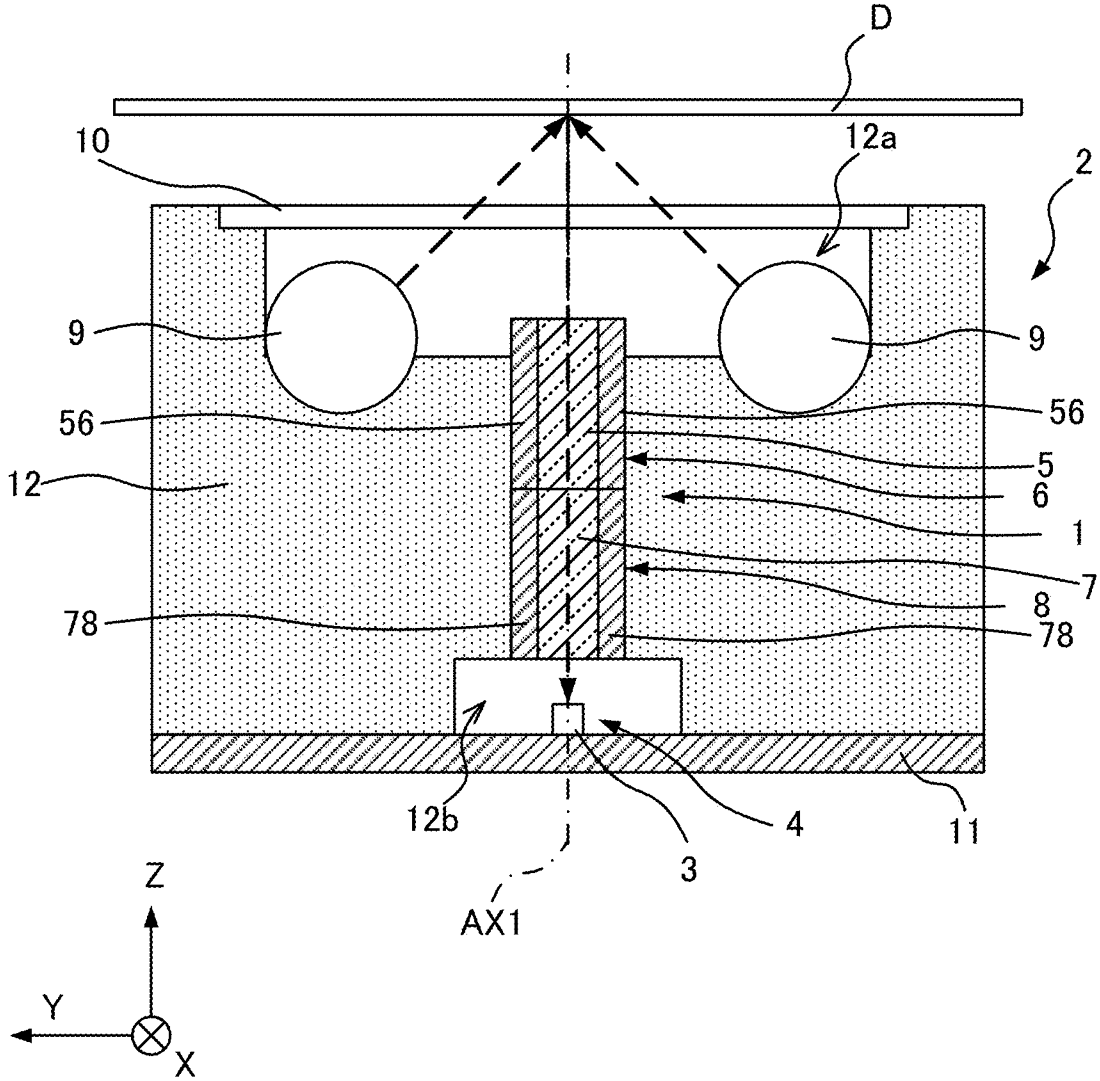


FIG.2

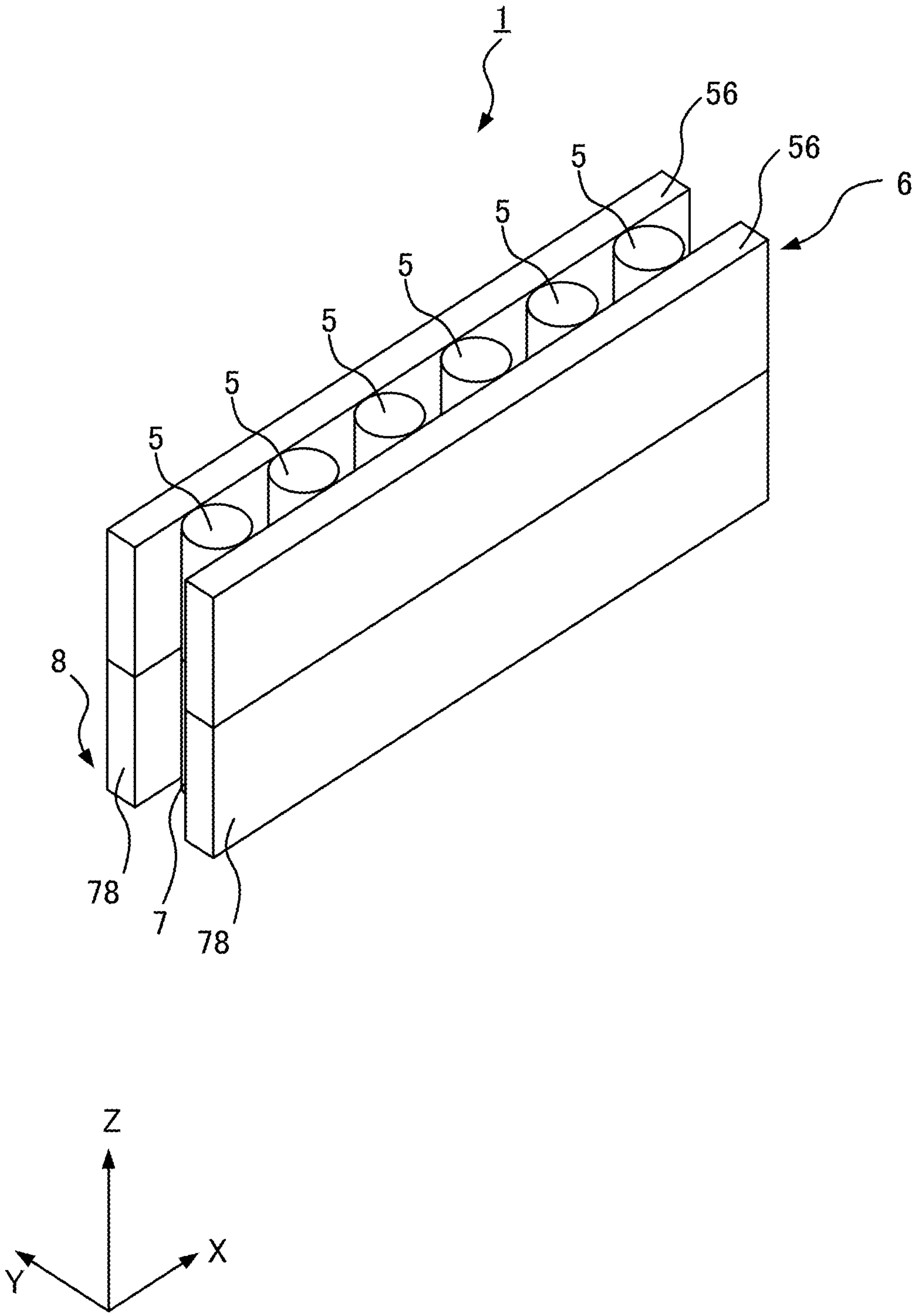
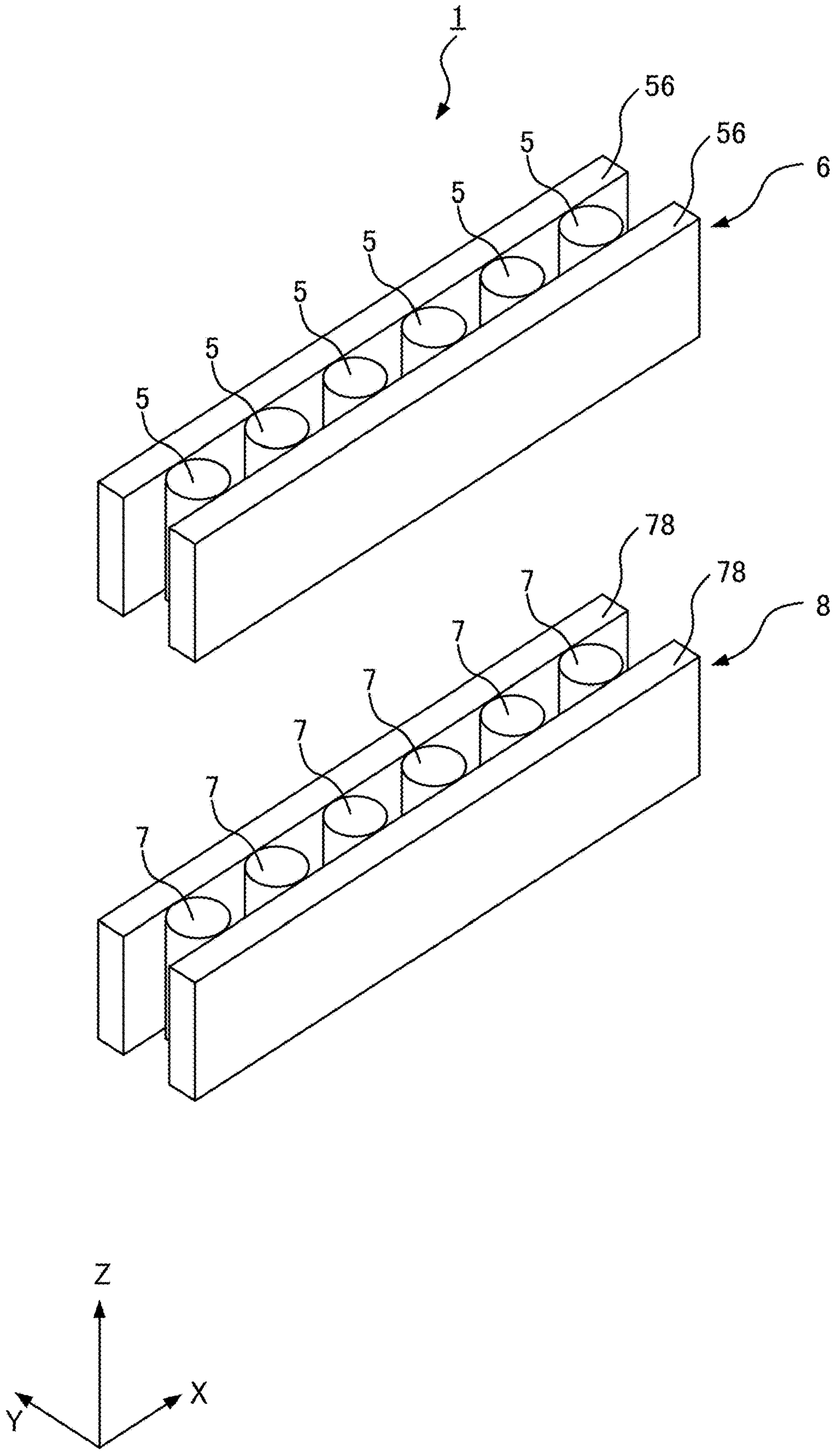


FIG.3



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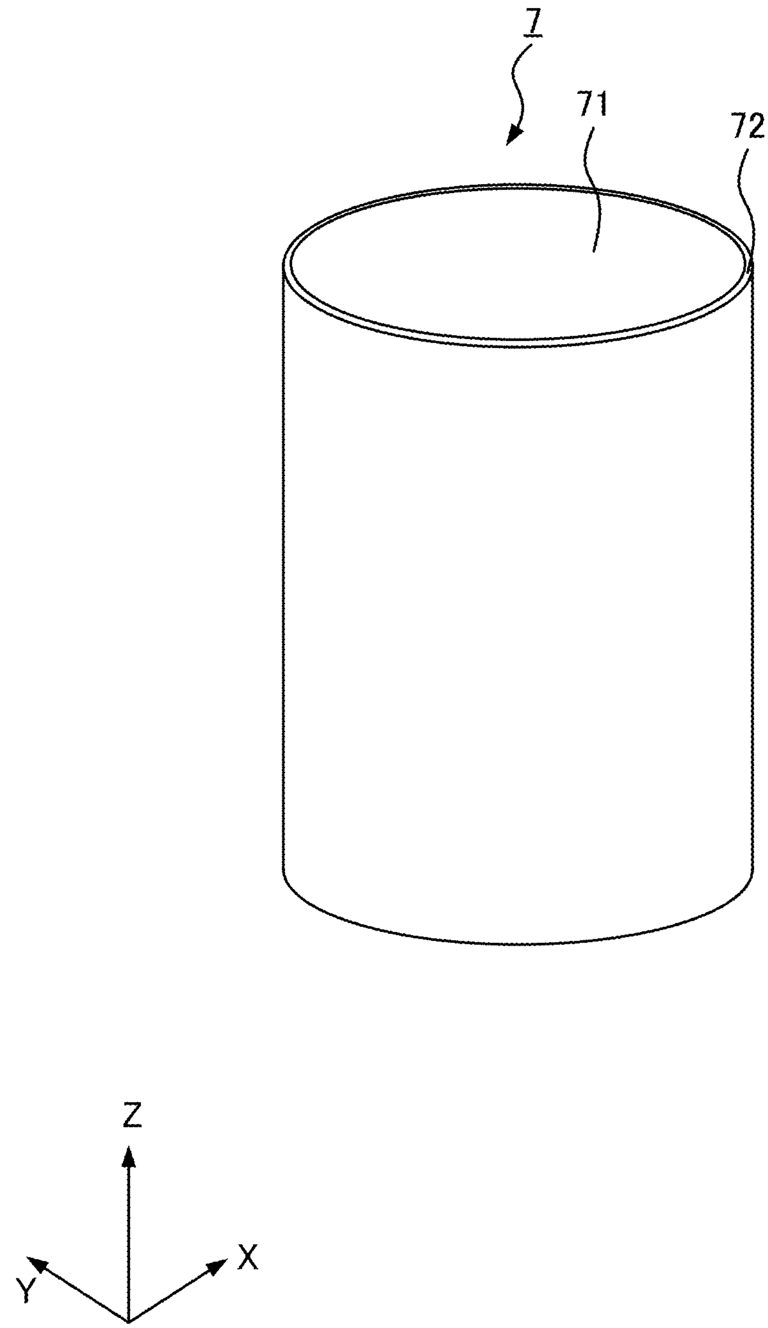

FIG.5

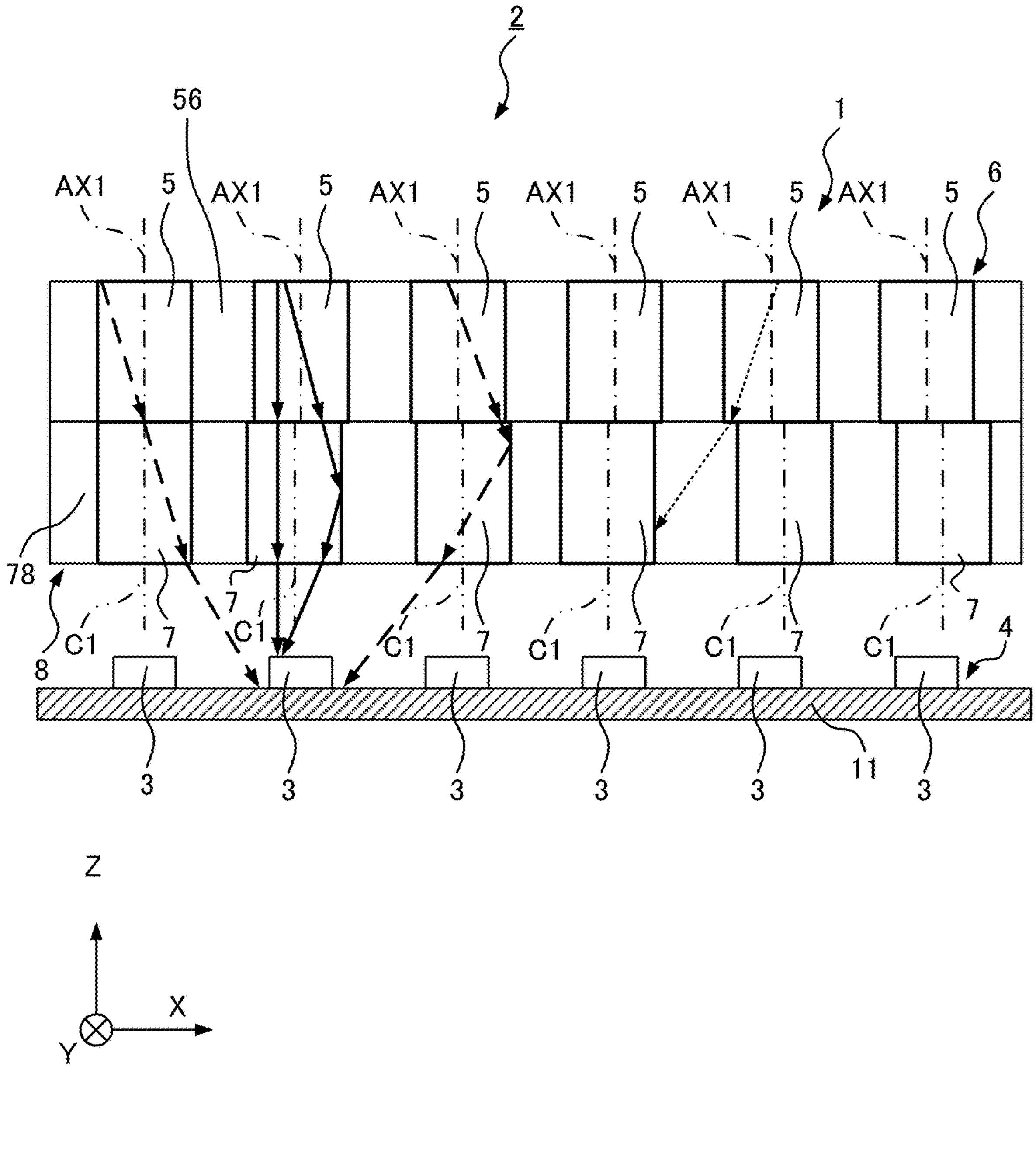
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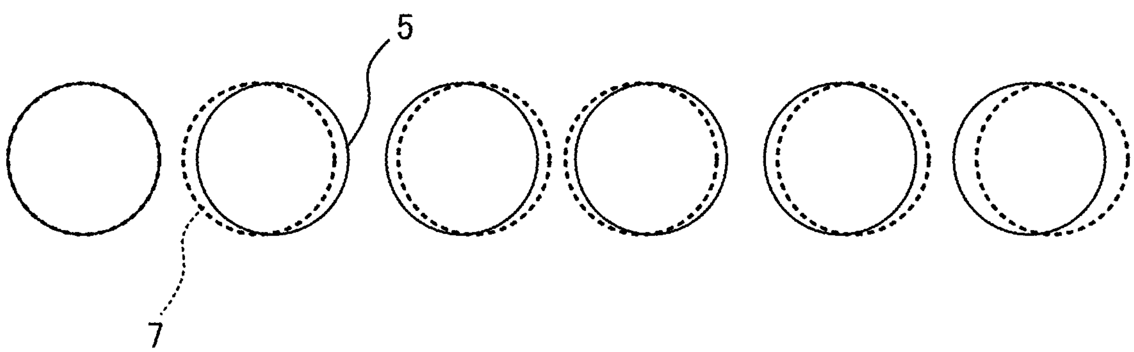
FIG.6



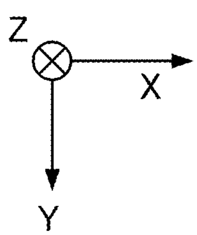
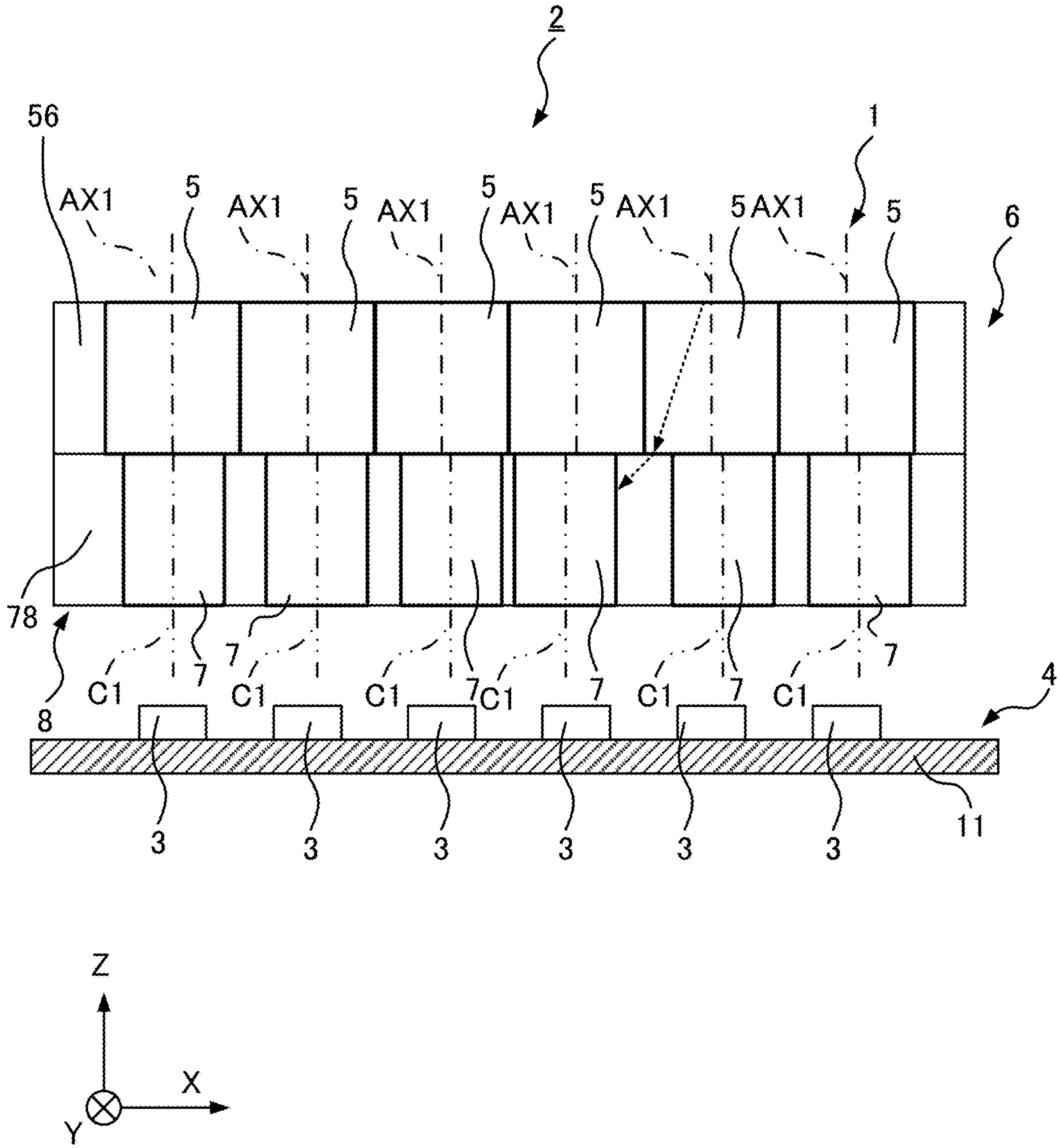


FIG.7



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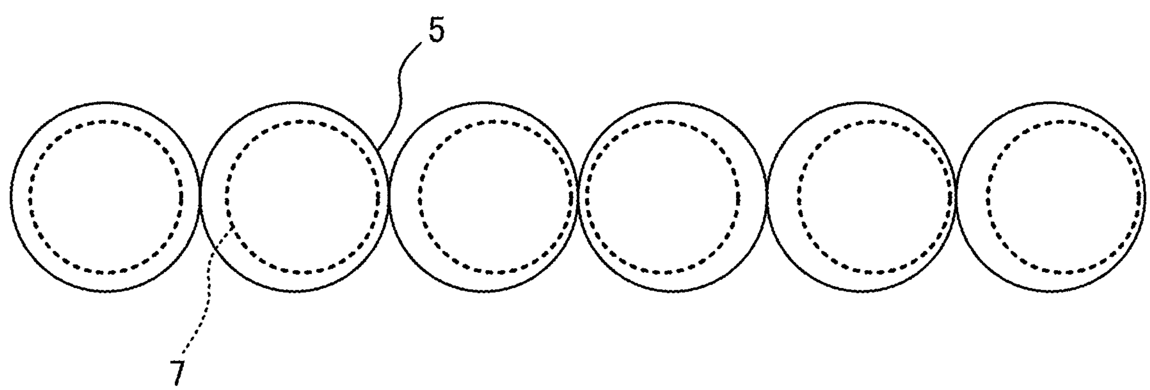

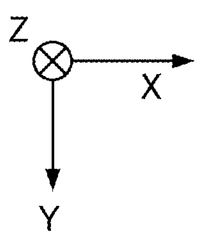

FIG.9

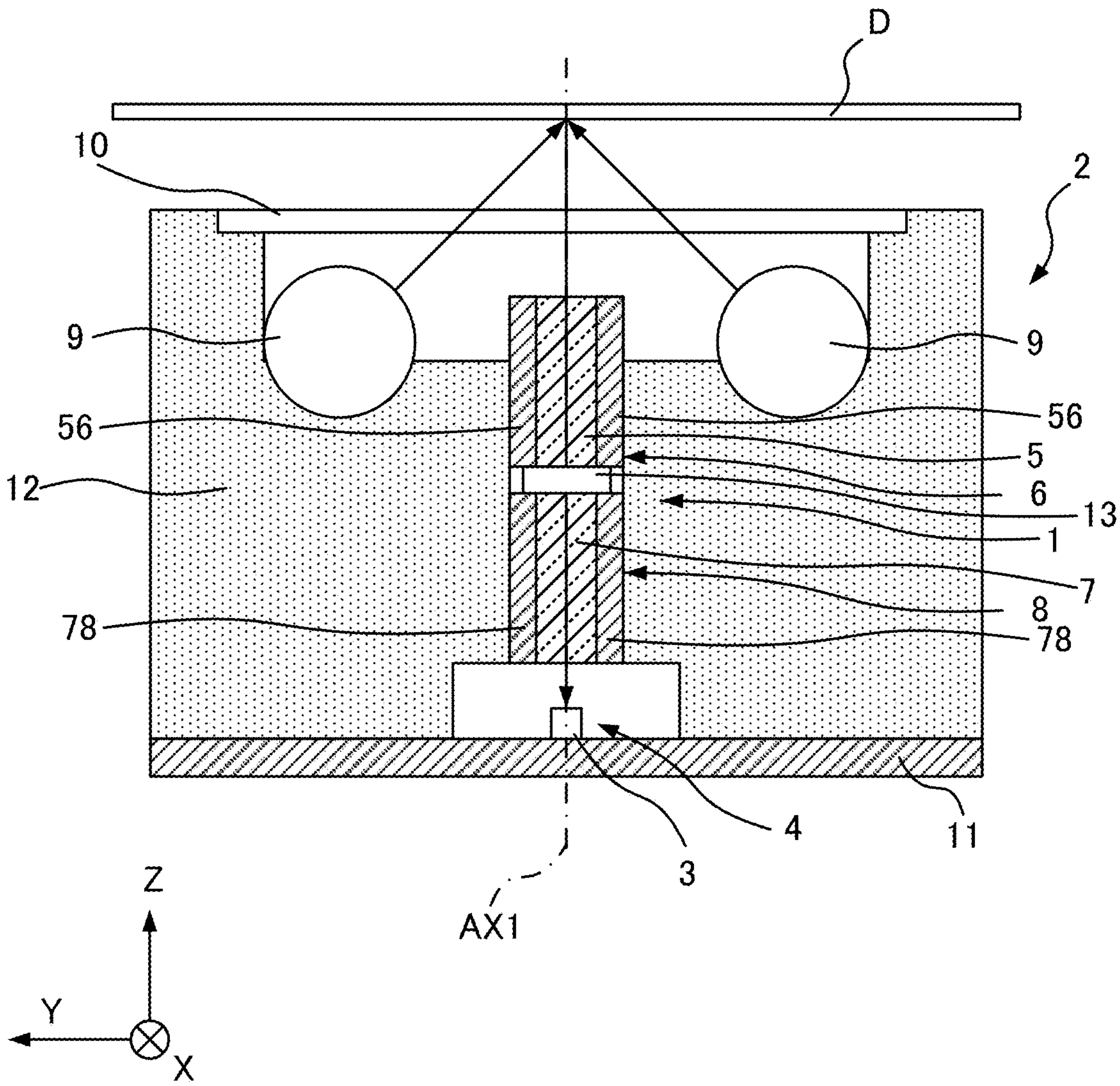

FIG.10

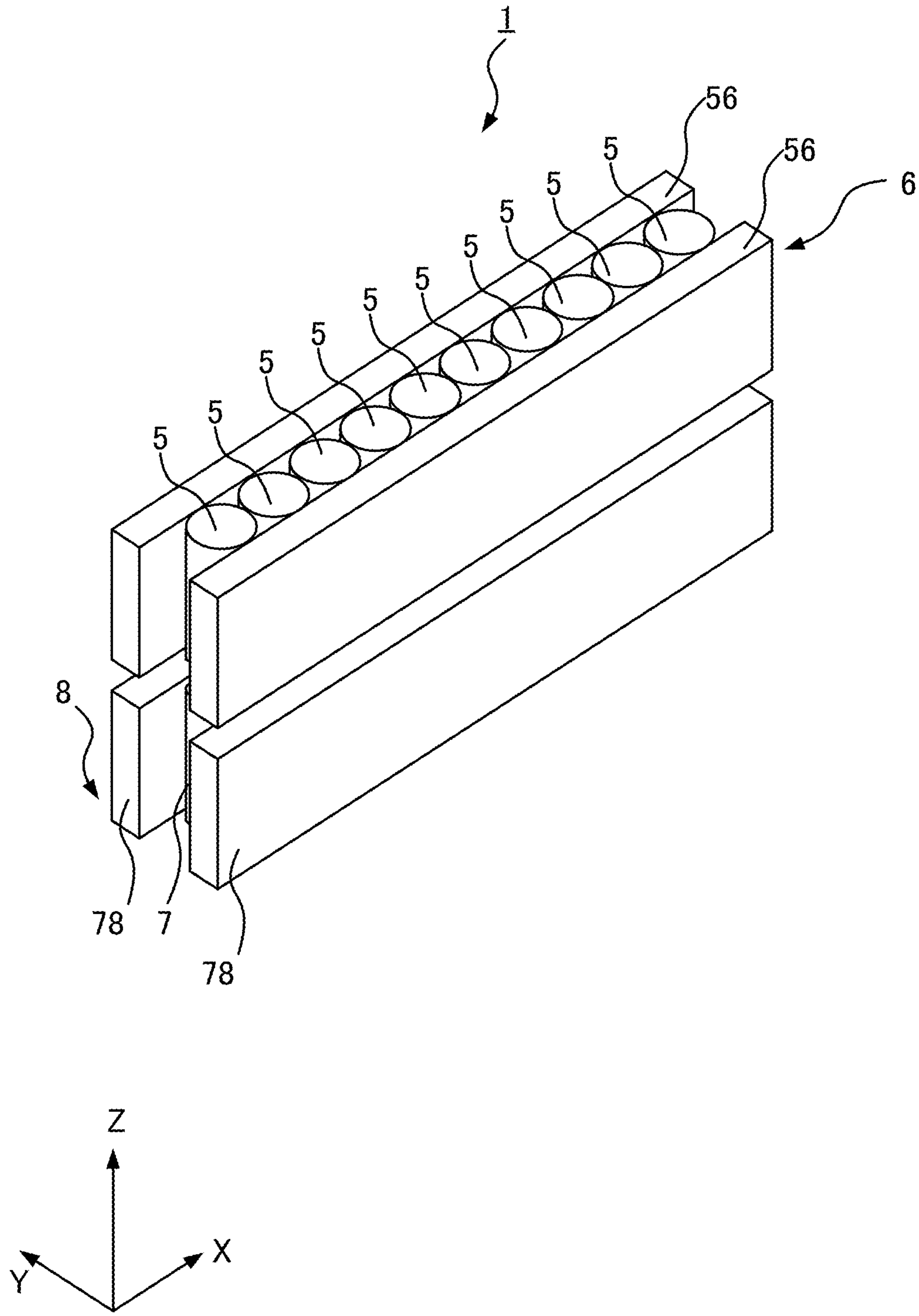

FIG.11

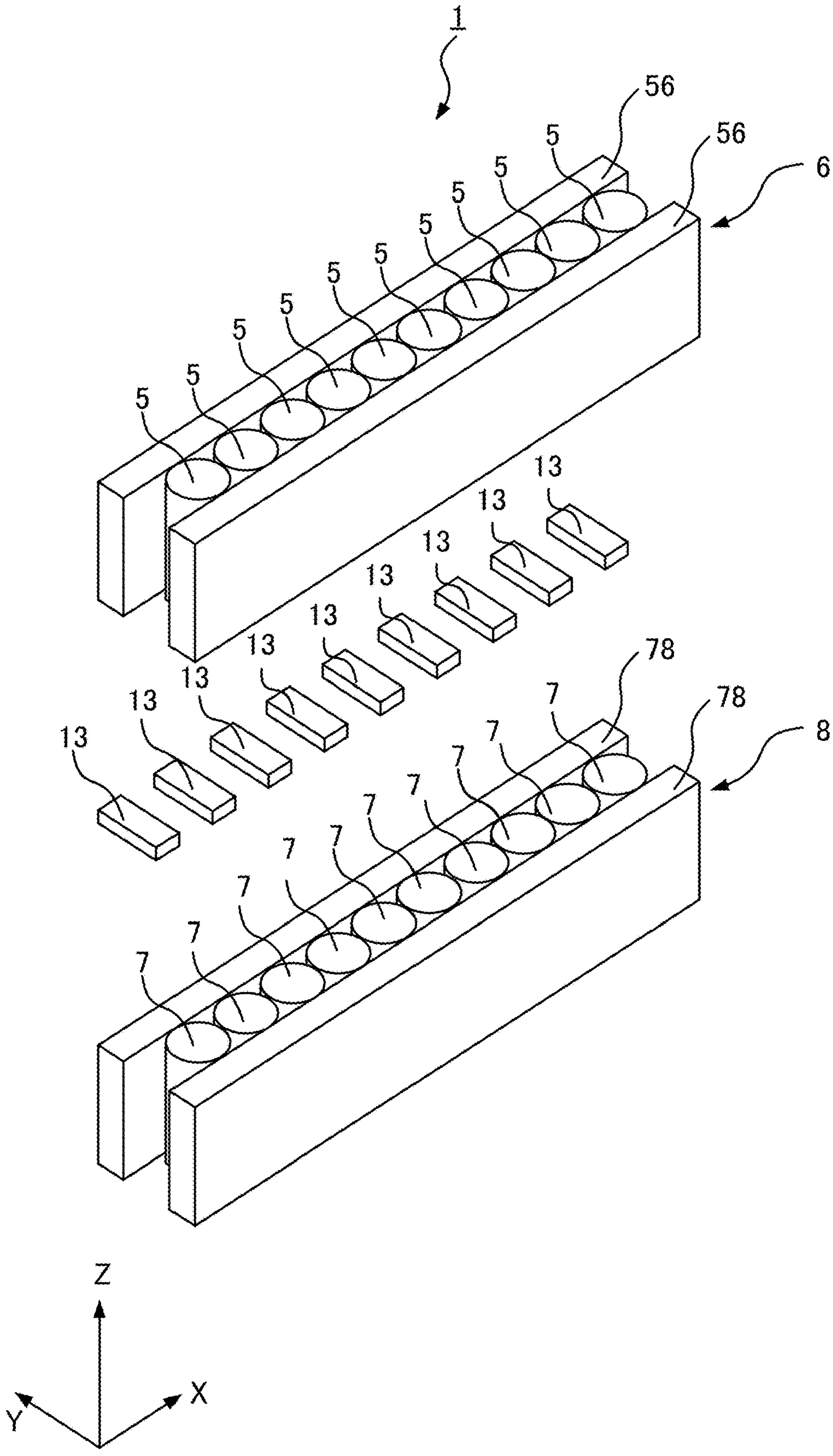
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FIG.12

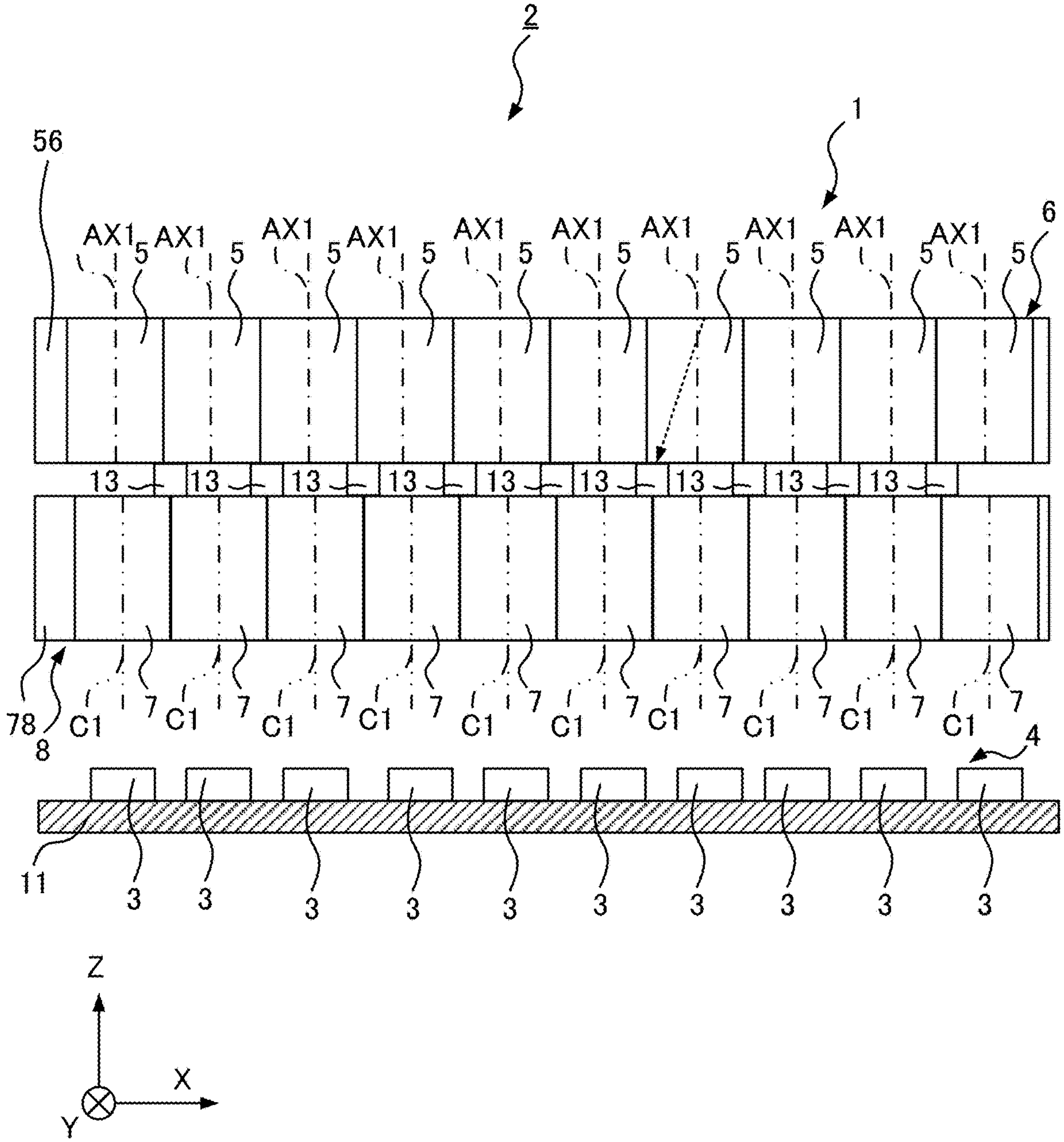

FIG.13

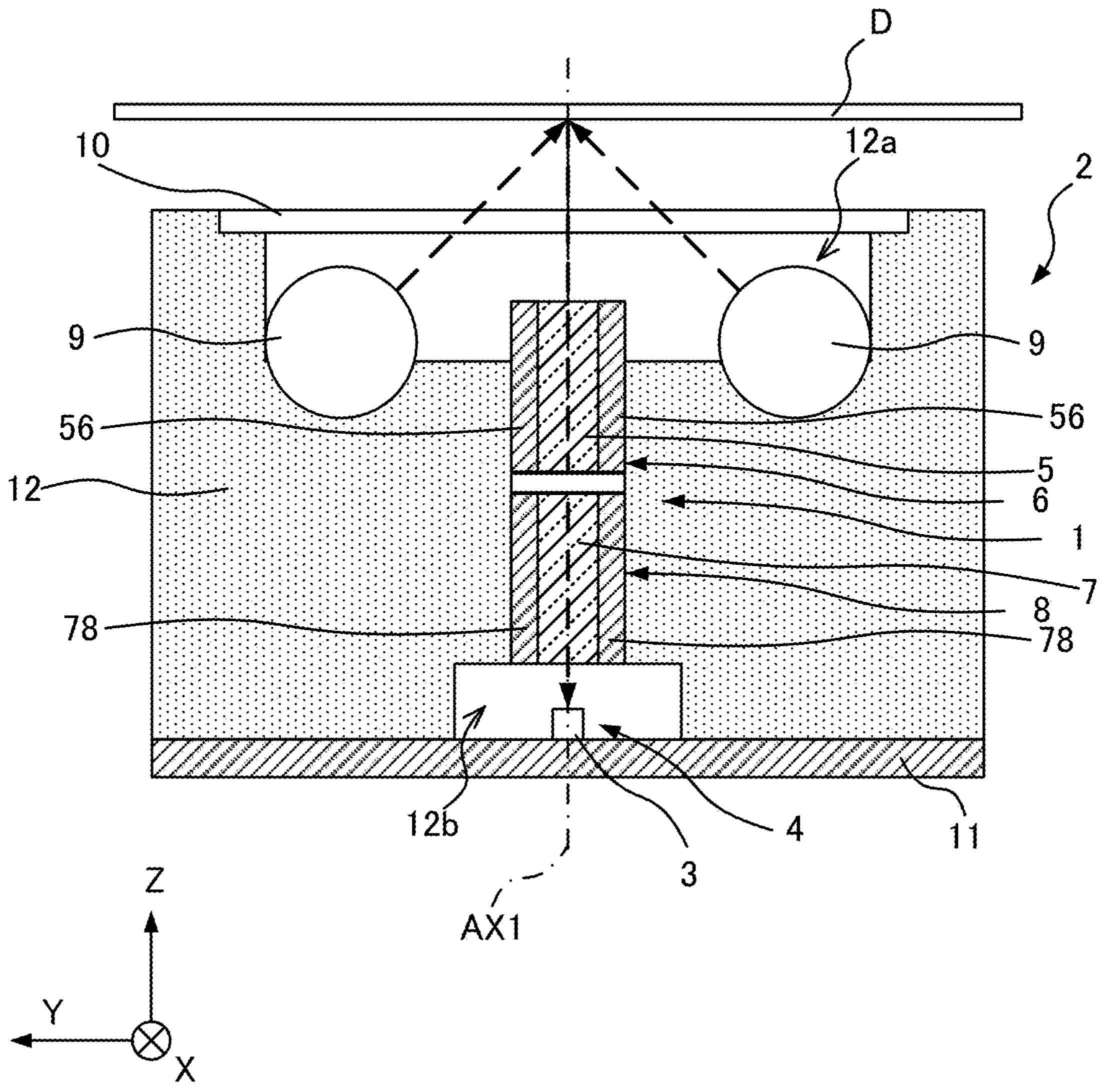

FIG.14

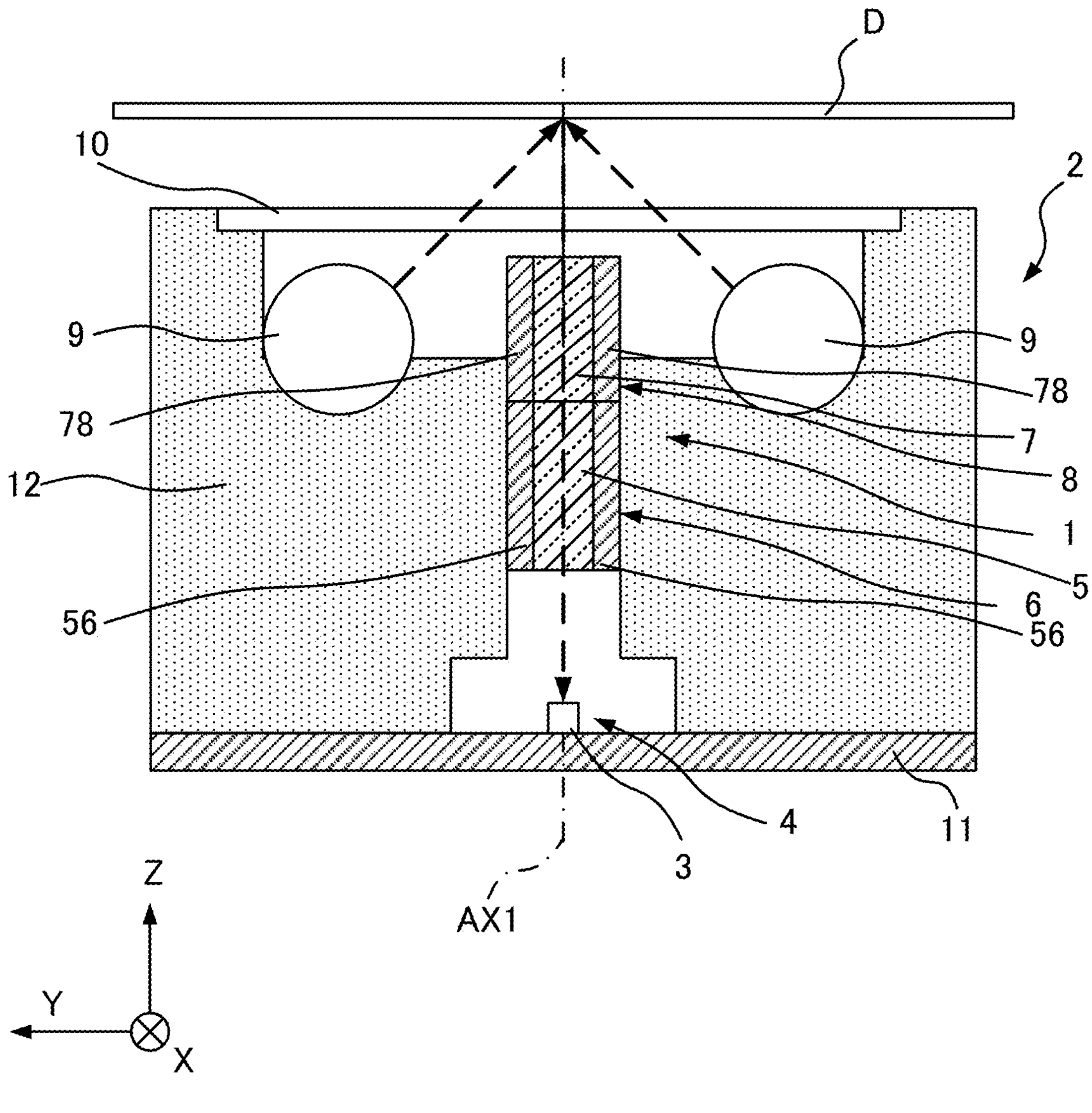

FIG.15

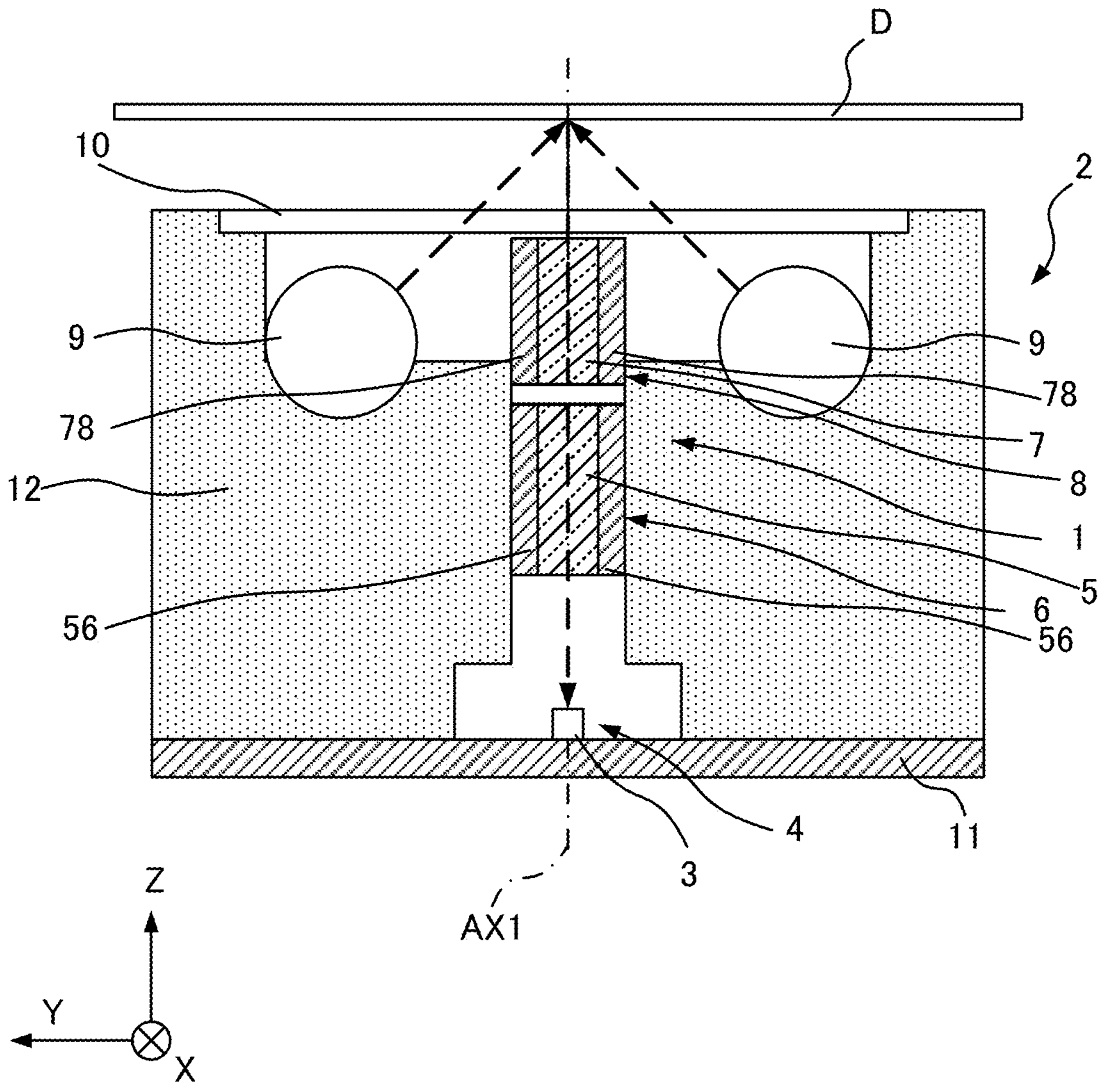

FIG.16

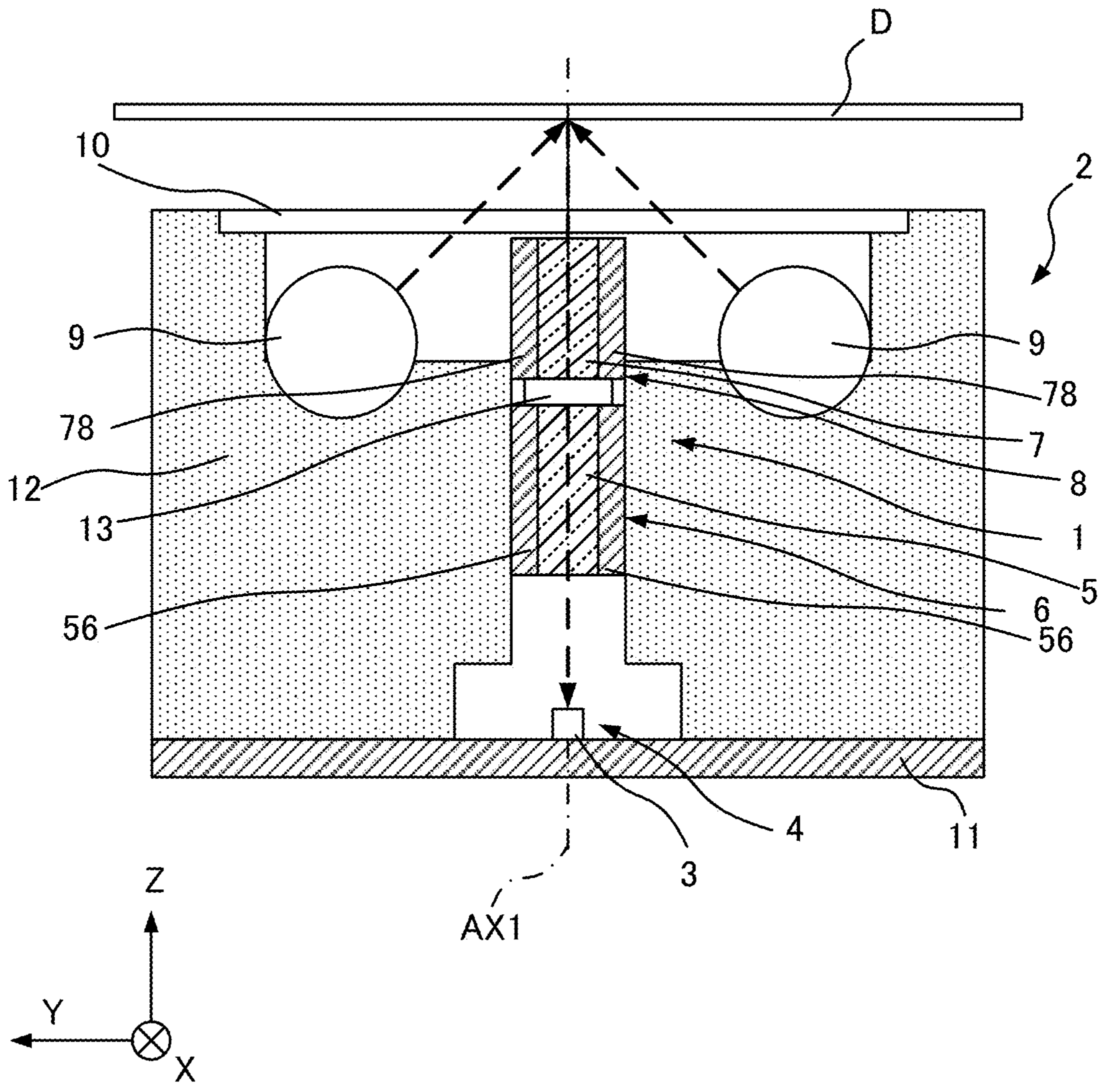

FIG.17

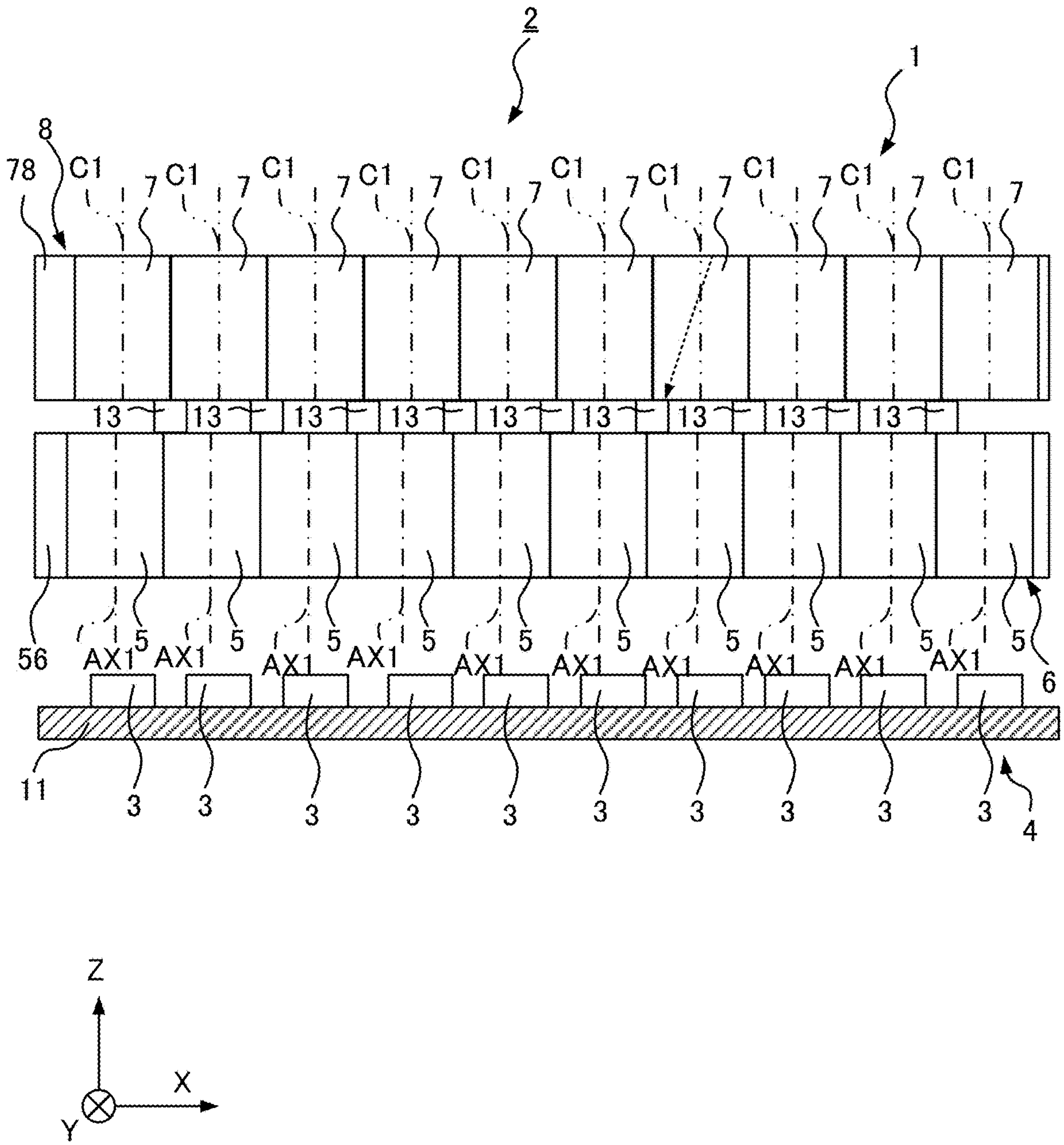

FIG.18

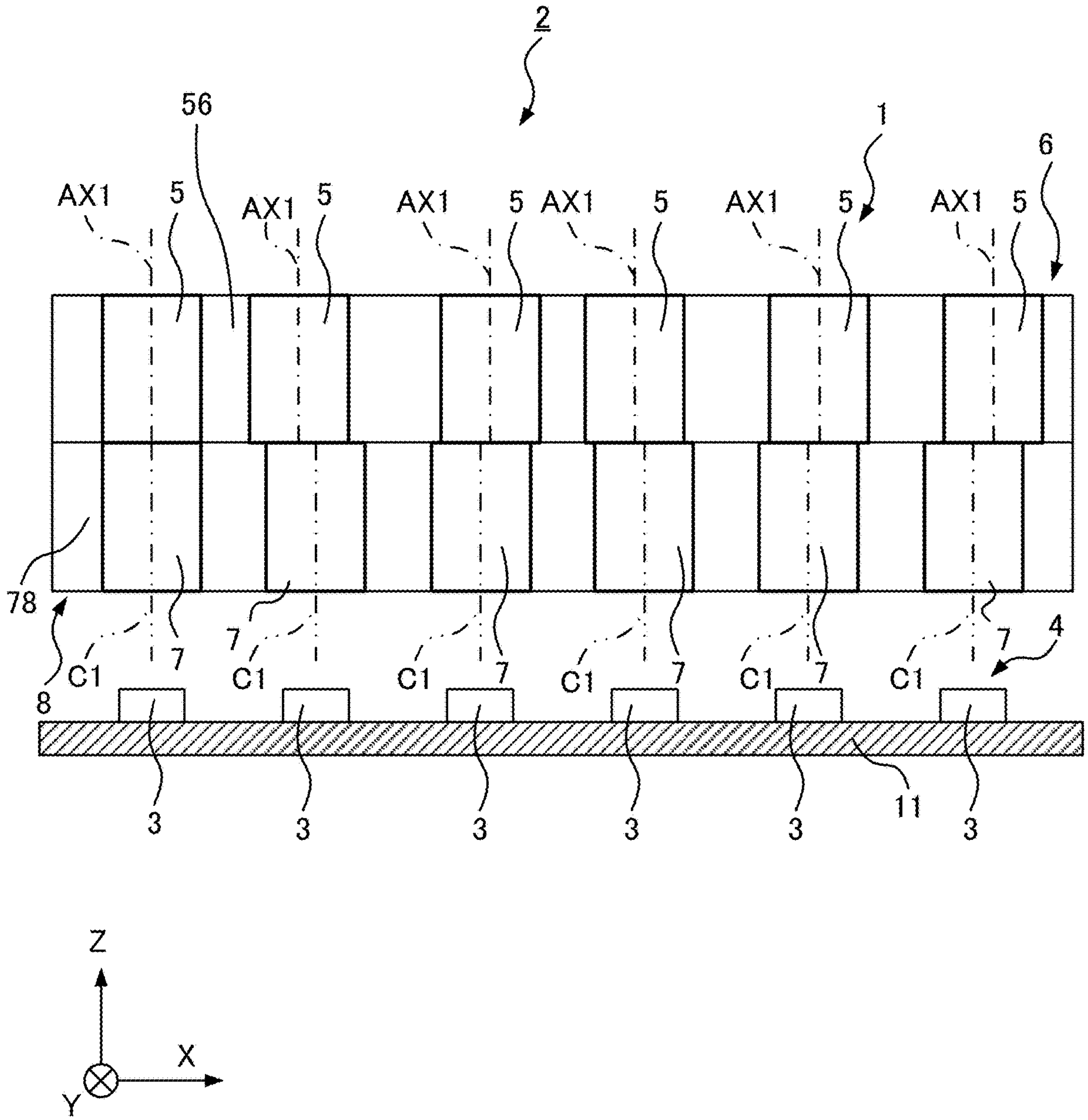
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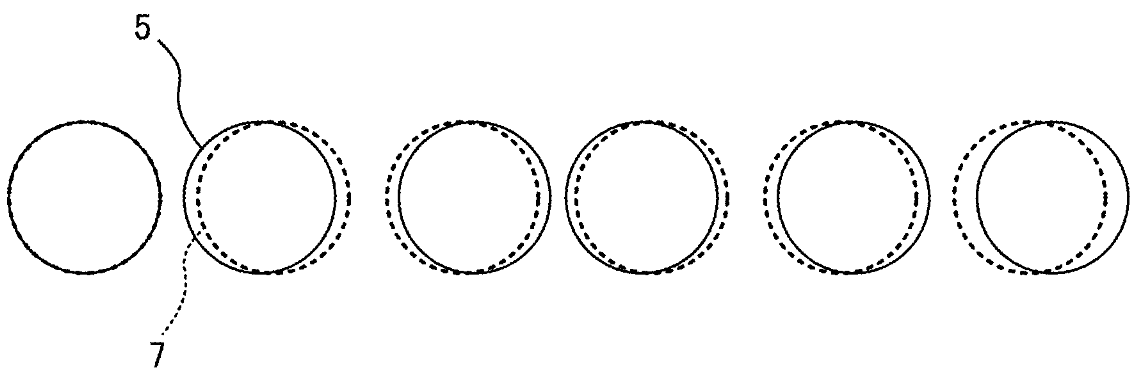
FIG.19



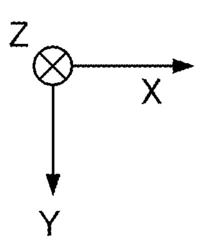
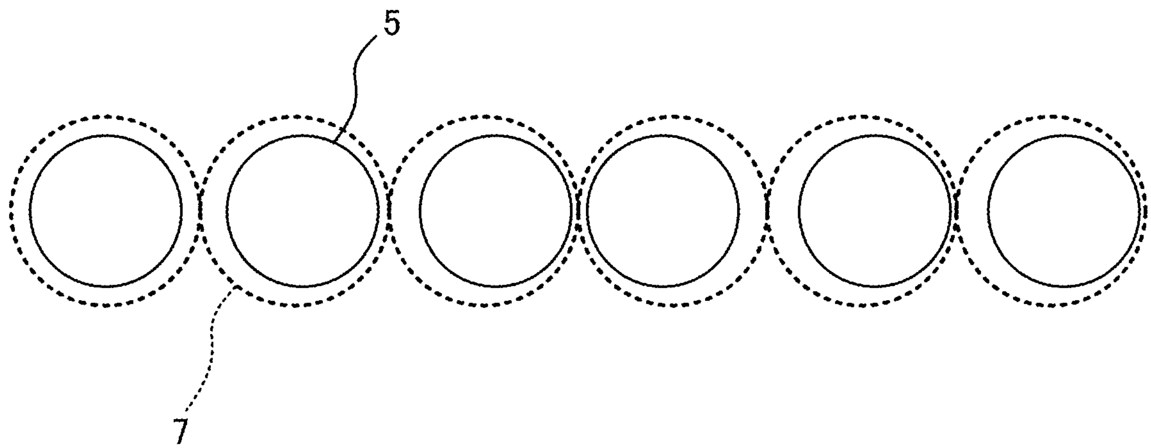
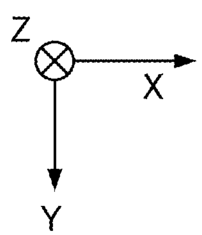


FIG.20





OPTICAL MEMBER AND IMAGE READING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on PCT filing PCT/JP2022/023184, filed Jun. 8, 2022, which claims priority from Japanese Patent Application No. 2021-096275, filed Jun. 9, 2021, the entire contents of each are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to an optical member and an image reading device.

BACKGROUND ART

Some image reading devices emit light to an object-to-be-read, cause multiple lens bodies arranged in an array to converge the light transmitted through or reflected by the object-to-be-read, and cause multiple optical sensing elements arranged in a line to detect the light. Examples of the image reading devices of this type are disclosed in Patent Literatures 1 and 2.

These image reading devices each include a lens array of an erecting equal-magnification optical system. Specific examples of the lens array include a rod lens array including multiple lens bodies having a circular cylindrical shape, and a microlens array.

Each of the image reading devices disclosed in Patent Literatures 1 and 2 provided with the above-mentioned lens array includes overlap prevention portions disposed between lens elements in order to increase the depth of field. The overlap prevention portions restrict an overlap between images formed by the lens elements, and can thus control the diameter of images formed by the lens elements and increase the depth of field.

The image reading device disclosed in Patent Literature 2 includes a light transmitting cylindrical array including multiple light transmitting cylindrical portions, which are examples of the overlap prevention portions. The light transmitting cylindrical portions are disposed between the lens array and a sensor array in association with the respective optical axes of lens bodies, and allow light incident from the lens bodies through one end faces to exit through the other end faces toward the sensor elements. Adjustment of the lengths of the light transmitting cylindrical portions in the directions of the optical axes can prevent images formed by the lens bodies from overlapping with each other.

CITATION LIST

Patent Literature

Patent Literature 1: Unexamined Japanese Patent Application Publication No. H6-342131
Patent Literature 2: International Publication No. WO 2020/196168

SUMMARY OF INVENTION

Technical Problem

The image reading device disclosed in Patent Literature 2 includes the lens bodies arranged in contact with each other, and the light transmitting cylindrical portions arranged in contact with each other in association with the respective lens bodies. When the optical axis of a lens body is deviated from the central axis of the corresponding light transmitting cylindrical portion, the light exiting the lens body unintentionally enters a light transmitting cylindrical portion adjacent to the light transmitting cylindrical portion corresponding to this lens body. This situation may cause an overlap between images formed by the lens bodies adjacent to each other.

An objective of the present disclosure, which has been accomplished to solve the above problems, is to provide an optical member and an image reading device that can suppress an overlap between images formed by lens bodies, regardless of an error in the arrangement of at least any one of the lens bodies and transmissive members for suppressing an overlap between images formed by the lens bodies.

Solution to Problem

An optical member according to the present disclosure includes a lens array and transmissive members. The lens array includes lens bodies that are arranged in a line in a main scanning direction and are configured to converge light from an object-to-be-read. The transmissive members are made of a material having a uniform refractive index, and are disposed at positions nearer the object-to-be-read than the corresponding lens bodies are disposed or at positions farther from the object-to-be-read than the corresponding lens bodies are disposed. The transmissive members have a columnar shape extending along optical axes of the lens bodies to allow light incident through one end faces to exit through the other end faces. At least either ones of the lens bodies or the transmissive members are arranged with distances therebetween larger than an error in arrangement of the lens bodies and an error in arrangement of the transmissive members.

Advantageous Effects of Invention

The optical member according to the present disclosure includes lens bodies, and transmissive members that are provided in accordance with the respective lens bodies and allow light incident through one end faces to exit through the other end faces. Each of the transmissive members can suppress an overlap between images formed by the lens bodies adjacent to each other in the main scanning direction. Since at least either ones of the lens bodies and the transmissive members are arranged with distances therebetween larger than errors in the arrangement of the lens bodies and the transmissive members, this structure enables the optical member to suppress an overlap between images formed by the lens bodies, regardless of an error in the arrangement of at least any one of the lens bodies and the transmissive members.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a sectional view of an image reading device according to Embodiment 1;

FIG. **2** is a perspective view of an optical member according to Embodiment 1;

FIG. **3** is an exploded perspective view of the optical member according to Embodiment 1;

FIG. **4** is a perspective view of a transmissive member according to Embodiment 1;

FIG. **5** illustrates a positional relationship between the optical member and a sensor array according to Embodiment 1;

FIG. **6** illustrates positional relationships between lens bodies and the transmissive members included in the optical member according to Embodiment 1;

FIG. **7** illustrates a positional relationship between an optical member and a sensor array according to Embodiment 2;

FIG. **8** illustrates positional relationships between lens bodies and transmissive members included in the optical member according to Embodiment 2;

FIG. **9** is a sectional view of an image reading device according to Embodiment 3;

FIG. **10** is a perspective view of an optical member according to Embodiment 3;

FIG. **11** is an exploded perspective view of the optical member according to Embodiment 3;

FIG. **12** illustrates a positional relationship between the optical member and a sensor array according to Embodiment 3;

FIG. **13** is a sectional view of a first modification of the image reading device according to the embodiments;

FIG. **14** is a sectional view of a second modification of the image reading device according to the embodiments;

FIG. **15** is a sectional view of a third modification of the image reading device according to the embodiments;

FIG. **16** is a sectional view of a fourth modification of the image reading device according to the embodiments;

FIG. **17** illustrates a positional relationship between an optical member and a sensor array included in the fourth modification of the image reading device according to the embodiments;

FIG. **18** illustrates another exemplary positional relationship between the optical member and the sensor array according to the embodiments;

FIG. **19** illustrates another example of the positional relationships between the lens bodies and the transmissive members included in the optical member according to the embodiments; and

FIG. **20** illustrates another example of the positional relationships between the lens bodies and the transmissive members included in the optical member according to the embodiments.

DESCRIPTION OF EMBODIMENTS

An optical member and an image reading device according to embodiments of the present disclosure are described in detail below with reference to the accompanying drawings. In the drawings, the components identical or corresponding to each other are provided with the same reference symbol.

Embodiment 1

The following describes an image reading device **2** according to Embodiment 1 with reference to the drawings, focusing on an exemplary image reading device for reading information, such as images, characters, and patterns, on a surface of an object-to-be-read D. Examples of the object-to-be-read D include sheet-like objects, such as documents, paper money, and securities, substrates, and webs made of sheet-shaped fibers. The image reading device **2** illustrated in FIG. **1** has the main scanning direction defined as X axis, the sub-scanning direction defined as Y axis, and the direction of reading depth defined as Z axis. The main scanning direction and the sub-scanning direction intersect each other, and are preferably orthogonal to each other. In Embodiment 1, the X, Y, and Z axes are orthogonal to each other. The same holds true for the other drawings.

As illustrated in FIG. **1**, which is a sectional view in a plane extending in the sub-scanning direction of the image reading device **2**, the image reading device **2** includes light sources **9** that emit light to the object-to-be-read D, a transmissive plate **10** that allows for transmission of the light emitted from the light sources **9**, and an optical member **1** including multiple lens bodies that converge the light reflected by the object-to-be-read D. The image reading device **2** further includes a sensor array **4** including multiple sensor elements **3** that receive the light converged by the optical member **1**, and a sensor substrate **11** provided with the sensor array **4**. The image reading device **2** further includes a housing **12** to which the transmissive plate **10** and the sensor substrate **11** are attached, and which accommodates the light sources **9**, the optical member **1**, and the sensor array **4** therein.

The light sources **9** are linear light sources that emit linear light to reading positions, through which the object-to-be-read D is transported, as illustrated with the dashed-line arrows in FIG. **1**. A typical example of the light sources **9** is a lateral light source. The lateral light source includes a light guide extending in the X-axis direction, and light source elements disposed at ends of the light guide in the X-axis direction. A typical example of the light emitted from the light sources **9** to be used for reading of information on the object-to-be-read D is visible light.

The transmissive plate **10** is attached to the housing **12** while closing an opening **12***a* of the housing **12** that faces the object-to-be-read D. The transmissive plate **10** allows for transmission of the light emitted from the light sources **9**. In detail, the transmissive plate **10** is made of a material, such as transparent glass or transparent resin, having a sufficiently high transmittance to allow the light emitted from the light sources **9** to reach the object-to-be-read D, as illustrated with the dashed-line arrows in FIG. **1**, and allow the light from the object-to-be-read D to reach the sensor elements **3**. The transmissive plate **10** has a flat-plate shape having flat surfaces extending in the main and sub-scanning directions. The transmissive plate **10** has one surface closing the opening **12***a* of the housing **12**, and the other surface serving as a reading surface for the object-to-be-read D. The reading surface restricts the reading positions for the object-to-be-read D.

The housing **12** has a box shape having the opening **12***a* that faces the object-to-be-read D and an opening **12***b* opposite to the opening **12***a*. The housing **12** is made of a material that blocks external light. Examples of the material include metals, such as aluminum and iron, and resins. The housing **12** accommodates the light sources **9**, the optical member **1**, and the sensor array **4**, which are directly or indirectly attached to the housing **12** and retained by the housing **12**. The housing **12** suppresses light from the outside of the image reading device **2** reaching light receivers, in specific, reaching the sensor elements **3**. The housing **12** also prevents contaminants, such as dust and water drops, from entering the image reading device **2**.

The sensor substrate **11** is made of a resin, such as glass/epoxy composite. The sensor substrate **11** is provided with multiple sensor elements **3**, and other components, including a drive circuit and a signal processing circuit, for example, which are not illustrated. The sensor substrate **11** is attached to the housing **12** while closing the vertically lower opening **12***b* of the housing **12** in such an orientation that the sensor elements **3** are located within the opening **12***b*.

The sensor elements **3** are arranged in the main scanning direction, and fixed to the sensor substrate **11** with a fixing member, such as an adhesive. Each of the sensor elements **3** is provided for the corresponding lens body **5**, and receives the light converged by the corresponding lens body **5**. The sensor element **3** is made of a sensor integrated circuit (IC), for example. The sensor element **3** receives the light converged by the corresponding lens body **5**, converts the light into an electrical signal through photoelectric conversion, and outputs the electrical signal. The electrical signals output from the sensor elements **3** are converted into image data by the signal processing circuit.

As illustrated in FIGS. **2** and **3**, the optical member **1** includes the lens array **6** including multiple lens bodies **5** arranged in a line in the main scanning direction, and a transmissive member array **8** including multiple transmissive members **7** that allow light incident through one end faces to exit through the other end faces.

The lens array **6** includes the lens bodies **5** and two lateral plates **56** to hold the lens bodies **5** therebetween. The lens bodies **5** in Embodiment 1 are arranged with distances therebetween in the main scanning direction. The distances between the lens bodies **5** are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**. The lens bodies **5** converge light from the object-to-be-read D. The directions of extension of the optical axes AX**1** of the lens bodies **5** are orthogonal to both of the main and sub-scanning directions. In other words, the optical axes AX**1** of the lens bodies **5** extend in parallel to the Z axis. The lens bodies **5** converge the light emitted from the light sources **9** and reflected by the object-to-be-read D. Each of the lens bodies **5** has a circular cylindrical shape, and is preferably made of a rod lens, which is a graded index lens having refractive indexes varying in radial directions and designed to form an erect unmagnified image.

The two lateral plates **56** hold the lens bodies **5** therebetween and are opposed to each other in the Y-axis directions. The lateral plates **56** have a flat shape and are made of a light-blocking material. Examples of the material include metals, such as aluminum and iron, and resins. The space between the two lateral plates **56** is preferably filled with a light-blocking adhesive. This structure can suppress deviation of relative positions of the lens bodies **5** and the lateral plates **56** to each other.

The transmissive member array **8** prevents an overlap between images formed by the lens bodies **5** adjacent to each other, in other words, separates the optical paths of light converged by the lens bodies **5** adjacent to each other. The transmissive member array **8** includes the transmissive members **7**, and two lateral plates **78** to hold the transmissive members **7** therebetween. The transmissive members **7** in Embodiment 1 are arranged with distances therebetween in the main scanning direction. The distances between the transmissive members **7** are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**.

The transmissive members **7** are provided in association with the respective lens bodies **5**. The transmissive members **7** are disposed at positions nearer the object-to-be-read D than the corresponding lens bodies **5** are disposed or at positions farther from the object-to-be-read D than the corresponding lens bodies **5** are disposed. The transmissive members **7** in Embodiment 1 are disposed at positions farther from the object-to-be-read D than the lens bodies **5** are disposed, in other words, between the lens bodies **5** and the sensor elements **3**. Each of the transmissive members **7** is disposed in contact with the end of the corresponding lens body **5** in the direction of extension of the optical axis AX**1**, in specific, the end on the negative side in the Z-axis directions.

The transmissive member **7** is made of a material having a uniform refractive index regardless of positions in the transmissive member **7**, and has a columnar shape extending along the optical axis AX**1** of the lens body **5**. The material having a uniform refractive index means that the material at any position has a refractive index falling within a predetermined range encompassing manufacturing errors. For example, the transmissive member **7** is a circular cylindrical member made of a glass or a resin having a uniform refractive index and a uniform transmittance regardless of positions in the transmissive member **7**. The transmissive member **7** is preferably made of a material having a sufficiently small distortion, for example, a material having no distortion. The transmissive member **7** in Embodiment 1 has a circular cylindrical shape having the same diameter as that of the lens body **5**.

The transmissive member **7** allows for transmission of the light emitted from the light sources **9**. In detail, the transmissive member **7** allows the light to enter through one end face and allows the light to exit through the other end face. The transmissive member **7** in Embodiment 1 allows the light incident from the lens body **5** through the end face facing the lens body **5**, that is, the end face facing in a positive Z-axis direction to exit through the end face facing the sensor element **3**, that is, the end face facing in a negative Z-axis direction.

The two lateral plates **78** hold the transmissive members **7** therebetween and are opposed to each other in the Y-axis direction. The lateral plates **78** have a flat-plate shape and are made of a light-blocking material. Examples of the material include metals, such as aluminum and iron, and resins. The space between the two lateral plates **78** is preferably filled with a light-blocking adhesive. This structure can suppress deviation of relative positions of the transmissive members **7** and the lateral plates **78** to each other.

The lateral surface of each transmissive member **7**, in other words, the outer periphery of the transmissive member **7** around the Z axis has experienced at least either of a treatment for suppressing diffuse reflection of external light arriving at the lateral surface and a treatment for suppressing regular reflection of external light arriving at the lateral surface. As illustrated in FIG. **4**, the transmissive member **7** in Embodiment 1 includes a circular cylindrical member **71**, and a reflection suppressing member **72** made of a tubular member of which the inner periphery is in contact with the outer periphery of the circular cylindrical member **71**. In detail, the transmissive member **7** is fabricated by applying the reflection suppressing member **72** made of a black resin on the outer periphery of the circular cylindrical member **71**. The reflection suppressing member **72**, which is made of a black resin, suppresses reflection of light on the lateral surface of the transmissive member **7**. The reflection suppressing member **72** also absorbs light inside the transmissive member **7** that tries to exit through the lateral surface. The above-mentioned light-blocking adhesive filled between the two lateral plates **78** may serve as the reflection suppressing member **72**.

As illustrated in FIG. **5**, and FIG. **6**, which is a view of the lens array **6** as seen toward the positive side in the Z-axis directions, the end face of a transmissive member **7** may be only partially opposed to the end face of the corresponding lens body **5**, in accordance with a deviation of the central axis C1 of the transmissive member **7** from the optical axis AX1 of the lens body **5**. FIGS. **5** and **6** illustrate an example in which an error occurs in at least one of arrangement of the lens bodies **5** and arrangement of the transmissive members **7**. In specific, the lens bodies **5** are arranged at regular intervals and the transmissive members **7** are arranged at irregular intervals in this example. FIG. **6** illustrates the contours of the lens bodies **5** with solid lines, and the contours of the transmissive members **7** with dotted lines. In the example illustrated in FIG. **5**, the central axis C1 of the transmissive member **7** at the left end accords with the optical axis AX1 of the lens body **5** at the left end, whereas the central axes C1 of the other transmissive members **7** do not accord with the optical axes AX1 of the corresponding lens bodies **5**. The end face of the transmissive member **7** at the left end is thus totally opposed to the end face of the corresponding lens body **5**, whereas the end faces of the other transmissive members **7** are only partially opposed to the end faces of the corresponding lens bodies **5**, as illustrated in FIG. **6**.

In the case where the central axis C1 of a transmissive member **7** is deviated from the optical axis AX1 of the corresponding lens body **5**, a part of the light exiting the lens body **5** propagates toward an adjacent transmissive member **7** as illustrated with the dotted-line arrows in FIG. **5**, without entering the transmissive member **7** corresponding to this lens body **5**, that is, the transmissive member **7** in contact with this lens body **5**. The light arriving at the lateral surface of the adjacent transmissive member **7** is absorbed by the lateral surface, which is provided with the reflection suppressing member **72** as described above. Because of the arrangement of the transmissive members **7** with distances therebetween and the reflection suppressing members **72** provided to the lateral surfaces of the transmissive members **7**, the configuration can achieve separation of the optical paths of light converged by the lens bodies **5** adjacent to each other, despite of deviations of the central axes C1 of the transmissive members **7** from the optical axes AX1 of the corresponding lens bodies **5**.

As illustrated with the solid-line arrows in FIG. **5**, a part of the light, incident from a lens body **5** through one end face of the transmissive member **7**, propagates straight inside the transmissive member **7**, and arrives at the sensor element **3**. Another part of the light, incident from the lens body **5** through the one end face of the transmissive member **7**, arrives at the lateral surface of the transmissive member **7**. When the light arrives at the lateral surface of the transmissive member **7** at an incident angle equal to or larger than the critical angle, the light is totally reflected, propagates straight inside the transmissive member **7**, and arrives at the sensor element **3**. When the light is incident through the one end face of the transmissive member **7** at a large angle from the central axis C1 and arrives at the lateral surface of the transmissive member **7** at a small incident angle, the light is not totally reflected, but refracted and then absorbed by the reflection suppressing member **72** provided to the lateral surface of the transmissive member **7**.

The length of the transmissive member **7** can be elongated in the direction of extension of the optical axis AX1 of the lens body **5**, in other words, in the Z-axis direction. The elongated transmissive member **7** can suppress the light incident through the one end face of the transmissive member **7** directly exiting through the other end face without arriving at the lateral surface of the transmissive member **7**. The light incident through the one end face of the transmissive member **7** at a large angle from the central axis C1 thus does not arrive at or exit through the other end face of the transmissive member **7**. In other words, the transmissive member **7** allows only the light arriving at the lateral surface of the transmissive member **7** at an incident angle equal to or larger than the critical angle to successfully exit.

The lens bodies **5** are arranged with distances therebetween, and the transmissive members **7** are arranged with distances therebetween. The sensor elements **3** are thus arranged with distances therebetween in association with the respective lens bodies **5**, as illustrated in FIG. **5**. The sensor elements **3** are arranged with sufficiently large distances therebetween to prevent the light, arriving at the lateral surface of each transmissive member **7** at an incident angle equal to or larger than the critical angle and exiting through the other end face of the transmissive member **7**, from reaching the other sensor elements **3** adjacent to the sensor element **3** opposed to this transmissive member **7**. Furthermore, the sensor elements **3** are arranged with sufficiently large distances therebetween to prevent the light, propagating straight not via the lateral surface of each transmissive member **7** and exiting the transmissive member **7**, from reaching the other sensor elements **3** adjacent to the sensor element **3** opposed to this transmissive member **7**. This structure can suppress the light exiting different transmissive members **7** reaching the same sensor element **3**, as illustrated with the dashed-line arrows.

The light received by a sensor element **3** when the central axis C1 of the transmissive member **7** is deviated from the optical axis AX1 of the lens body **5** has a lower intensity than that of the light received by the sensor element **3** when the central axis C1 of the transmissive member **7** accords with the optical axis AX1 of the lens body **5**. The deviation of the central axis C1 of the transmissive member **7** from the optical axis AX1 of the lens body **5** is preferably within the range that can ensure an intensity of light received by the sensor element **3** sufficient for reading of information on the object-to-be-read D, for the purpose of highly accurate scanning of the object-to-be-read D. The central axis C1 of at least any one of the transmissive members **7** preferably accords with the optical axis AX1 of the corresponding lens body **5**.

As described above, the optical member **1** of the image reading device **2** according to Embodiment 1 includes the lens bodies **5** arranged with distances therebetween, and the transmissive members **7** arranged with distances therebetween in association with the respective lens bodies **5**. In accordance with the arrangement of the lens bodies **5** with distances therebetween and the arrangement of the transmissive members **7** with distances therebetween, the sensor elements **3** provided in association with the respective lens bodies **5** are also arranged with distances therebetween. This structure can suppress the light exiting a lens body **5** being received by the sensor elements **3** corresponding to the other lens bodies **5** adjacent to this lens body **5**, despite of a deviation of the optical axis AX1 of the lens body **5** from the central axis C1 of the transmissive member **7**. The structure can therefore provide the optical member **1** and the image reading device **2** capable of suppressing an overlap between images formed by the lens bodies **5**, regardless of an error in at least one of arrangement of the lens bodies **5** and arrangement of the transmissive members **7**.

The distances between the lens bodies **5** at least in the main scanning direction are larger than errors in the arrangement of the lens bodies **5**. The distances between the transmissive members **7** at least in the main scanning direction are larger than errors in the arrangement of the transmissive members **7**. Being larger than errors in the arrangement means being larger than the maximum value of expected errors in the arrangement. At least either ones of the lens bodies **5** and the transmissive members **7** are arranged with distances therebetween larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**.

In addition, the reflection suppressing member **72** provided to the lateral surface of each transmissive member **7** can separate the optical paths of light converged by the lens bodies **5** adjacent to each other.

Embodiment 2

The lens bodies **5** and the transmissive members **7** may have a shape and may be arranged in a manner other than those in the above-described example. The description of Embodiment 2 is directed to an optical member **1** including lens bodies **5** and transmissive members **7** having different shapes and arranged in different manners from those in Embodiment 1, and an image reading device **2** including this optical member **1**, focusing on the differences from Embodiment 1.

In the optical member **1** of the image reading device **2** according to Embodiment 2, either ones of the lens bodies **5** and the transmissive members **7** are arranged with distances therebetween, and the other ones of the lens bodies **5** and the transmissive members **7** are arranged in contact with each other. The distances are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**. As illustrated in FIG. **7**, and FIG. **8**, which is a view of the lens array **6** as seen toward the positive side in the Z-axis directions, the lens bodies **5** in Embodiment 2 are arranged in contact with each other, and the transmissive members **7** are arranged with distances therebetween. The distances between the transmissive members **7** in the main scanning direction are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**.

As illustrated in FIG. **8**, the lens bodies **5** and the transmissive members **7** have circular cylindrical shapes, and the diameter of the lens bodies **5** is different from the diameter of the transmissive members **7**. The lens bodies **5** have a diameter larger than that of the transmissive members **7**. The lens bodies **5** are arranged in contact with each other, that is, at regular intervals, and the transmissive member **7** are arranged at irregular intervals. The central axis C**1** of the transmissive member **7** at the left end thus accords with the optical axis AX**1** of the corresponding lens body **5**, whereas the central axes C**1** of the other transmissive members **7** are deviated from the optical axes AX**1** of the corresponding lens bodies **5** in FIG. **7**.

Due to the diameter of the transmissive member **7** smaller than the diameter of the lens body **5**, a part of the light exiting a lens body **5** propagates toward an adjacent transmissive member **7** as illustrated with the dotted-line arrows in FIG. **7**, without entering the transmissive member **7** corresponding to this lens body **5**, that is, the transmissive member **7** in contact with this lens body **5**. The light exiting the lens body **5** and failing to enter the corresponding transmissive member **7** in contact with this lens body **5** does not enter the adjacent transmissive member **7** but propagates toward the lateral surface of the adjacent transmissive member **7**, because of the arrangement of the transmissive members **7** with distances therebetween in contrast to the arrangement of the lens bodies **5** in contact with each other. The light arriving at the lateral surface of the adjacent transmissive member **7** is absorbed by the lateral surface, which is provided with the reflection suppressing member **72** as in Embodiment 1.

The transmissive members **7** are preferably arranged at such positions that the end faces of the transmissive members **7** having a smaller diameter are totally opposed to the end faces of the lens bodies **5** having a larger diameter. The central axis C**1** of at least any one of the transmissive members **7** preferably accords with the optical axis AX**1** of the corresponding lens body **5**.

As described above, the optical member **1** of the image reading device **2** according to Embodiment 2 includes the lens bodies **5** arranged in contact with each other, and the transmissive members **7** arranged with distances therebetween in association with the respective lens bodies **5**. Because of the arrangement of the transmissive members **7** with distances therebetween, the light exiting a lens body **5** and failing to enter the transmissive member **7** in contact with this lens body **5** arrives at the lateral surface of another transmissive member **7** adjacent to this transmissive member **7** and is absorbed by the lateral surface of the adjacent transmissive member **7**. This structure can suppress the light exiting a lens body **5** being received by the sensor elements **3** corresponding to the other lens bodies **5** adjacent to this lens body **5**, despite of a deviation of the optical axis AX**1** of the lens body **5** from the central axis C**1** of the transmissive member **7**. The structure can therefore provide the optical member **1** and the image reading device **2** capable of suppressing an overlap between images formed by the lens bodies **5**, regardless of an error in at least one of arrangement of the lens bodies **5** and arrangement of the transmissive members **7**.

Embodiment 3

The optical member **1** may further include light-blocking members to suppress an overlap between images formed by the lens bodies **5**. The description of Embodiment 3 is directed to the optical member **1** further including light-blocking members disposed between the lens bodies **5** of the lens array **6** and the transmissive members **7** of the transmissive member array **8**, and the image reading device **2** including the optical member **1**, focusing on the differences from Embodiment 1.

The optical member **1** of the image reading device **2** illustrated in FIG. **9** includes a lens array **6** including multiple lens bodies **5** arranged adjacent to each other, and a transmissive member array **8** including multiple transmissive members **7** arranged adjacent to each other, as illustrated in FIGS. **10** and **11**. The lens bodies **5** and the transmissive members **7** have circular cylindrical shapes having the same diameter.

The lens array **6** and the transmissive member array **8** are disposed with a space therebetween in the Z-axis direction, as illustrated in FIGS. **9** and **10**. In detail, the transmissive members **7** are disposed with a space from the ends of the lens bodies **5** in the directions of extension of the optical axes AX**1**, that is, the ends of the lens bodies **5** in the Z-axis directions.

The optical member **1** further includes one or more light-blocking members **13** between the lens bodies **5** and the transmissive members **7**. The light-blocking members **13** are disposed at positions having predetermined distances from the straight lines formed by extending the optical axes of the lens bodies **5**. FIG. **11** illustrates multiple light-blocking members **13** disposed between the lens array **6** and the transmissive member array **8**. The light-blocking members **13** are made of a light-blocking material, such as black resin. Each of the light-blocking members **13** is in contact with two transmissive members **7** adjacent to each other, as illustrated in FIG. **12**. The light-blocking members **13** are also in contact with the lens bodies **5**.

In the example illustrated in FIG. **12**, the central axes C**1** of the transmissive members **7** are deviated from the optical axes AX**1** of the corresponding lens bodies **5**. One end face of a transmissive member **7** is thus partially opposed in the Z-axis direction to another lens body **5** adjacent to the lens body **5** corresponding to this transmissive member **7**. As illustrated with the dotted-line arrow in FIG. **12**, the light propagating from a lens body **5** toward another transmissive member **7** adjacent to the transmissive member **7** corresponding to this lens body **5** arrives at and is absorbed by the light-blocking member **13**, which is disposed in contact with two transmissive members **7** adjacent to each other as described above. The light-blocking member **13** can thus separate the optical paths of light converged by two lens bodies **5** adjacent to each other.

As described above, the optical member **1** of the image reading device **2** according to Embodiment 3 includes the light-blocking members **13** disposed between the lens bodies **5** and the transmissive members **7**. The light-blocking members **13** each separate the optical paths of light converged by the lens bodies **5** adjacent to each other. This structure can suppress the light exiting a lens body **5** entering another transmissive member **7** adjacent to the transmissive member **7** corresponding to this lens body **5** and being received by another sensor element **3** adjacent to the sensor element **3** corresponding to this lens body **5**, despite of a deviation of the optical axis AX**1** of the lens body **5** from the central axis C**1** of the transmissive member **7**. The structure can therefore provide the optical member **1** and the image reading device **2** capable of suppressing an overlap between images formed by the lens bodies **5**, regardless of an error in at least one of arrangement of the lens bodies **5** and arrangement of the transmissive members **7**.

The above-described embodiments are not to be construed as limiting the scope of the present disclosure. The components of the optical member **1** may be arranged in a manner other than that in the above-described examples. As illustrated in FIG. **13**, the lens array **6** and the transmissive member array **8** may be disposed with a space therebetween in the Z-axis directions, and retained by the housing **12**.

The transmissive member array **8** may also be disposed at a position nearer the object-to-be-read D than the lens array **6** is disposed. In detail, as illustrated in FIG. **14**, the optical member **1** may include a transmissive member array **8** including multiple transmissive members **7** that allow light incident from the object-to-be-read D through one end faces to exit through the other end faces, and a lens array **6** including multiple lens bodies **5** that converge the light exiting through the other end faces of the transmissive members **7** and cause the corresponding sensor elements **3** to form images.

Although the other end faces of the transmissive members **7** of the transmissive member array **8** are in contact with the end faces of the lens bodies **5** of the lens array **6** in the example illustrated in FIG. **14**, the transmissive members **7** and the lens bodies **5** may also be disposed with a space therebetween as illustrated in FIG. **15**. The distances between the lens bodies **5** and the distances between the transmissive members **7** are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**.

As illustrated in FIG. **16**, the light-blocking members **13** may be disposed between the transmissive member array **8** and the lens array **6**. As illustrated with the dotted-line arrow in FIG. **17**, a light-blocking member **13** absorbs the light from the object-to-be-read D that fails to propagate toward the lens body **5** corresponding to this transmissive member **7** and arrives at the light-blocking member **13** through the transmissive member **7**.

The lens bodies **5** and the transmissive members **7** may be arranged in a manner other than that in the above-described examples. As illustrated in FIGS. **18** and **19**, the lens bodies **5** may be arranged at irregular intervals, and the transmissive members **7** may be arranged at regular intervals.

The lens bodies **5** and the transmissive members **7** may have any shape other than those in the above-described examples. For example, the transmissive members **7** may have a circular cylindrical shape having a larger diameter than that of the lens bodies **5**. In this case, as illustrated in FIG. **20**, the transmissive members **7** are arranged in contact with each other, and the lens bodies **5** are arranged with distances therebetween. The distances between the lens bodies **5** are larger than errors in the arrangement of the lens bodies **5** and the transmissive members **7**. The transmissive members **7** have experienced a treatment for suppressing diffuse reflection of external light arriving at the lateral surfaces, in specific, a process of applying an adhesive containing carbon black to the transmissive members **7**. Application of the adhesive is preferably performed while suppressing formation of air layers.

The transmissive members **7** may be made of a material other than that in the above-described examples. The transmissive members **7** may be made of any material that allows for transmission of the light emitted from the light sources **9** to be used for scanning of the object-to-be-read D. In an exemplary case where the light sources **9** emit light, such as infrared light or ultraviolet light, other than visible light, the transmissive members **7** are made of a material, such as germanium, acrylic resin, or glass, for example.

The reflection suppressing members **72** may be made of a material other than that in the above-described examples. The reflection suppressing members **72** may be made of any material that can suppress reflection of the light emitted from the light sources **9** to be used for scanning of the object-to-be-read D.

Although the object-to-be-read D is displaced relative to the fixed image reading device **2** in the above-described embodiments, the image reading device **2** may be displaced relative to the fixed object-to-be-read D to read information on the object-to-be-read D. The transportation of the object-to-be-read D in the sub-scanning direction, that is, in the transport direction may be achieved by transportation of the object-to-be-read D itself or by displacement of the image reading device **2**.

The light sources **9** may also be disposed at positions other than those in the above-described examples. For example, the image reading device **2** may include light sources **9** that are disposed at positions nearer the positive side in the Z-axis directions than the transmissive plate **10** is disposed. In this case, the object-to-be-read D is transported between the transmissive plate **10** and the light sources **9**.

The light sources **9** may be installed outside the image reading device **2**. In specific, the light sources **9** may be installed outside the housing **12**, in the optical member **1** designed to converge the reflected light reflected by the object-to-be-read D, and in the optical member **1** designed to converge the transmitted light passing through the object-to-be-read D.

The transmissive plate **10** allows for transmission of the light emitted from the light sources **9**, which may be light other than visible light. The transmissive plate may be made of a material that allows for transmission of light, such as infrared light or ultraviolet light. The transmissive plate **10** may be made of any material that allows for transmission of light emitted from the light sources **9** even if the material does not allow for transmission of visible light. The transmissive plate **10** is not necessarily attached to the image reading device **2**, in specific, to the housing **12**, unless the transmissive plate **10** needs to define the surface for transporting the object-to-be-read D.

The light sources **9** may have a configuration other than that in the above-described examples. For example, the light sources **9** may each include multiple light-emitting diodes (LEDs), and an LED substrate extending in the main scanning direction and provided with the LEDs. In this case, the LEDs are arranged in an array in the main scanning direction. The two light sources **9** on both sides of the optical member **1** illustrated in FIG. **1** may be replaced with a single light source **9**.

The sensor substrate **11** may be disposed at any position other than that in the above-described examples, provided that the sensor array **4** mounted on the sensor substrate **11** can receive the light converged by the lens array **6**.

Although the lens bodies **5** are graded index lenses having a circular cylindrical shape in the above-described embodiments, the lens bodies **5** may each be any lens body of an erecting equal-magnification optical system. For example, the lens bodies **5** may be microlenses.

The transmissive members **7** may have any structure other than that in the above-described examples, provided that the transmissive members **7** allow light incident through one end faces to exit through the other end faces. For example, the transmissive members **7** may have a shape of a circular cylinder having a through hole extending through the cylinder in the direction of extension of the central axis C**1**. In other words, the transmissive members **7** may have a hollow cylindrical shape.

The foregoing describes some example embodiments for explanatory purposes. Although the foregoing discussion has presented specific embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined only by the included claims, along with the full range of equivalents to which such claims are entitled.

REFERENCE SIGNS LIST

D Object-to-be-read
1 Optical member
2 Image reading device
3 Sensor element
4 Sensor array
5 Lens body
6 Lens array
56 Lateral plate
7 Transmissive member
71 Circular cylindrical member
72 Reflection suppressing member
8 Transmissive member array
78 Lateral plate
9 Light source
10 Transmissive plate
11 Sensor substrate
12 Housing
12*a*, **12***b* Opening
13 Light-blocking member
AX**1** Optical axis
C**1** Central axis

The invention claimed is:

1. An optical member, comprising:

a lens array including lens bodies that are arranged in contact with each other in a line in a main scanning direction, have a circular cylindrical shape, and are configured to converge light from an object-to-be-read;

transmissive members made of a material having a uniform refractive index, the transmissive members being disposed at positions nearer the object-to-be-read than the corresponding lens bodies being disposed or at positions farther from the object-to-be-read than the corresponding lens bodies being disposed, with the transmissive members spaced apart and adjacent to each other, the transmissive members having a circular cylindrical shape extending along optical axes of the lens bodies, the transmissive members being configured to allow light incident through one end faces to exit through other end faces; and

one or more light-blocking members disposed between the lens bodies and the transmissive members, the one or more light-blocking members being disposed between straight lines formed by extending the optical axes of the lens bodies arranged adjacent to each other, each of the one or more light-blocking members being configured to separate optical paths of light to be incident to mutually adjacent ones of the lens bodies or optical paths of light converged by mutually adjacent ones of the lens bodies, wherein

the lens bodies have a diameter larger than a diameter of the corresponding transmissive members.

2. The optical member according to claim **1**, further comprising:

reflection suppressing members disposed in contact with lateral surfaces of the transmissive members to suppress reflection.

3. The optical member according to claim **1**, wherein a central axis of at least any one of the transmissive members accords with the optical axis of the corresponding lens body.

4. The optical member according to claim **1**, wherein the transmissive members are in contact with ends of the lens bodies in directions of extension of the optical axes of the lens bodies.

5. The optical member according to claim **1**, wherein the transmissive members are disposed with a space from ends of the lens bodies in directions of extension of the optical axes of the lens bodies.

6. The optical member according to claim **1**, wherein the transmissive members each have a shape of a circular cylinder having a through hole extending through the circular cylinder in a direction of extension of a central axis.

7. An image reading device, comprising:

the optical member according to claim **1**; and

a sensor array including sensor elements provided in association with the respective lens bodies of the lens array of the optical member, the sensor elements being configured to receive light converged by the lens bodies.

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