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GB 2560552 B

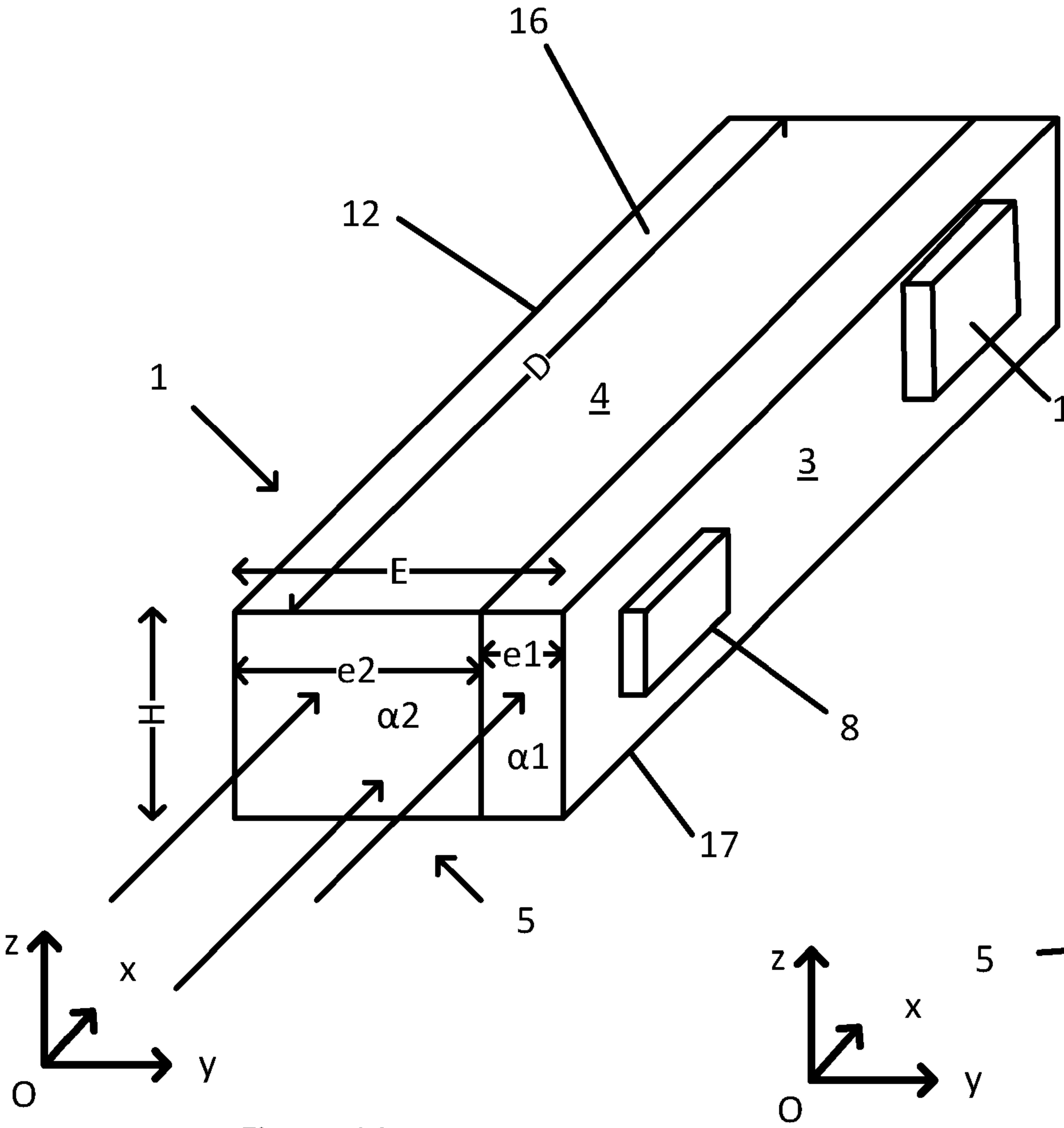

Figure 1A

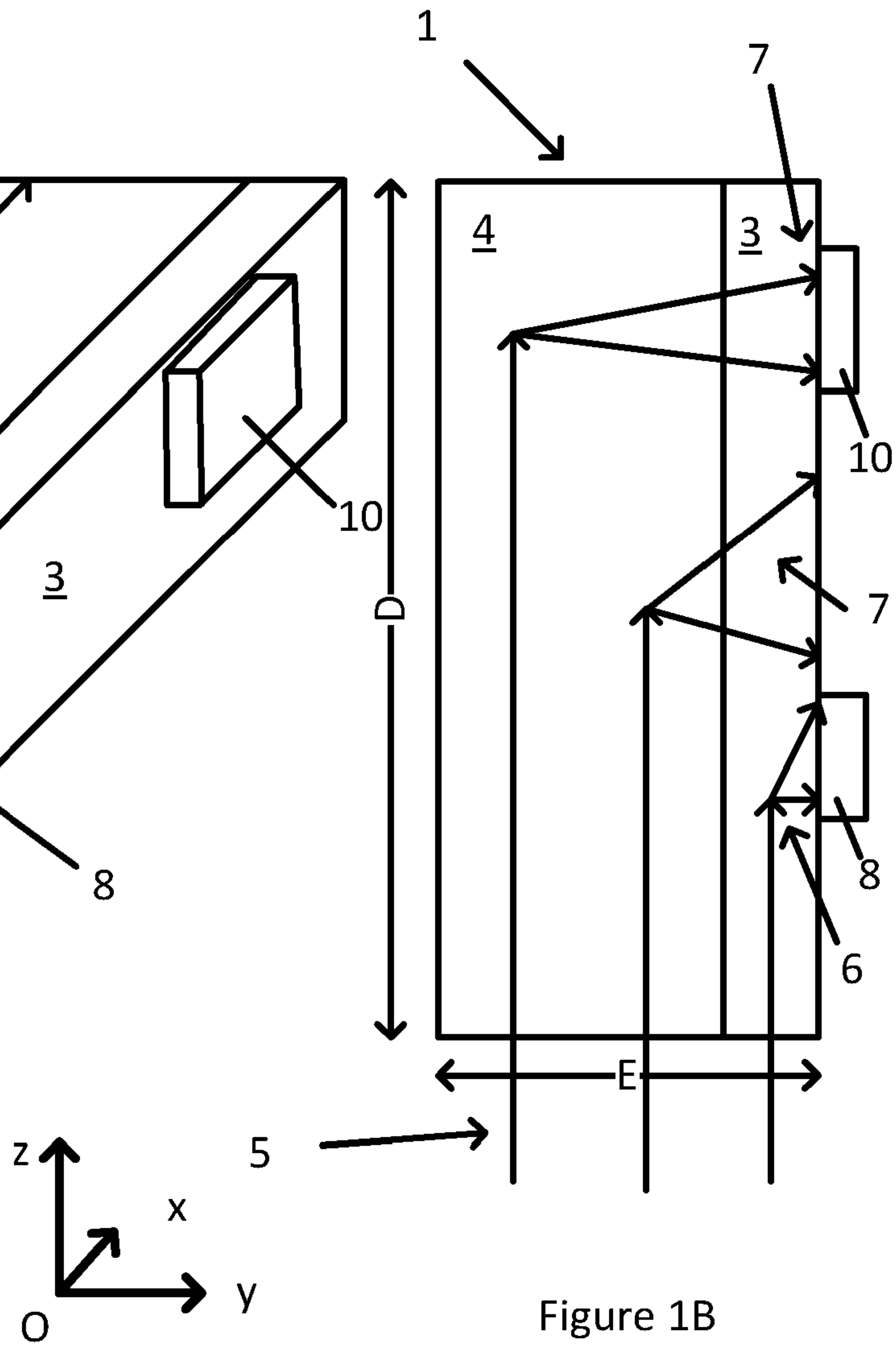

Figure 1B

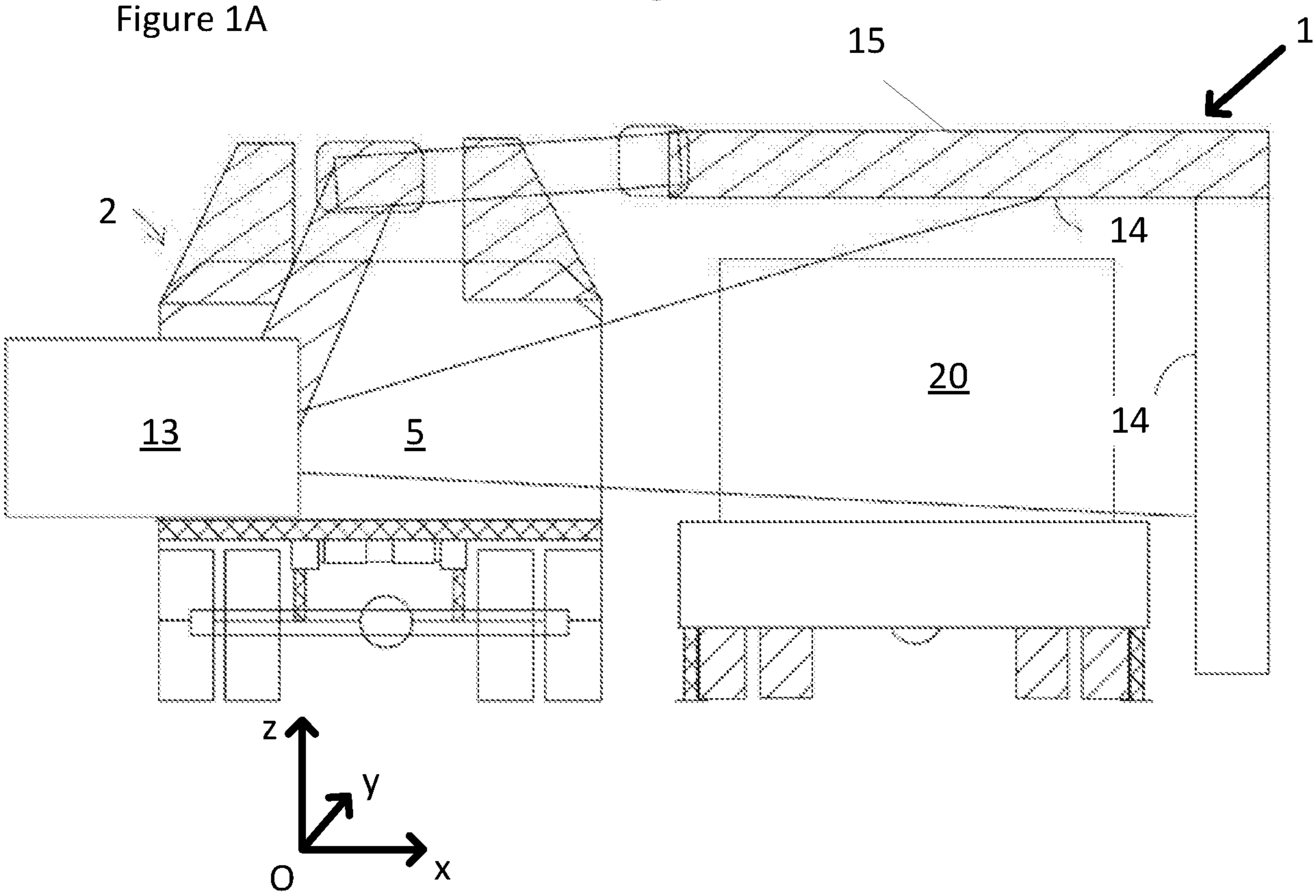

Figure 2

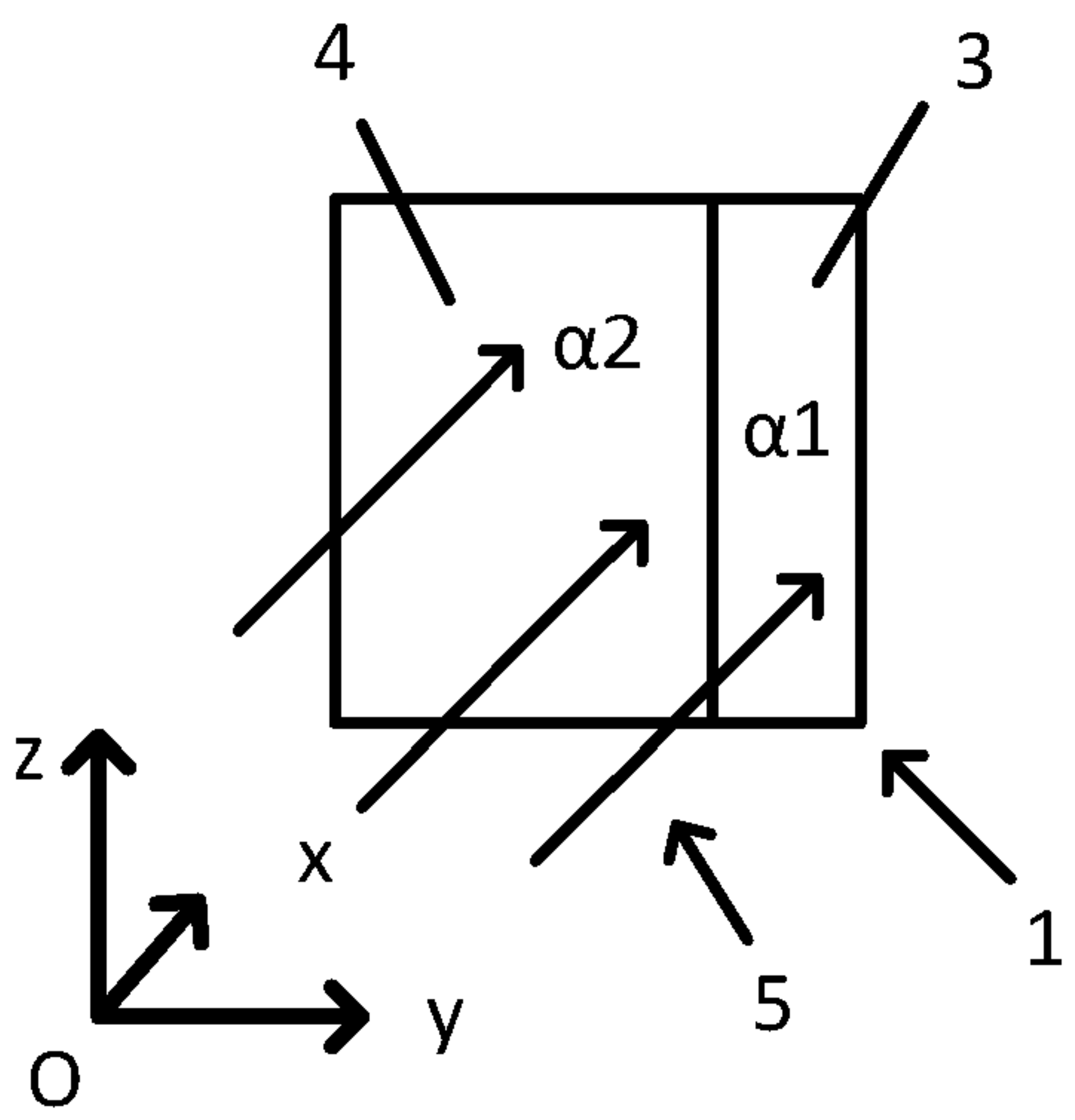

Figure 3A

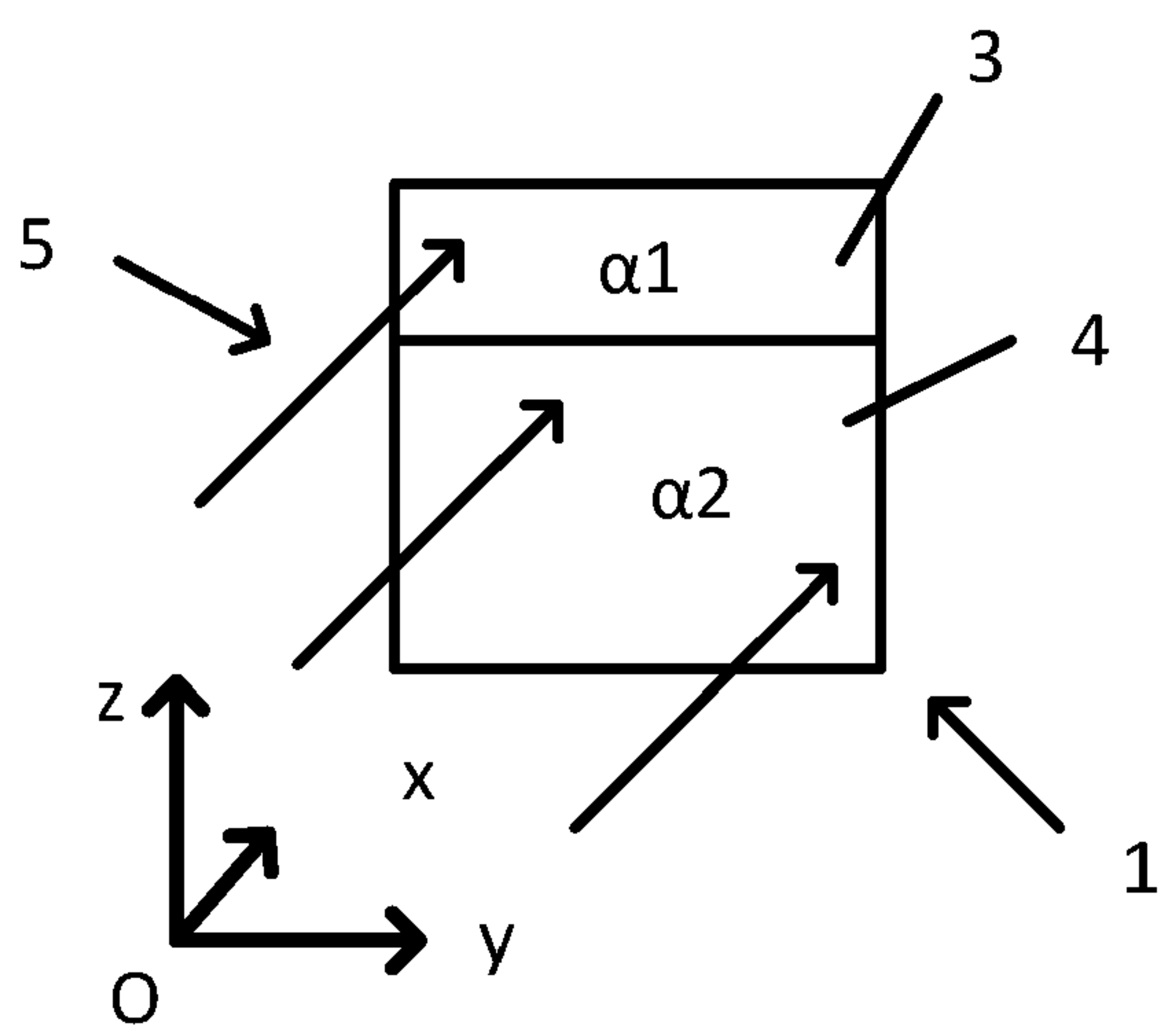

Figure 3B

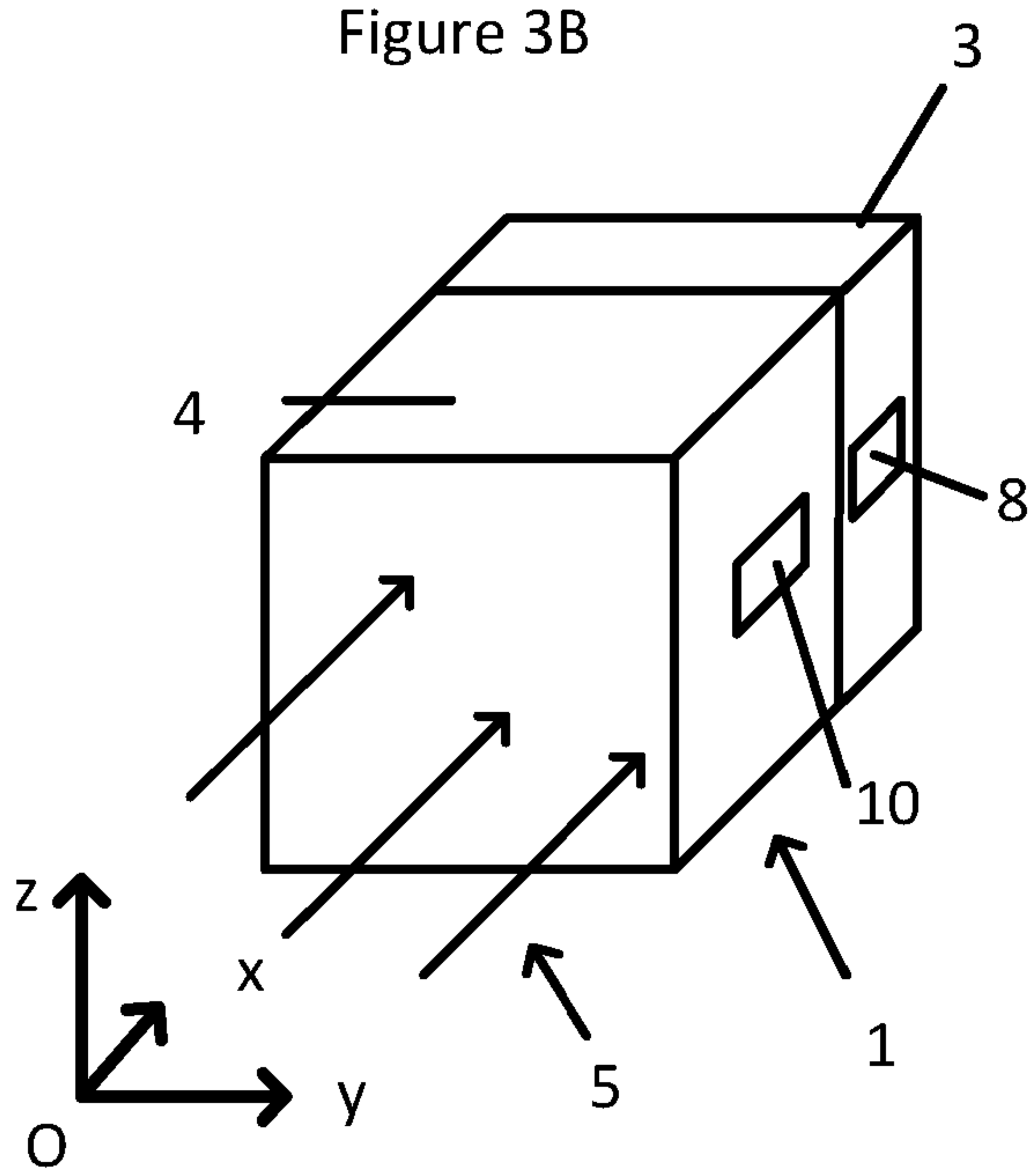

Figure 3C

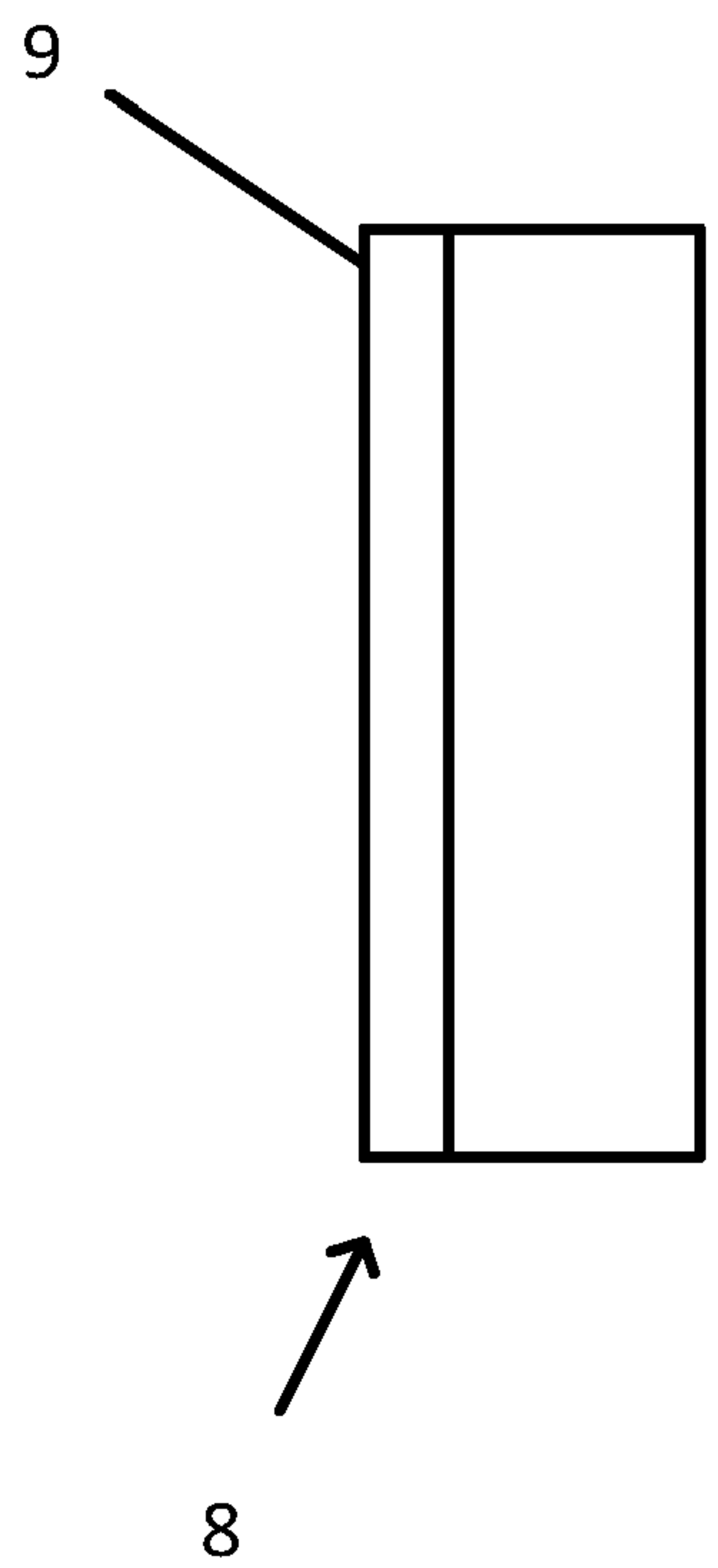

Figure 4A

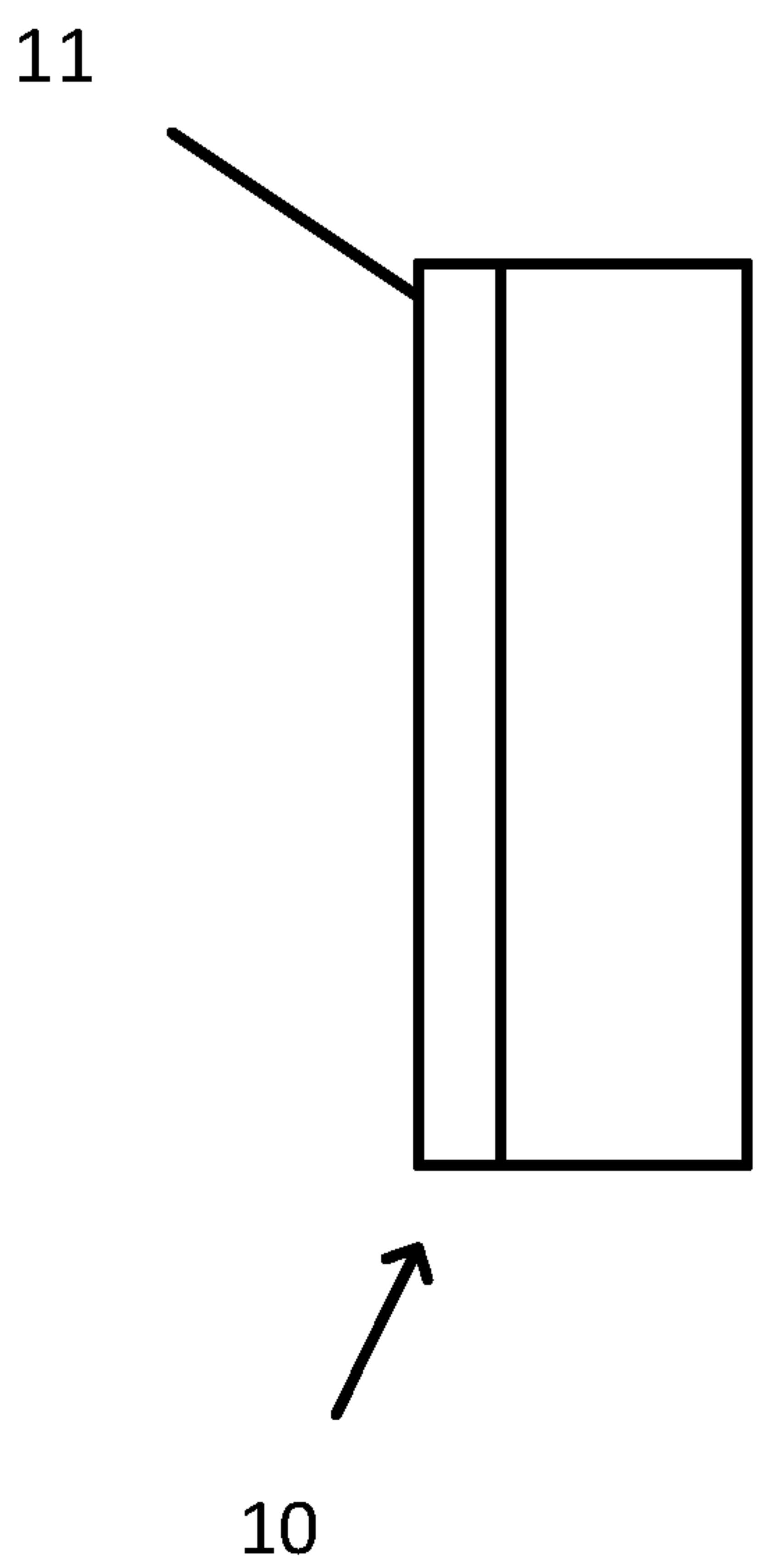

Figure 4B

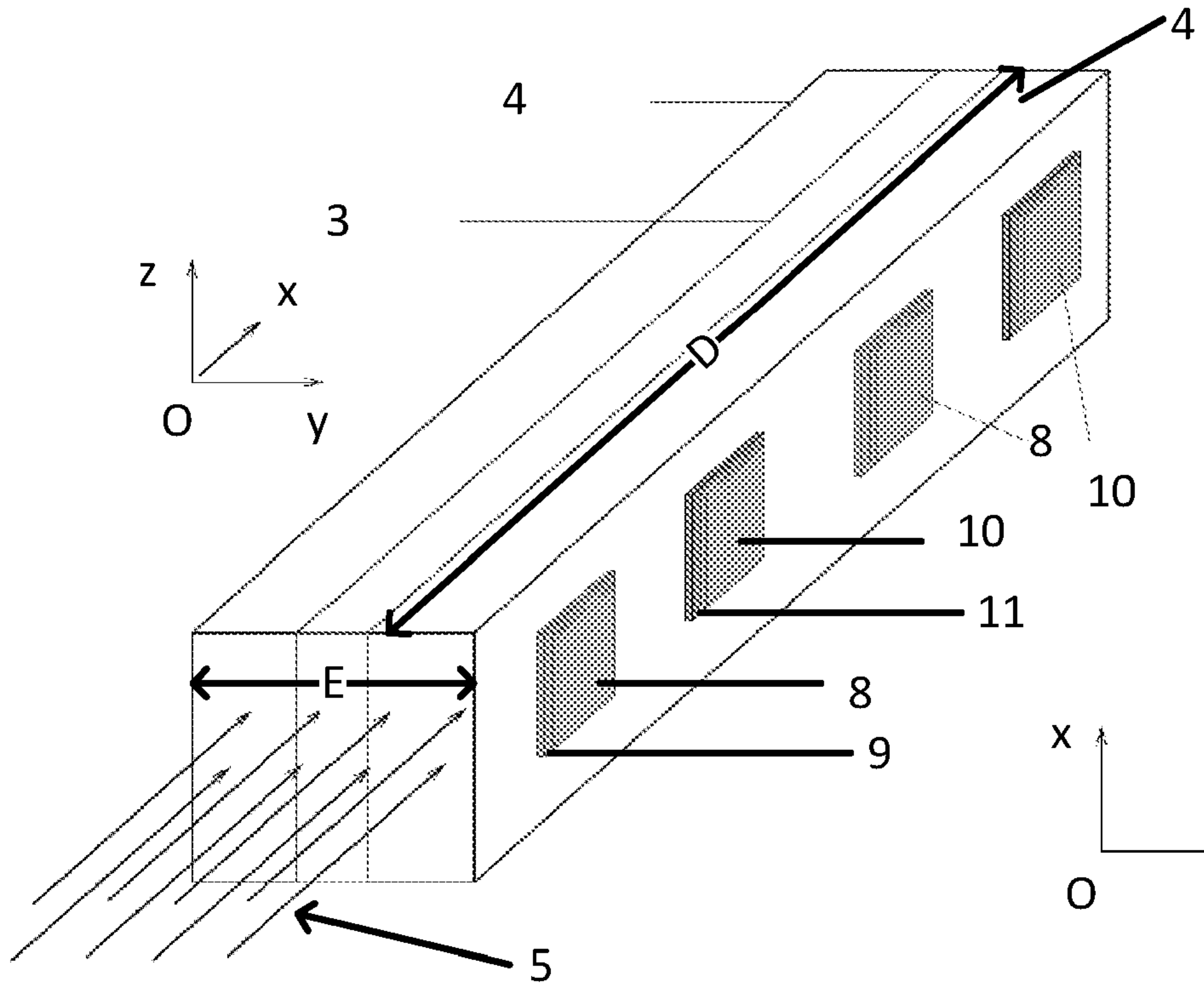

Figure 5A

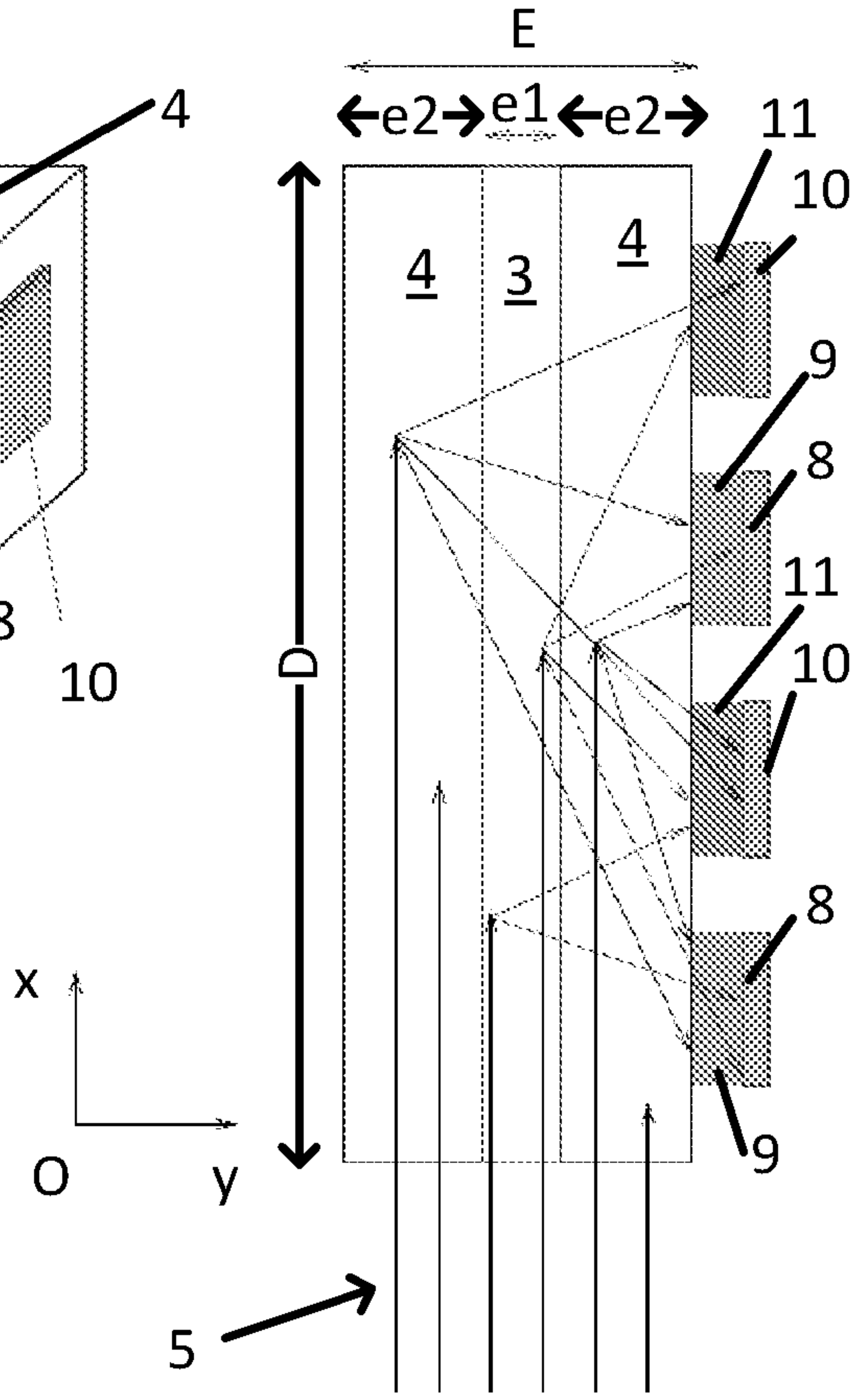

Figure 5B

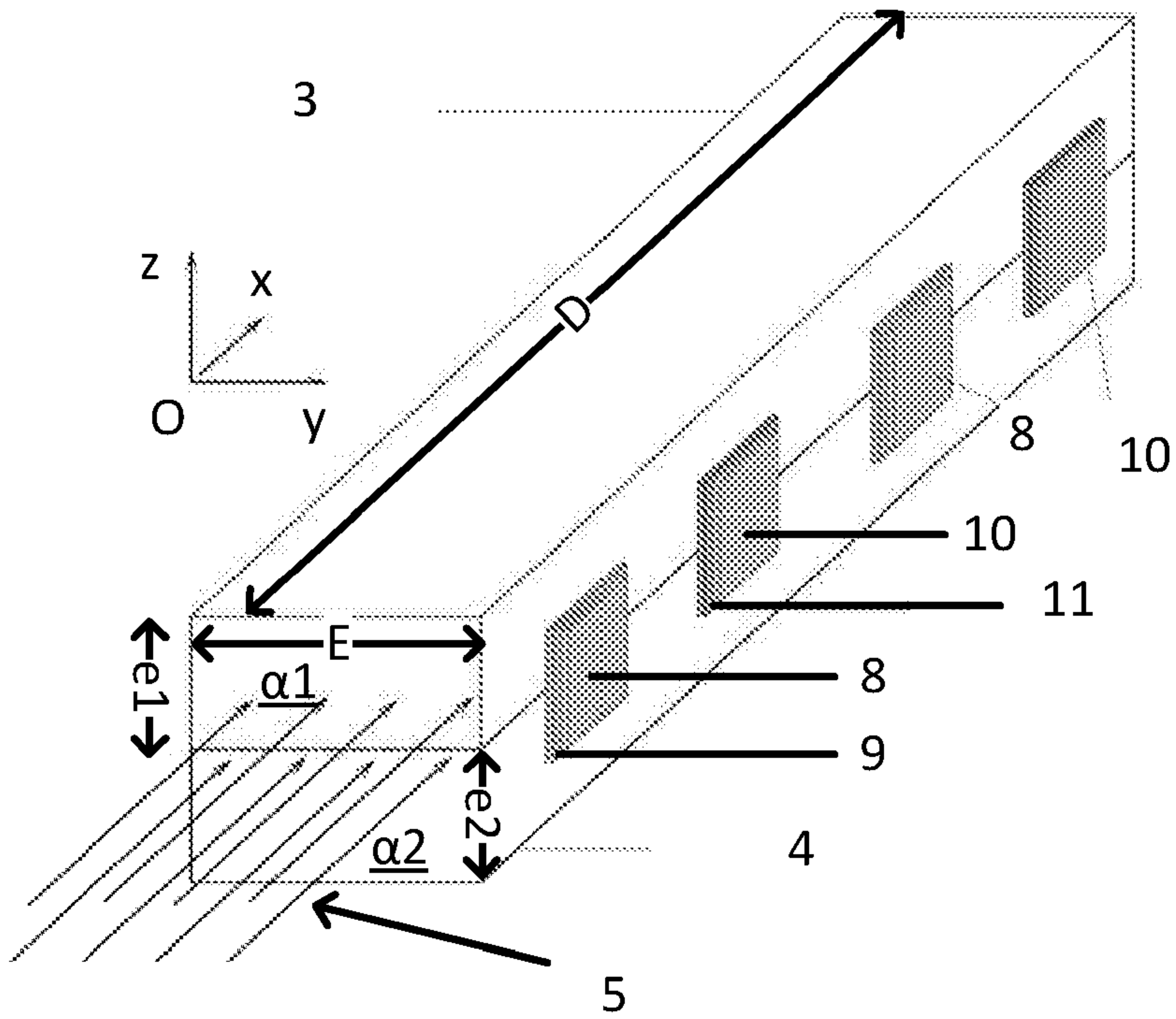

Figure 6

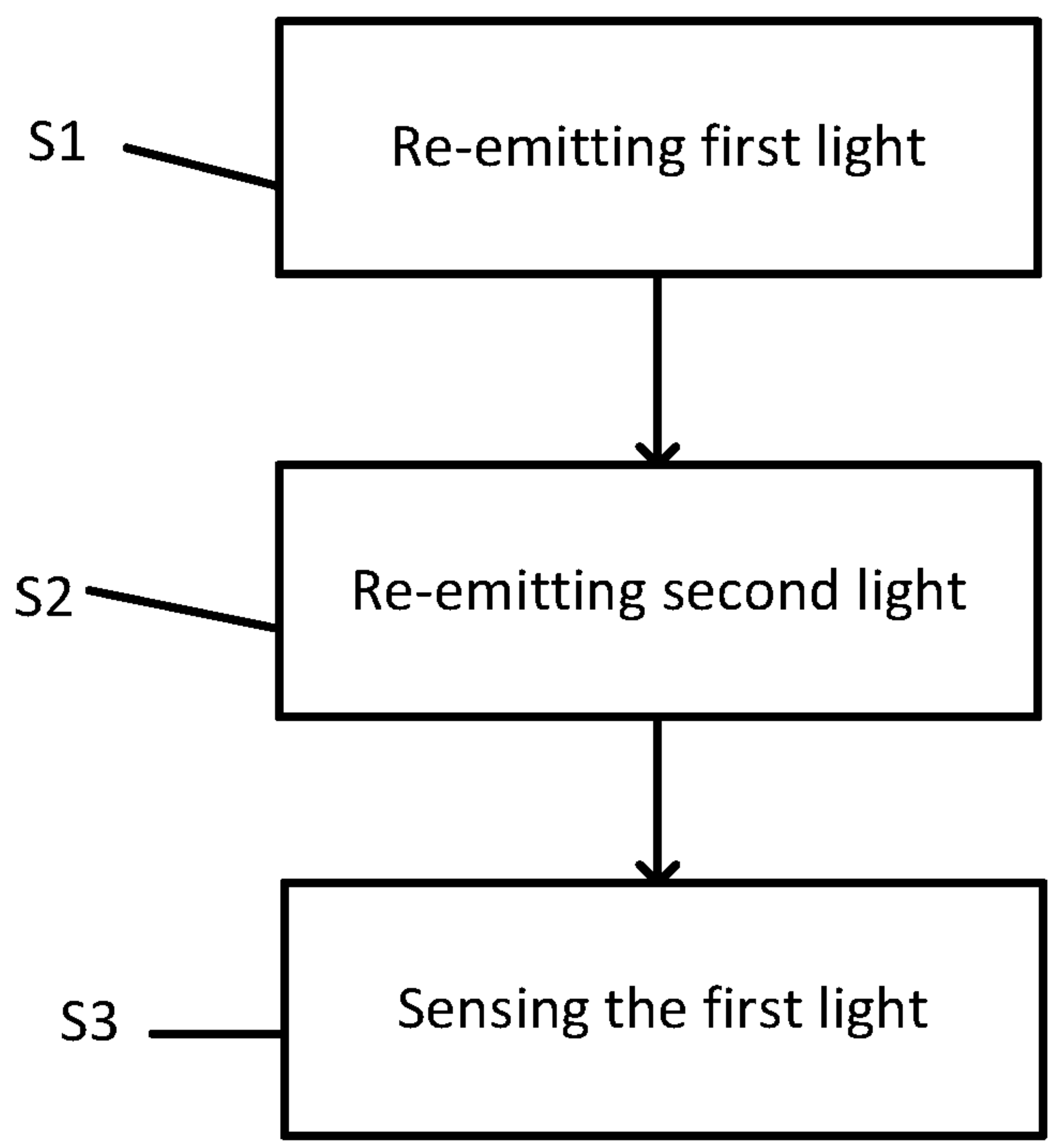

Figure 7

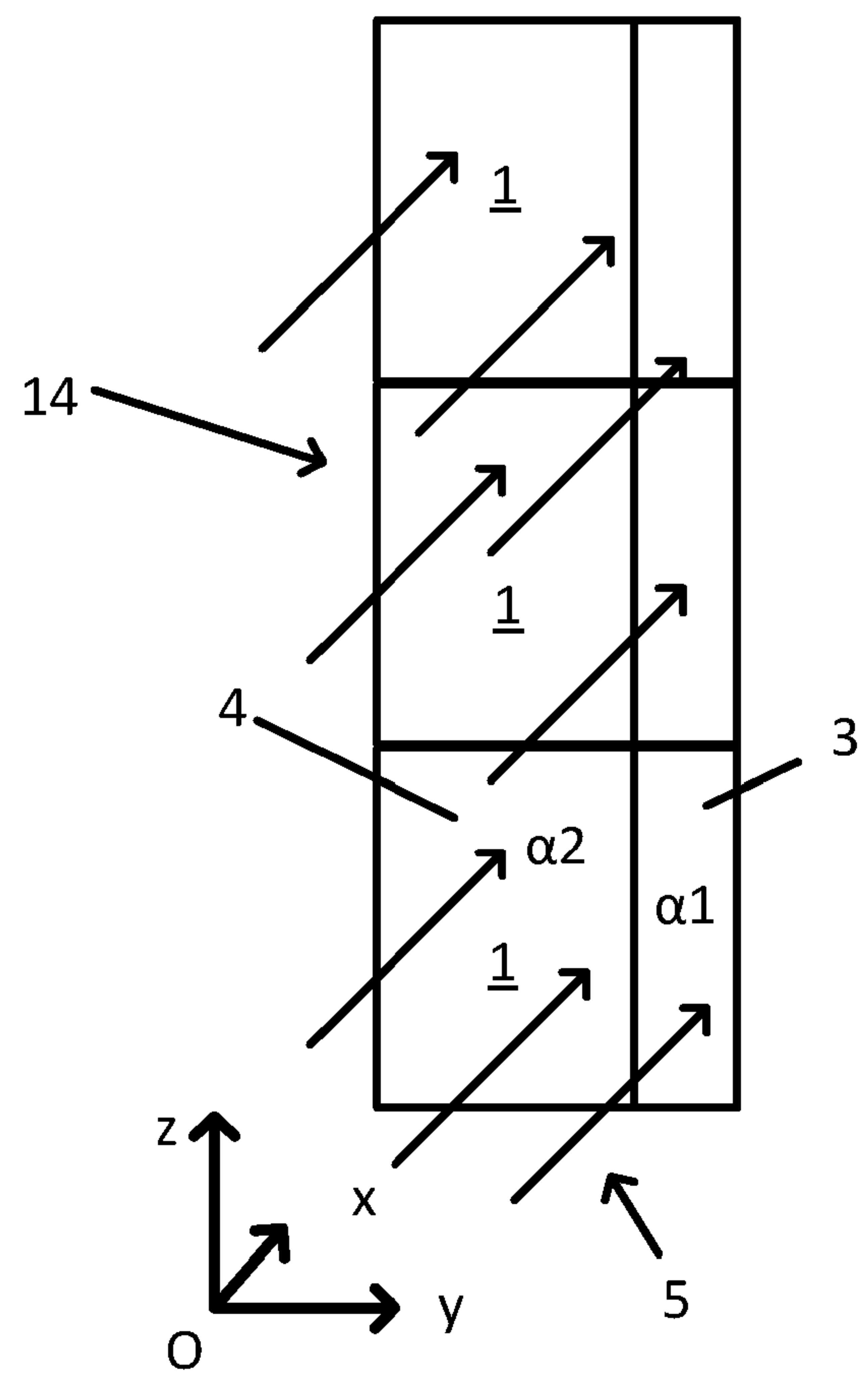

Figure 8

Method and Apparatus

Field of Invention

The present disclosure relates to scanning apparatus and methods and to the detection of objects concealed in cargo, for example by imaging.

Background

Inspection systems use inspection radiation for inspecting cargo (such as a vehicle), for example to detect hidden objects (such as weapons or dangerous material).
Detectors used in the known inspection systems usually generate a relatively large signal so that an image derived from the signal may have a satisfying contrast. However resolution may not always be optimal.

Aspects of the present invention address some of the above issues.

Summary of Invention

Aspects and embodiments of the present disclosure, such as those set out in the appended claims, aim to address the above mentioned technical problem, and related technical problems.

Presentation of the Figures

Embodiments of the disclosure will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1A shows an example detector, in a perspective view;

FIG. 1B shows the example detector of Figure 1A, in a top view;

FIG. 2 shows an example system for inspection, viewed from a rear side;

FIG. 3A shows an example detector, in a front view;

FIG. 3B shows another example detector, in a front view;

FIG. 3C shows an example detector, in a perspective view;

FIG. 4A shows an example first sensor, in a side view;

FIG. 4B shows an example second sensor, in a side view;

FIG. 5A shows an example detector, in a perspective view;

FIG. 5B shows the example detector of Figure 5A, in a top view;

FIG. 6 shows an example detector, in a perspective view;

FIG. 7 shows a flowchart that illustrates an example method according to the disclosure; and

FIG. 8 shows an example detection array, in a front view.

In the drawings, like elements are referred to by the same numerical references.

Description of Example Embodiments

Overview

Figures 1A and 1B show a schematic illustration of a detector 1. As illustrated by Figure 2, the detector 1 is suitable for being used with an inspection system 2, e.g. for inspection of cargo 20.

The detector 1 comprises at least one first scintillator 3 configured to, in response to interaction with a pulse 5 of inspection radiation, re-emit first light 6 in a first wavelength domain.

The inspection radiation may comprise X-ray radiation as a non-limiting example. In some examples, the inspection may be performed by transmission of successive inspection radiation pulses through the cargo 20 to be inspected.

The detector 1 comprises at least one second scintillator 4 configured to, in response to interaction with the pulse 5 of inspection radiation, re-emit second light 7 in a second wavelength domain different from the first wavelength domain.

The detector 1 further comprises at least one first sensor 8 configured to measure (e.g. sense and/or acquire) the first light 6 and not the second light 7 (e.g. the first sensor 8 is configured to be insensitive to and/or not acquire the second light 7).

Given that the first light 6 produced by the first scintillator 3 and the second light 7 produced by the second scintillator 4 are different, and that the first sensor 8 measures the first light only, the detector 1 according to the present disclosure enables determining energy deposition associated with the pulse 5 at the level of the first scintillator 3 only. As illustrated in Figures 1A and 3A, the first scintillator 3 may have an area α1 exposed to the pulse 5 which is a fraction of the total area of the detector 1 exposed to the pulse 5.

As illustrated in Figures 1A and 3A, when the first scintillator 3 and the second scintillator 4 are positioned adjacent along a direction (Oy) transverse to a direction (Ox) of propagation of the pulses 5, a resolution of an image obtained using a signal associated with the first scintillator 3 and the first sensor 8 may be increased in the (Oy) direction. As illustrated in Figures 3B and 6, when the first scintillator 3 and the second scintillator 4 are positioned adjacent along a direction (Oz) transverse to the direction (Ox) of propagation of the pulses 5, a resolution of an image obtained using a signal associated with the first scintillator 3 and the first sensor 8 may be increased in the (Oz) direction.

In the example of Figures 1A, 1B, 5A, 5B and 6 the detector 1 further comprises at least one second sensor 10 configured to measure (e.g. sense and/or acquire) at least the second light 7.

As illustrated in Figure 6, the second scintillator 4 may have an area α2 exposed to the pulse 5 which is equal to α1. A resolution of an image obtained using a signal associated with the second scintillator 4 and the second sensor 10 may be increased in the (Oz) direction.

As illustrated in Figures 1A, 1B, 3A and 3B, the second scintillator 4 may have an area α2 exposed to the pulse 5 which is greater than α1. The signal associated with the second scintillator 4 and the second sensor 10 will generate a better contrast compared to the signal associated with the first scintillator 3 and the first sensor 8, because the area α2 is larger than the area α1 and more energy from the pulse 5 is deposited in the second scintillator 4.

In some examples, the at least one second sensor 10 is configured not to measure (e.g. to be insensitive to) the first light 6. In that case the signal associated with the second scintillator 4 and the at least one second sensor 10 may be proportional to the energy deposition on the area α2. However, in some examples, the at least one second sensor 10 may be configured to measure both the first light 6 and the second light 7. In that case the signal associated with the at least one second sensor 10 may thus be proportional to the energy deposition in the whole detector (i.e. both the areas α1 and α2).

As illustrated in Figure 3C, when the first scintillator 3 and the second scintillator 4 are positioned adjacent along the direction (Ox) of propagation of the pulses 5, information about a material of the cargo may be derived from a signal associated with the first scintillator 3 and the first sensor 8 on the one hand, and the second scintillator 4 and the second sensor 10 on the other hand, as some material may have specificities on the first scintillator 3 and the first sensor 8 on the one hand and the second scintillator 4 and the second sensor 10 on the other hand.

In some examples, the at least one first sensor 8 and the at least one second sensor 10 have each their own electronic channel.

Detailed Description of Example Embodiments

In the example illustrated by Figure 2, the inspection system 2 may be mobile and may be transported from a location to another location. In some examples the system 2 may comprise an automotive vehicle. The inspection system 2 may be configured to inspect the cargo 20 by transmission of successive radiation pulses 5, emitted from an inspection radiation source 13 to at least one detection array 14, through the cargo 20. In some examples, the detection array 14 may comprise a detection line 14 comprising a plurality of detectors 1 according to the disclosure, as illustrated in Figure 8. The array 14 of Figure 8 comprises only three detectors 1. However it should be understood that the array 14 may comprise any number of detectors 1, such as up to 1200 detectors or more as a non-limiting example.

Figure 2 illustrates that the cargo 20 may be a trailer and/or a boot of a vehicle such as a truck, a van and/or a car, and/or may be a shipping container.

The system 2 may further comprise other types of detectors, such as optional gamma and/or neutrons detectors, e.g., adapted to detect the presence of radioactive gamma and/or neutrons emitting materials within the cargo 20, e.g., simultaneously to the X-ray inspection. In the example illustrated in Figure 2, the system 2 may also comprise an electro-hydraulic boom 15 which can operate in a retracted position in a transport mode (not illustrated in the Figures) and in an inspection position (Figure 2). The boom 15 may be operated by hydraulic activators (such as hydraulic cylinders).

In the example illustrated in Figure 4A, the at least one first sensor 8 comprises a first filter 9 configured to let through the first wavelength domain and inhibit (e.g. block or at least attenuate) the second wavelength domain.

In the example illustrated in Figure 4B, the at least one second sensor 10 comprises a second filter 11 configured to let through the second wavelength domain and inhibit (e.g. block or at least attenuate) the first wavelength domain.

As already stated, the at least one second sensor 10 need not being configured not to measure (e.g. configured to be insensitive to) the first light 6, and, in some examples, the at least one second sensor 10 may be sensitive to both the first light 6 and the second light 7. The fact that the at least one second sensor 10 may be sensitive to both the first light 6 and the second light 7 means that the signal associated with the at least one second sensor 10 is greater than that of a sensor sensitive only to the second light 7. This means that the penetration and/or contrast associated with the second sensor 10 is greater.

In some examples, the at least one first sensor 8 and/or the at least one second sensor 10 comprises a photodiode.

In some examples, the first scintillator 3 comprises an organic and/or an inorganic material. Alternatively or additionally, the second scintillator 4 comprises an organic and/or an inorganic material. Some non-limiting examples of organic material include:

BC400, which produces light in the blue wavelength domain, and/or

BC428, which produces light in the green wavelength domain, and/or

BC430, which produces light in the red wavelength domain.

As non-limiting examples, each of the at least one first scintillator 3 is configured to re-emit the first light 6 in the red first wavelength domain, and each of the at least one second scintillator 4 is configured to re-emit the second light 7 in the blue second wavelength domain. Other wavelength domains are envisaged.

Alternatively or additionally, the first scintillator 3 may comprise one or more wavelength shifters for re-emitting the first light in the first wavelength domain. Alternatively or additionally, the second scintillator 4 may comprise one or more wavelength shifters for re-emitting the second light in the second wavelength domain different from the first wavelength domain.

A dimension Δ of the detector in a direction transversal to a direction of extension of a depth of the first scintillator and/or of the second scintillator extending in a direction parallel to a plane of propagation of the inspection radiation may be such that:

$$1mm \leq \Delta \leq 5mm \,.$$

As illustrated in Figures 1A and 1B, a dimension Δ=E of the detector 1 in a direction (Oy) transversal to a direction (Ox) of extension of a depth D of the first scintillator 3 and/or of the second scintillator 4 extending in a direction (Ox) parallel to a plane of propagation of the inspection radiation 5 is such that:

$$1mm \leq E \leq 5mm \,.$$

As illustrated in Figure 1A, a dimension Δ=H of the detector 1 in a direction (Oz) transversal to the direction (Ox) of extension of the depth D of the first scintillator 3 and/or of the second scintillator 4 extending in the direction (Ox) parallel to a plane of propagation of the inspection radiation 5 is such that:

$$1mm \leq H \leq 5mm .$$

In some examples, the detector 1 may have a square shape in a plane (yOz) transversal to the direction (Ox) of extension of the depth D of the first scintillator 3 and/or of the second scintillator 4, i.e.

$$E = H .$$

In some examples, D may be such that

$$10mm \leq D \leq 100mm .$$

In some examples, the at least one first sensor 8 and/or the at least one second sensor 10 are located on at least one side of the at least one first scintillator 3 and/or the at least one second scintillator 4, along the depth D of the first scintillator 3 and/or along the depth D of the second scintillator 4.

As illustrated in Figures 1A and 1B, the at least one first sensor 8 and the at least one second sensor 10 are located on a side of the at least one first scintillator 3, along the depth D of the first scintillator 3. It should be understood that the device 1 illustrated in Figures 1A and 1B may comprise at least one first sensor and/or at least one second sensor located on a side 12 of the at least one second scintillator 4, along the depth D of the second scintillator 4, or on an upper face 16 or a lower face 17.

As illustrated in Figures 1A and 1B, the first scintillator 3 is located adjacent the second scintillator 4. A dimension e1 of the first scintillator 3 in the direction (Oy) transversal to the depth D of the first scintillator 3 and the second scintillator 4 may be such that:

$$0.5mm \leq e1 \leq 3.5mm .$$

In some examples, e1 may be equal to about 1mm.

A dimension e2 of the second scintillator 4 in the direction (Oy) transversal to the depth D of the first scintillator 3 and of the second scintillator 4 may be such that:

$$1mm \leq e2 \leq 4.5mm \text{ , and}$$

$$e2 \geq e1 .$$

In some examples, e2 may be equal to about 4mm.

The fact that e2 is greater than e1 means that the signal associated with the second scintillator 4 and the second sensor 10 is greater than the signal associated with the first scintillator 3 and the first sensor 8. This means that the penetration and/or contrast associated with the second scintillator 4 and the second sensor 10 is greater than the penetration and/or contrast associated with the first scintillator 3 and the first sensor 8.

The signal associated with the first scintillator 3 and detected by the at least one first sensor 8 is proportional to the energy deposition in the first scintillator 3 only. However the fact that e1 is smaller than e2 means that the resolution associated with the first scintillator 3 and the first sensor 8 is greater than the resolution associated with the second scintillator 4 and the second sensor 10.

In the example of Figure 5A and 5B, the detector 1 comprises one first scintillator 3 located between two second scintillators 4. The dimension e1 of the first scintillator 3 in the direction (Oy) transversal to the depth D of the first scintillator 3 and of the second scintillators 4 is such that:

$$0.5mm \leq e1 \leq 3.5mm\ .$$

In some examples, e1 may be equal to about 1mm.

The dimension e2 of each of the second scintillators 4 in the direction (Oy) transversal to the depth D of the first scintillator 3 and the second scintillators 4 is such that:

$$1mm \leq e2 \leq 4mm\ .$$

In some examples, e2 may be equal to about 2mm. The dimension of the two second scintillators 4 in the direction (Oy) transversal to the depth D of the first scintillator 3 and the second scintillators is thus equal to 2xe2.

The fact that 2xe2 is greater than e1 means that the signal associated with the second scintillators 4 and the second sensors 10 is greater than the signal associated with the first scintillator 3 and the first sensors 8. This means that the penetration and/or contrast associated with the second scintillators 4 and the second sensors 8 is greater than the penetration and/or contrast associated with the first scintillator 3 and the first sensors 8.

The fact that e1 is smaller than 2xe2 means that the resolution associated with the first scintillator 3 and the first sensors 8 is greater than the resolution associated with the second scintillators 4 and the second sensors 10.

In the example illustrated in Figure 6, the detector 1 comprises one first scintillator 3 located adjacent one second scintillator 4, in the direction (Oz) transversal to the depth D of the first scintillator 3 and of the second scintillator 4. A dimension e1 of the first scintillator 3 in the direction (Oz) transversal to the depth D of the first scintillator 3 and of the second scintillator 4 is such that:

$$0.5mm \leq e1 \leq 3.5mm\ .$$

In some examples, e1 may be equal to about 2.5mm.

A dimension e2 of the second scintillator 4 in the direction (Oz) transversal to the depth D of the first scintillator 3 and of the second scintillator 4 is such that:

$$1mm \leq e2 \leq 4mm .$$

In some examples, e2 may be equal to about 2.5mm.

In the examples of Figure 1A, 1B, 3A, 3B, 3C, 5A, 5B and 6, the at least one first scintillator 3 has a refractive index, and the at least one second scintillator 4 has a refractive index substantially equal to the refractive index of the first scintillator. Both first light 6 and second light 7 may then exit the first scintillator 3 and the second scintillator 4 to reach the first and second sensors 8 and 10.

The successive first radiation pulses 5 may comprise at least one of X-ray radiation and/or gamma radiation and/or neutron radiation.

As illustrated in Figure 7, a method according to the disclosure may comprise:

re-emitting, at S1, first light in a first wavelength domain, in response to interaction with a pulse of inspection radiation;

re-emitting, at S2, second light in a second wavelength domain different from the first wavelength domain, in response to interaction with the pulse of inspection radiation; and

sensing, at S3, the first light and not the second light.

In some examples, the method described above may be performed, at least partly, on a detection device as described above.

Variations and modifications

A first light domain and a second light domain have been disclosed. It should be appreciated that embodiments of the disclosure may, additionally or alternatively, use the disclosed light selection to separate an undesirable afterglow from the desired signal to measure (the afterglow may correspond to an undesirable signal which can last several seconds and may deteriorate an obtained image by generating «bleeding» in the image). Other variations and modifications will be apparent to the skilled in the art in the context of the present disclosure, and various features described above may have advantages with or without other features described above.

The energy of the X-rays may be comprised between 1MeV and 15MeV, and the dose may be comprised between 2mGy and 20Gy (Gray). In the example illustrated by Figure 2, the power of the X-ray generator may be e.g., between 500keV and 9.0MeV, typically e.g., 2MeV, 3.5MeV, 4MeV, or 6MeV, for a steel penetration capacity e.g., between 150mm to 350mm, typically e.g., 200mm (7.9in). In the example illustrated by Figure 2, the dose may be e.g., between 20mGy and 50mGy.

The system may also be static with respect to the ground. In such examples, the power of the X-ray generator may be e.g., between 4MeV and 10MeV, typically e.g., 9MeV, for a steel penetration capacity e.g., between 300mm to 450mm, typically e.g., 410mm (16.1in). The dose may be 17Gy.

It is understood that the inspection radiation generator may comprise sources of other radiation, such as neutrons. The inspection radiation generator may also comprise sources which are not adapted to be activated by a power supply, such as radioactive sources, such as using Co60 or Cs137.

As one possibility, there is provided a computer program, computer program product, or computer readable medium, comprising computer program instructions to cause a programmable computer to carry out any one or more of the methods described herein. In example implementations, at least some portions of the activities related to the device herein may be implemented in software. It is appreciated that software components of the present disclosure may, if desired, be implemented in ROM (read only memory) form. The software components may, generally, be implemented in hardware, if desired, using conventional techniques.

In some examples, components of the detector 1 may use specialized applications and hardware.

In some examples, one or more memory elements can store data used for the operations described herein. This includes the memory element being able to store software, logic, code, or processor instructions that are executed to carry out the activities described in the disclosure.

A processor can execute any type of instructions associated with the data to achieve the operations detailed herein in the disclosure. In one example, the processor could transform an element or an article (e.g., data) from one state or thing to another state or thing. In another example, the activities outlined herein may be implemented with fixed logic or programmable logic (e.g., software/computer instructions executed by a processor) and the elements identified herein could be some type of a programmable processor, programmable digital logic (e.g., a field programmable gate array (FPGA), an erasable programmable read only memory (EPROM), an electrically erasable programmable read only memory (EEPROM)), an ASIC that includes digital logic, software, code, electronic instructions, flash memory, optical disks, CD-ROMs, DVD ROMs, magnetic or optical cards, other types of machine-readable mediums suitable for storing electronic instructions, or any suitable combination thereof.

The above embodiments are to be understood as illustrative examples, and further embodiments are envisaged. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

Claims

1. A detector for an inspection system, comprising:

at least one first scintillator configured to, in response to interaction with a pulse of inspection radiation, re-emit first light in a first wavelength domain;

at least one second scintillator configured to, in response to interaction with the pulse of inspection radiation, re-emit second light in a second wavelength domain different from the first wavelength domain;

at least one first sensor configured to measure the first light and not the second light; and

at least one second sensor configured to measure at least the second light,

wherein the at least one first sensor and the at least one second sensor are located on at least one side of the at least one first scintillator and/or the at least one second scintillator, along a depth of the first scintillator and/or along a depth of the second scintillator, the depth of the first scintillator and/or of the second scintillator extending in a direction parallel to a plane of propagation of the inspection radiation.

2. The detector of claim 1, wherein the at least one first sensor comprises a first filter configured to let through the first wavelength domain and inhibit the second wavelength domain.

3. The detector of claim 1, wherein the at least one second sensor is configured not to measure the first light.

4. The detector of claim 3, wherein the at least one second sensor comprises a second filter configured to let through the second wavelength domain and inhibit the first wavelength domain.

5. The detector of any one of claims 1 to 4, wherein the at least one first sensor and/or the at least one second sensor comprises a photodiode.

6. The detector of any one of claims 1 to 5, wherein the first scintillator comprises an organic material and/or the second scintillator comprises an organic material.

7. The detector of any one of claims 1 to 6, wherein the first scintillator comprises one or more wavelength shifters and/or the second scintillator comprises one or more wavelength shifters.

8. The detector of any one of claims 1 to 7, wherein a dimension Δ of the detector in a direction transversal to a direction of extension of a depth of the first scintillator and/or of the second scintillator extending in a direction parallel to a plane of propagation of the inspection radiation is such that:

$$1mm \leq \Delta \leq 5mm .$$

9. The detector of any one of claims 1 to 8, wherein the at least one second scintillator is located adjacent the at least one first scintillator, the detector having a square shape in a plane transversal to the direction of extension of the depth of the first scintillator and/or of the second scintillator.

10. The detector of any one of claims 1 to 9, comprising one first scintillator located between two second scintillators, and wherein

a dimension e1 of the first scintillator in a direction transversal to the depth of the first scintillator and/or of the second scintillators is such that:

$$0.5mm \leq e1 \leq 3.5mm \text{, and}$$

a dimension e2 of each of the second scintillators in the direction transversal to the depth of the first scintillator and/or of the second scintillators is such that:

$$1mm \leq e2 \leq 4.5mm .$$

11. The detector of any one of claims 1 to 10, comprising one first scintillator located adjacent one second scintillator, and wherein

a dimension e1 of the first scintillator in a direction transversal to the depth of the first scintillator and/or of the second scintillator is such that:

$$0.5mm \leq e1 \leq 3.5mm ,$$

a dimension e2 of the second scintillator in the direction transversal to the depth of the first scintillator and/or of the second scintillator is such that:

$$1mm \leq e2 \leq 4.5mm \text{, and}$$

$$e2 \geq e1 .$$

12. The detector of any one of claims 1 to 11, wherein the at least one first scintillator has a refractive index and the at least one second scintillator has a refractive index substantially equal to the refractive index of the first scintillator.

13. The detector of any one of claims 1 to 12, wherein:

each of the at least one first scintillator is configured to re-emit the first light in the red first wavelength domain, and

each of the at least one second scintillator is configured to re-emit the second light in the blue second wavelength domain.

14. A detection array for inspection of cargo, comprising:

a plurality of detectors according to any one of the preceding claims.

15. A method comprising:

at least one first scintillator of a detector re-emitting first light in a first wavelength domain, in response to interaction with a pulse of inspection radiation;

at least one second scintillator of the detector re-emitting second light in a second wavelength domain different from the first wavelength domain, in response to interaction with the pulse of inspection radiation; and

at least one first sensor sensing the first light and not the second light; and

at least one second sensor sensing at least the second light,

wherein the at least one first sensor and the at least one second sensor are located on at least one side of the at least one first scintillator and/or the at least one second scintillator, along a depth of the first scintillator and/or along a depth of the second scintillator, the depth of the first scintillator and/or of the second scintillator extending in a direction parallel to a plane of propagation of the inspection radiation.

16. The method of claim 15, performed on a detector according to any one of claims 1 to 13 or on a detection array according to claim 14.