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Paper A(E/M)

Electricity / Mechanics

This paper comprises:

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Client's Letter

Dear Mr. Lupin,

[001] My company produces articles comprising force sensors based on optical fibres. Optical fibres are thin flexible fibres of transparent material, such as glass or plastic, which can conduct light. They can be integrated into a sheet of material, so that a force applied on the surface of the sheet can be detected.

[002] When an optical signal is input into a first optical fibre, most of the light propagates along the fibre. However, tiny irregularities in the fibre cause a small amount of light to be scattered out of the fibre. A second optical fibre can collect a part of the scattered light, provided that the distance between both fibres is small enough. In this way, an optical signal input into the first fibre can be coupled into the second fibre at a given location. In the following, such a location is called a coupling location. The smaller the distance between both fibres, the more light is coupled into the second fibre. This effect can be used in a force sensor.

[003] Fig. 1a schematically shows the working principle of a force sensor. An optical fibre 1 overlaps an optical fibre 2 at a coupling location 3. The fibres 1 and 2 are embedded in a transparent elastic sheet 4. A LED (Light Emitting Diode) L injects an optical signal into the fibre 1. A photo-detector PD is arranged at an end of the fibre 2 for receiving a coupled optical signal and converting it into an electrical signal. Fig. 1b shows a vertical cross-section of the sheet 4 at the coupling location 3 along the fibre 1.

[004] If no force is applied on the sheet 4 at the coupling location 3, no light is coupled from the fibre 1 into the fibre 2. When a force is applied on the sheet 4 at the coupling location 3 in the direction of the arrow A, the sheet 4 is compressed. This reduces the distance d between the fibre 1 and the fibre 2 at the coupling location 3, so that the optical signal is coupled from the fibre 1 into the fibre 2. The amount of light coupled increases as the distance between the fibres 1 and 2 is reduced. The coupled optical signal is received by the photo-detector PD. The electrical signal produced by the photo-detector PD can therefore be measured to detect the force applied at the coupling location 3.

[005] Fig. 1c schematically shows a floor mat 14 used to detect an intruder approaching pictures 15 hung on a wall. For many years we have sold this floor mat 14 under the name "Alpha". "Alpha" comprises input optical fibres 1 and output optical fibres 2 which are arranged such that each output optical fibre 2 overlaps each input optical fibre 1 at a respective coupling location 3. The input and output fibres 1 and 2 are embedded in a transparent elastic sheet 4. They form a matrix of coupling locations 3.

[006] A light injecting device 5 comprises three identical LEDs L1-L3 and a switch 7. The switch 7 turns the LEDs L1-L3 on and off simultaneously so that each LED injects a pulsed optical signal into a corresponding input fibre 1. This reduces the power consumption of the light injecting device 5. A faint light spot appears at the end of each fibre 1 remote from the LEDs L1-L3, providing a visual indication that the LEDs are functioning.

[007] A light receiving device 6 comprises photo-detectors PD1-PD6 and an alarm unit 8. Each photo-detector PD1-PD6 is arranged for receiving a coupled optical signal from an output fibre 2 and converting it into an electrical signal, which can trigger the alarm unit 8.

[008] If an intruder treads on the sheet 4, a force is applied at one or more of the coupling locations 3. At least one of the photo-detectors PD1-PD6 receives a coupled optical signal and converts it into an electrical signal. The alarm unit 8 is triggered by the electrical signal.

[009] "Alpha" cannot determine at which coupling location 3 a force is applied. However, some applications require the determination of the location at which a force is applied. Our competitor XY has developed a force sensor that addresses this problem. XY´s sensor is described in document D1. However, this sensor requires many components and is complex. This led me to an invention, which is explained referring to Figs. 2 to 5.

[010] Fig. 2 schematically shows a first example of my invention: a mattress 14 comprising a force sensor for determining the position of a patient. The mattress 14 comprises four input optical fibres 1a, 1b, 1c, 1d and four output optical fibres 2a, 2b, 2c, 2d. Analogously to the arrangement of the fibres in “Alpha”, each output fibre 2a-2d overlaps each input fibre 1a-1d at a respective coupling location 3, where light can be coupled from the input fibre into the output fibre upon application of a force. The fibres 1a-1d and 2a-2d are embedded in a transparent elastic sheet 4.

[011] A light injecting device 5 comprises LEDs L1, L2, L3 and L4 and a control unit 7. Each LED L1-L4 injects an optical signal into a respective input fibre 1a-1d. The control unit 7 turns each LED L1-L4 on and off rapidly at differing frequencies in the following way:
L1 is turned on and off at a frequency f1,
L2 at a frequency f2,
L3 at a frequency f3, and
L4 at a frequency f4.
Consequently, each LED L1-L4 injects into a respective input fibre 1a-1d a pulsed optical signal, each optical signal having a different pulse frequency.

[012] A light receiving device 6 comprises photo-detectors PD1-PD4 and a processing unit 8. Each photo-detector PD1-PD4 is arranged for receiving a coupled optical signal from an output fibre 2a-2d and converting it into an electrical signal. The processing unit 8 monitors each electrical signal produced by the photo-detectors PD1-PD4 to determine the pulse frequency of each coupled optical signal. This allows the coupling locations at which a force is applied to the mattress 14 to be determined.

[013] For example, if a force is applied to the mattress 14 at the location 3y, the optical signal coupled from the input fibre 1c into the output fibre 2c is pulsed at the frequency f3. The processing unit 8 determines that the photo-detector PD3 receives a coupled optical signal pulsed at the frequency f3. Therefore, on the basis of the pulse frequency f3 the processing unit 8 identifies the coupling location 3y at which the received optical signal is coupled. The processing unit 8 thereby detects that a force is applied at the coupling location 3y.

[014] If, at the same time, another force is applied at another coupling location along the fibre 2c, another optical signal is coupled at the other coupling location. The other coupled optical signal is pulsed at a frequency different from f3 and received by the photo-detector PD3. Since the processing unit 8 determines the pulse frequency of each optical signal received by the photo-detector PD3, it detects each force independently.

[015] If, at the same time, another force is applied at another coupling location along one of the fibres 2a, 2b, 2d, another optical signal is coupled at the other coupling location and received by one of the photo-detectors PD1, PD2, PD4. Since the processing unit 8 monitors each electrical signal produced by the photo-detectors PD1-PD4, it detects each force independently.

[016] If the processing unit 8 is arranged to determine the intensity of the electrical signals produced by the photo-detectors PD1-PD4, the magnitude of a force applied at a coupling location 3 may also be determined.

[017] An alternative light injecting device 5 for the first example of my invention is schematically shown in Fig. 3. It comprises a lamp 12, four mechanical shutters 13a-13d and a control unit (not shown). Each shutter 13a-13d includes a movable element which allows or blocks the passage of light from the lamp 12 into the respective input fibre 1a-1d. In order to inject into each input fibre 1a-1d an optical signal with a different pulse frequency, the control unit opens and closes each shutter 13a-13d at a different frequency.

[018] The sensitivity of the force sensor may be improved by increasing the amount of light coupled from an input optical fibre into an output optical fibre. For example, as shown in Fig. 4, the fibres 2 may be arranged in a curved manner so that the fibres 1 and the fibres 2 are parallel to each other at the coupling locations 3. This increases the length of the overlap between the fibres. Furthermore, the fibres can have a roughened surface at the coupling locations to increase light scattering.

[019] The matrix of 4x4 coupling locations 3 in Fig. 2 is merely exemplary: the same working principle can be applied to matrices of other sizes.

[020] Fig. 5 schematically shows a second example of my invention: a floor mat 14 used to detect whether someone stands in front of one of the doors along a corridor. The floor mat 14 has three input optical fibres 1a, 1b and 1c and a single output optical fibre 2. The output fibre 2 is laid along the corridor. Close to each door xx, yy and zz, the output fibre 2 overlaps one of the input fibres 1a, 1b and 1c at a respective coupling location 3. The input fibres 1a, 1b and 1c are parallel to the output fibre 2 at the coupling locations 3.

[021] A light injecting device 5 comprises three LEDs L1, L2 and L3. Each LED L1, L2, L3 injects a continuous optical signal of different colour (red, green or blue) into a respective input fibre 1a, 1b, 1c.

[022] A light receiving device 6 comprises a camera 9 and a processing unit 8. The camera 9 is arranged for receiving from the output fibre 2 coupled optical signals and converting them into separate electrical signals according to their colour. The processing unit 8 monitors each electrical signal produced by the camera 9 to determine the colour of each coupled optical signal. This allows the coupling locations at which a force is applied to the floor mat 14 to be determined.

[023] For example, if someone stands in front of the door xx, a force is applied to the floor mat 14 at a location 3x and an optical signal is coupled from the input fibre 1a into the output fibre 2. The coupled optical signal has the colour of the light emitted by the LED L1 (red). The processing unit 8 determines the colour (red) of the coupled optical signal received by the camera 9 and identifies, on the basis of that colour, the coupling location 3x at which the received optical signal is coupled. The processing unit 8 thereby detects that a force is applied at the identified coupling location.

[024] If a person stands in front of the door xx and another person in front of the door zz at the same time, the light received by the camera 9 is a superposition of a red optical signal and a blue optical signal. Since the camera 9 converts these optical signals into separate electric signals, the processing unit 8 detects that forces are simultaneously applied in front of the doors xx and zz.

[025] Multiple output fibres could be used instead of the single output fibre 2. In this case, the output fibres are connected to the camera in such a way that the camera receives the optical signals from the output fibres independently from each other.

[026] In an alternative arrangement of the second example of my invention (not shown), a single white lamp in combination with red, green and blue colour filters respectively associated to the input fibres 1a, 1b and 1c can replace the LEDs L1, L2 and L3.

[027] The examples of my invention use different characteristics of optical signals: a pulse frequency in the first example and a colour in the second example. Other characteristics could be used, as long as they allow the optical signals to be distinguished from each other.

[028] In both examples of my invention, it is not necessary to embed the optical fibres in the transparent elastic sheet. They may be glued at the opposite surfaces of the sheet. In both cases, overlapping fibres are separated by an elastic layer through which light can pass. An input fibre and an output fibre overlapping each other can be separated at a coupling location in another way, e.g. by a cavity, provided that a force applied at the coupling location can reduce the distance between the fibres.

[029] Please draft a set of claims and an introductory part of the description for a European patent application to protect my invention, assuming that the drawings accompanying this letter will form part of the application. We plan to sell mattresses and floor mats according to the examples described above. Please note that I will not pay any claims fee for this patent application or any fees for further patent applications.

Best regards,

Dr. Zenigata

Client's Drawings

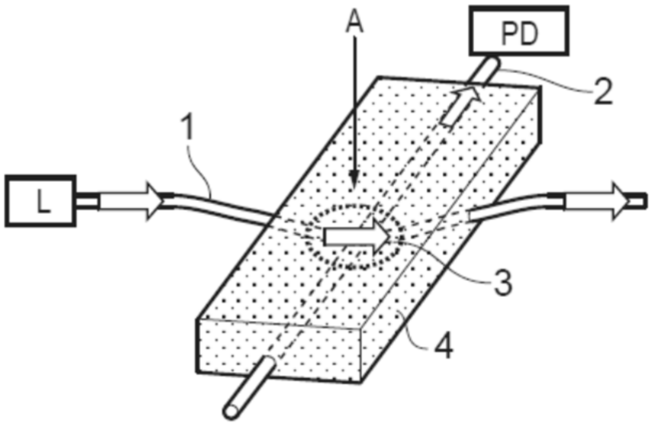

FIG. 1a

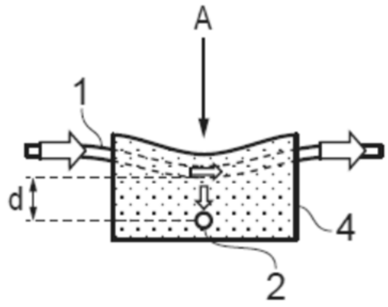

FIG. 1b

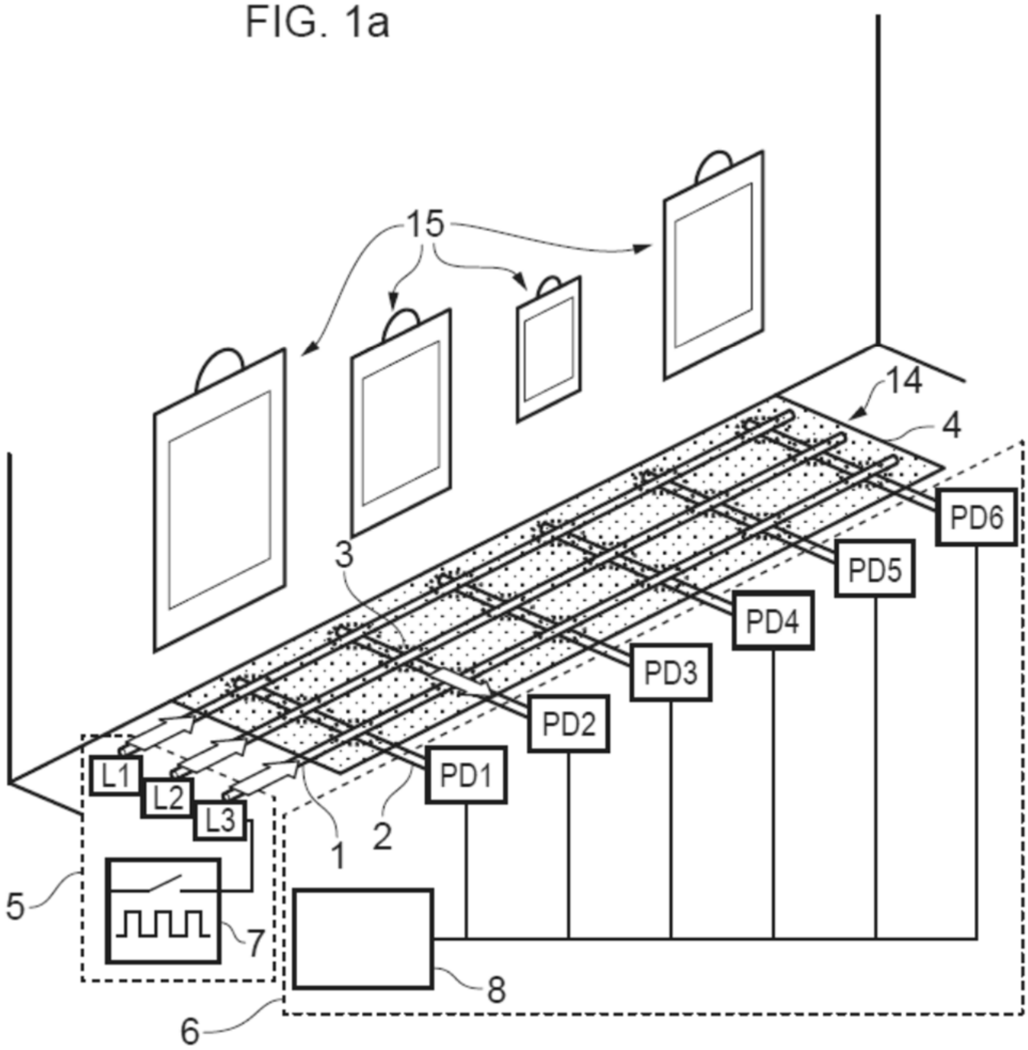

FIG. 1c

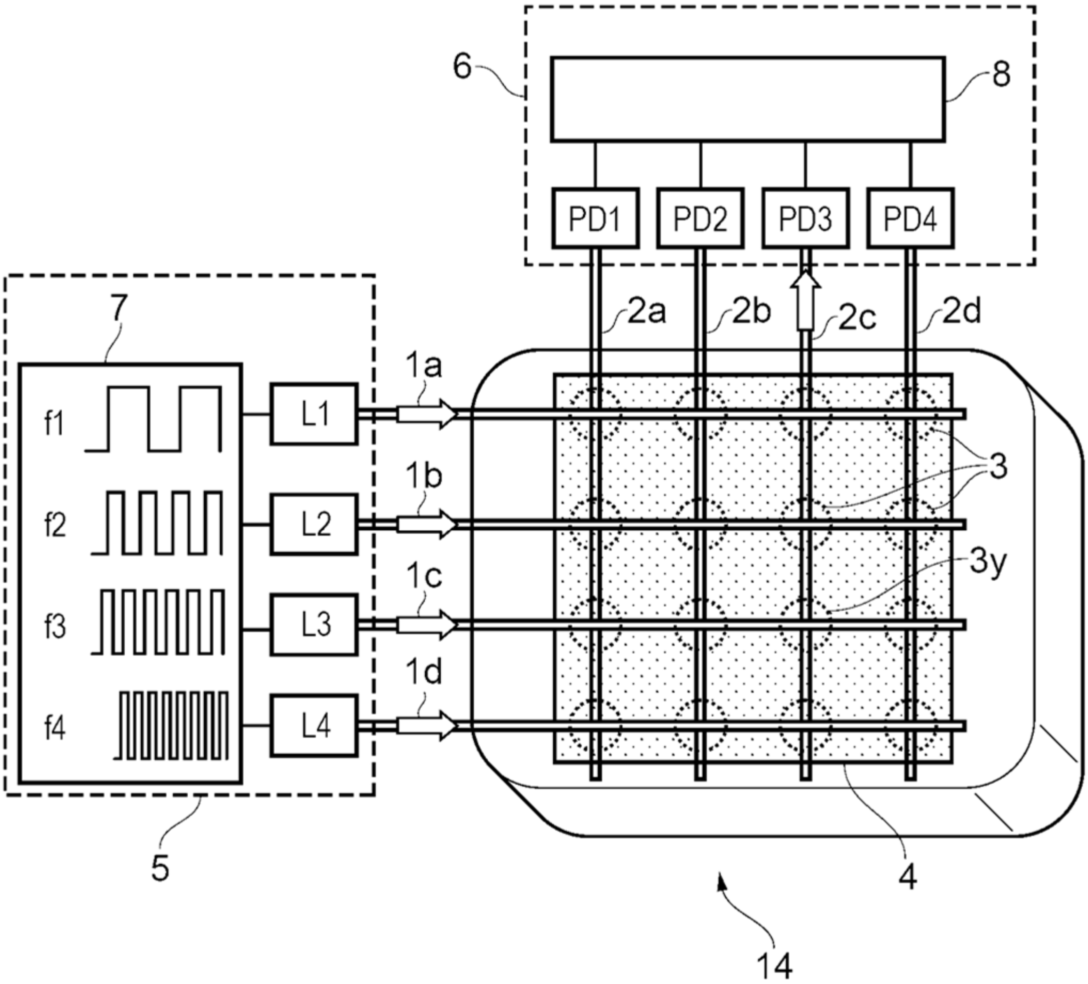
6
8
PD1
PD2
PD3
PD4
7
2a
2b
2c
2d
f1
f2
f3
f4
L1
L2
L3
L4
1a
1b
1c
1d
3
3y
5
4
14

FIG. 2

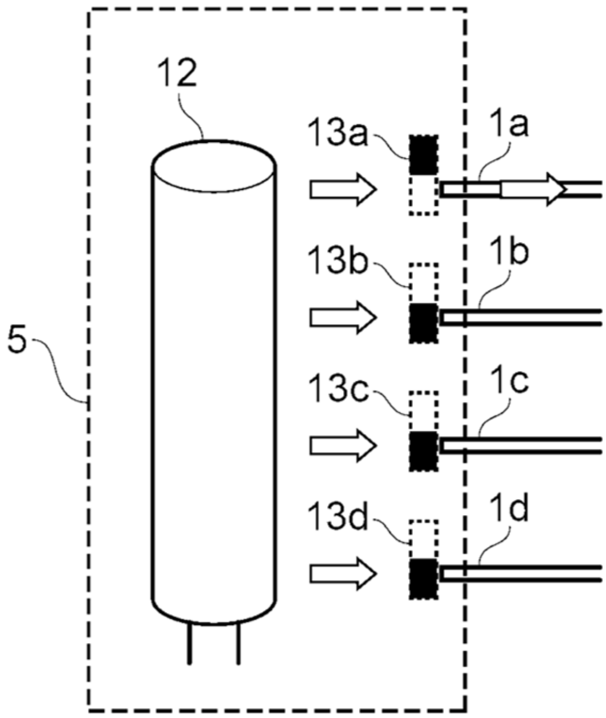

FIG. 3

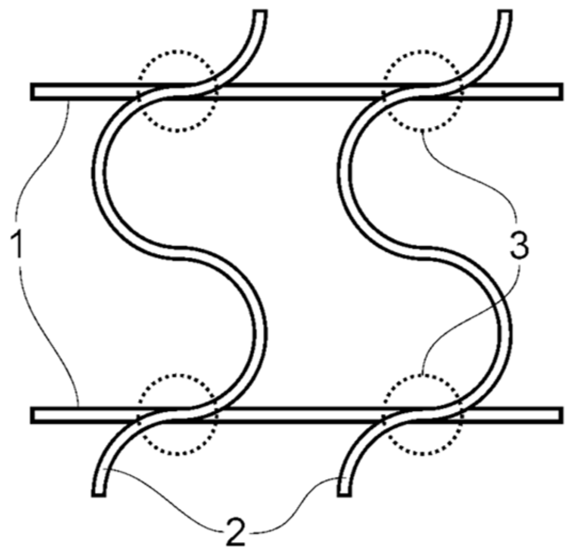

FIG. 4

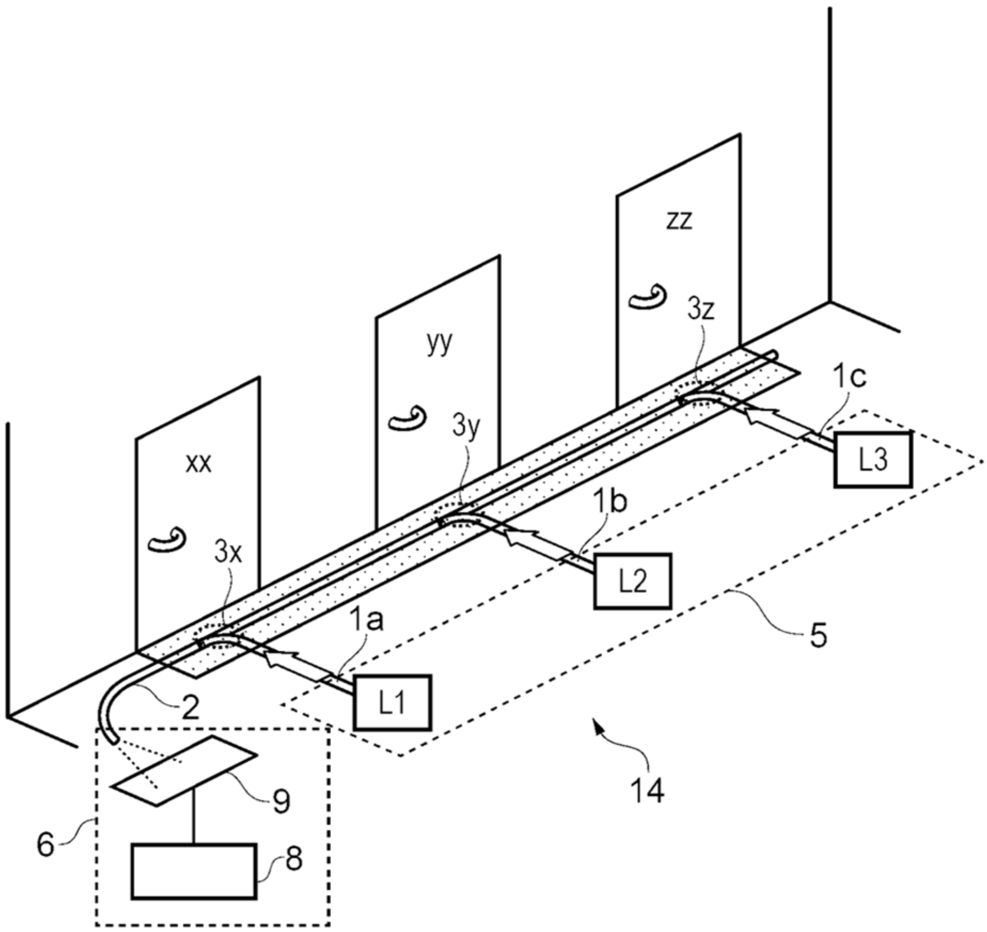

FIG. 5

<u>Document D1</u>

[001] We have developed a force sensor for detecting forces applied at multiple locations. Our sensor includes optical fibres embedded in a transparent elastic sheet. The sensor can be integrated in various items such as mattresses or floor mats.

[002] The working principle of our sensor is shown in Fig. 1. An input optical fibre 3 overlaps an output optical fibre 5 at a location 4. Both fibres 3 and 5 are embedded into an elastic transparent material, so that a force applied at the location 4 in the direction of the arrow A brings the fibres closer to each other. When the distance between both fibres is reduced, an optical signal injected by a LED L into the input fibre 3 is coupled from the input fibre into the output fibre 5. A photo-detector P receives the coupled optical signal and converts it into an electrical signal. As the intensity of the electrical signal increases with the magnitude of the force applied at the location 4, the magnitude of the force can be determined.

[003] To increase the amount of light coupled from the input fibre 3 into the output fibre 5, both fibres have a roughened surface at the location 4.

[004] In order to detect forces simultaneously applied at multiple locations, the force sensor schematically shown in figure 2 applies the principle of figure 1 at said locations. The sensor has input fibres 3 and output fibres 5 defining a 3x3 matrix of locations 4. Each LED L injects a continuous optical signal into three input fibres 3. Each photo-detector P is arranged to receive from an output fibre 5 a coupled optical signal. By providing as many photo-detectors P as locations 4, forces applied at different locations can be detected independently.

[005] At the ends of the input fibres 3 at the locations 4 faint light spots appear. If one of these light spots is no longer visible, it means that a LED is no longer functioning and must be replaced. If the LEDs L are not identical but emit light of different colours (e.g. red, green and blue), it is easier to identify which LED is no longer functioning based on the colours still visible.

Drawings Document D1

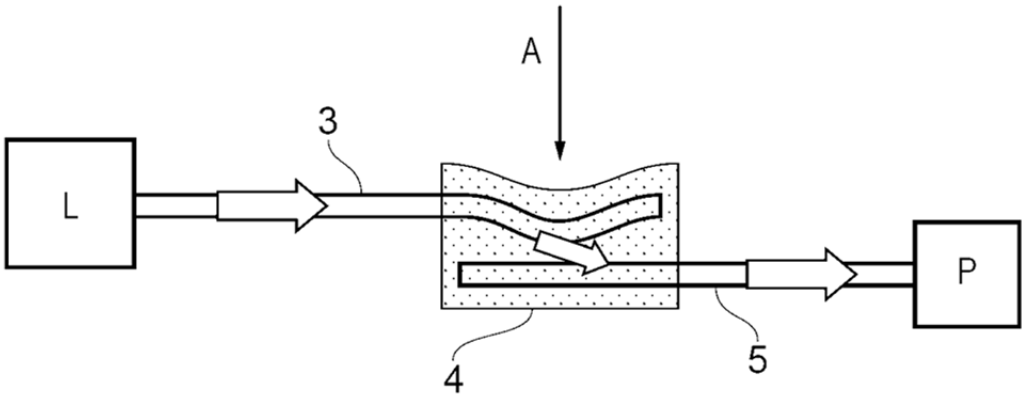

FIG. 1

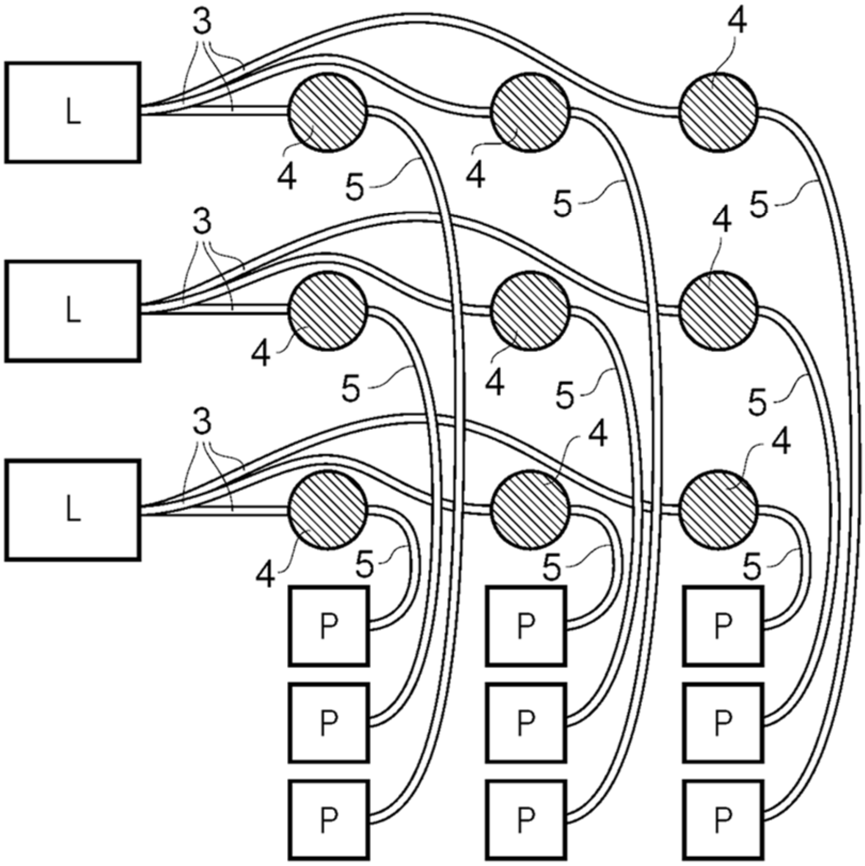

FIG. 2