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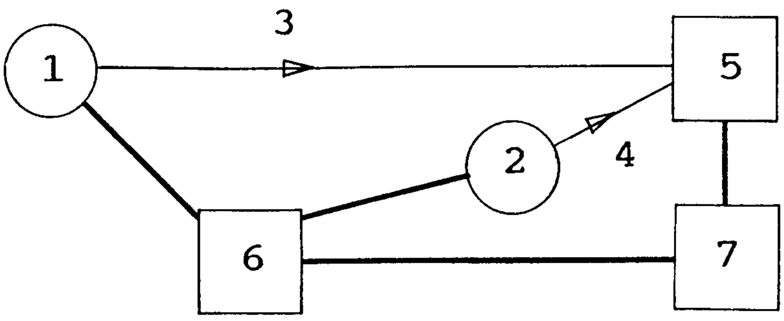
(54) Obscuration type smoke detector.

(57) A sensor for sensing the presence in a medium of species which absorb or scatter radiation, such as smoke particles in air, by means of changes in the attenuation of radiation transmitted through the medium, in which visible or infra-red radiation is transmitted from two sources (1 and 2), along dissimilar paths (3 and 4), to a receiver (5). A control means (6) causes the sources to emit and accurately controls the ratio of the emitted energies. The signal received from one source is subtracted from the signal received from the other source by another means (7). The difference signal is used by the control means as the basis for controlling the ratio of the energies emitted by the sources. Changes in the absorption co-efficient are measured by sensing changes in the difference signal and/or by changes in the ratio of the emitted energies.

Figure 1



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(3.10/3.09/3.3.4)

This invention relates to a sensor for sensing the presence of species which absorb or scatter radiation, such as smoke particles in air, by means of changes in the attenuation of radiation transmitted through a medium, suitable for use in smoke (fire) detectors, in particular those referred to as point obscuration (or light extinction) fire detectors.

It is well known that the presence of smoke particles suspended in a medium may be sensed by measuring the reduction in intensity (attenuation or obscuration) of a beam of visible or infrared radiation passing through the medium. This attenuation is a combination of absorption by the particles and several scattering mechanisms, eg:

- scattering due to absorption and re-transmission (Rayleigh scattering);
- diffraction at the particle;
- scattering due to surface waves on the particle;
- geometric reflection.

The relative of importance of the scattering mechanisms depends on a number of factors, including the particle sizes and the wavelength of the radiation.

The principle is used in so called optical beam smoke detectors, in which a beam of radiation is arranged to travel near ceiling level along a path of sufficient length (typically >10m) for a significant level of attenuation to be caused by smoke concentrations characteristic of the presence of a fire in the same volume. Often, optical beam smoke detectors are inconvenient to apply, and so called point smoke detectors are used. These are mounted on the ceiling of the protected volume and contain a sensitive device for detecting the presence of smoke in a chamber through which part of any airflow past the detector may by sampled. A number of techniques are currently used to sense the presence of smoke in the chamber, the most common being the ionisation chamber (used in ionisation smoke detectors), and light scattering (used in optical smoke detectors).

In an ionisation chamber, an applied electric field causes an electrical current to flow in air which is ionised by particles emitted from a radioactive source. Smoke particles act as ion capture sites, causing a reduction in the current, which is sensed by an electronic circuit. In an optical detector, a pulse of infrared radiation is emitted from a source into the chamber. Smoke particles scatter or reflect a small proportion of the radiation, and this is sensed by a receiver, mounted so that it cannot receive radiation from the source by a direct path. Many optical detectors use a scatter angle of about 45 degrees (forward scatter), which is found to offer a reasonable level of sensitivity together with a convenient arrangement. Detectors using predominant scatter angles between 90 and of 180 degrees (backwards scatter) are also known.

It has been known for some time that if the radiation attenuation technique could be used in a point smoke detector this could provide a significantly improved means of detection. An estimate of relative performance can be made from standard fire tests. The table below gives approximate maximum values, measured in fire tests FT2 to FT5 of the relevant European standard (EN54:part 9;1984), for the following parameters:

- m value (obscuration at a wavelength of approximately 900 nm, in terms of dB/m);
- relative forward scatter at a predominant angle of 45 degrees, and a wavelength of approximately 900 nm;
- relative backwards scatter at a predominant angle of 180 degrees, and a wavelength of approximately 900 nm;
- y value (a well known measure of ionisation detector sensitivity, derived from a standard ionisation chamber).

Fire test	m value (dB/m)	45 deg. scatter	180 deg. scatter	y value
FT2 (smouldering wood)	2.0	2.4	4.8	1.4
FT3 (smouldering cotton)	2.0	3.8	3.0	4.1
FT4 (plastic foam fire)	1.7	1.4	0.5	6.0
FT5 (n-heptane fire)	1.1	1.0	0.3	6.0

The range of measured m values is seen to be significantly smaller than for the other parameters. An obscuration detector would therefore have a more even response in the four tests, and its overall level of sensitivity would not need to be so high, which would lower the risk of false alarms. The typical fire test gradings achieved by existing optical detectors and ionisation detectors indicates that a point obscuration fire detector could achieve a grading in all four tests equivalent to the best achieved by optical or ionisation detectors, if it had an alarm threshold corresponding to an m value of less than 0.40 dB/m. If the effective path length were 50 mm, this would correspond to a threshold obscuration signal level of a 0.46% reduction from the clean air signal. To achieve this with an acceptable stability and accuracy the sensor should ideally have:

- a signal resolution of <0.02% of the clean air signal over time periods up to several minutes;
- a signal stability <0.05% of the clean air signal over time periods exceeding 1 hour.

As well as meeting these sensitivity and stability requirements, a point obscuration fire detector should also ideally:

- be as compact as existing point smoke detectors;
- be at least as reliable as existing point smoke detectors, with a low false alarm rate;
- have a low quiescent power consumption (eg. <2mW);
- have a similar manufacturing cost to that of an optical detector of equivalent quality.

A point obscuration fire detector would have a number of additional advantages over existing point smoke detectors, eg:

- it is non-radioactive, and also free from the surface leakage and wind sensitivity effects of ionisation detectors;
- the detection components may be easily monitored;
- it will require less maintenance, since the smoke sensitivity will not vary as a function of time, or the state of contamination of the sensor;
- the signal to noise ratio should be greater than for an optical detector, important in reducing the influence of RFI interference and other potential causes of false alarms.

The principal technical difficulty is known to lie in achieving signal stability at the required sensitivity in a compact, low cost arrangement. This has not been achieved using known techniques. The main object of the present invention is to achieve a high level of signal stability in an obscuration sensor, permitting an adequate sensitivity to be achieved with a short radiation path length consistent with its use in a point obscuration fire detector.

According to the present invention there is provided a sensor for sensing the presence of species in a medium which absorb or scatter radiation wherein visible or infra-red radiation is transmitted from at least two sources to a receiver along paths so arranged that the absorbing or scattering species attenuate a different proportion of the radiation transmitted along each path, characterized in that means are operable to subtract the signals resulting from the radiation received from one source from the signals resulting from the radiation received from another source and to sense the resulting difference signal, and wherein the ratio of the average energies radiated from the sources may be controlled by means of passing through the sources quantities of charge determined by gating a given current for times in a known ratio, so as to maintain the difference signal at zero or at a small proportion of the signal from one source, and wherein the ratio of the gating times, and the difference signal are analyzed in order to permit changes in the quantity of radiation attenuated by the species to be calculated.

The invention will now be described by way of example with reference to the accompanying drawing, in which:

- figure 1 shows a block diagram of a sensor using two sources and one receiver;
- figure 2 shows a block diagram of a sensor using two sources and two receivers;
- figure 3 is a simplified schematic representation of a circuit for controlling two sources;
- figure 4 is a simplified schematic representation of a receiver circuit;
- figure 5 shows a possible arrangement of a smoke sensor using two sources and one receiver photodiode;
- figure 6 shows a possible arrangement of a smoke sensor using two sources and two receivers in which the active paths are co-incident;
- figure 7 shows a possible arrangement of a smoke sensor using two sources and two receivers in which the active paths are separated;
- figure 8 shows a possible arrangement of the sensor of figure 7 within the envelope of a point smoke detector.

As shown in figure 1, two sources 1 and 2 are arranged to transmit radiation along paths 3 and 4 to a receiver 5. It is arranged such that the absorbing or scattering species attenuates a different proportion of the radiation in the two paths, for example by the paths being of different lengths, having a different degree of exposure to the species, or by the use of a different radiation wavelength in cases where the attenuation is known to be wavelength dependent. A control means 6 causes the sources to transmit radiation, the ratio of the radiant energies emitted by the sources being accurately controlled. The receiver 5 is connected to means 7 in which the signal received from one source is subtracted from the signal received from the other source and the difference between them is accurately sensed. The difference signal is used by the control means 6 as the basis for controlling the ratio of the energies emitted by the sources.

If the ratio of the energies were kept constant, the presence of species which absorbed or scattered the radiation would result in a change in the ratio of the signals received from the sources, which would be a function of the difference in the length of the paths and of the change in the attenuation per unit length (the absorption coefficient). Since the path lengths will be known, the changes in the absorption coefficient may be readily calculated. Alternatively, the control means 7 may attempt to maintain the difference signal from the receiver at zero, in which case the changes in the absorption coefficient will an inverse function of the change in the ratio of the energies. In practice it is often found to be convenient to use both techniques in combination. Small changes in the absorption coefficient are measured by analysing the difference signal, whilst the ratio of the energies is controlled in order to measure larger changes in the absorption co-efficient and to adjust the sensor for long term drifts. The control means 6 could routinely, under known conditions, change the ratio of the energies and measure the resultant change in the difference signal, and thereby calibrate the relationship between these two parameters.

The fundamental advantage of this type of sensor is that a very high degree of resolution and stability may be achieved with a simple low cost arrangement. Because the difference signal can be maintained at a very small proportion of the signal received from either source, the stability of the receiver gain becomes relatively unimportant. If the ratio of the energies can be controlled to a good resolution, the difference signal need not be sensed to a high resolution. This permits the use of easily available, low cost the use of an 8-bit analogue to digital to convertor to measure the difference signal.

The stability of the sensor depends on the ability to accurately control the ratio of the energies emitted by the sources. A preferred embodiment to control this is described later. When used with pulsed light emitting diode (LED) sources, the sensor arrangement using two source and one receiver can achieve a good performance. It will be understood however that the radiation emission efficiency of LED sources is quite strongly influenced by temperature, as well as by other factors. To achieve the very high levels of stability with temperature demanded by a point obscuration fire detector, the difference in temperature of the sources must be kept very small, and the temperature coefficients of emission of the individual sources must be very well matched.

In order to overcome effects of temperature on the sources, the arrangement shown in figure 2 may be used. Sources 8 and 9 each transmit to receivers 10 and 11. Source 8 transmits via a path 12 to receiver 11 and via a different path 13 to receiver 10, whilst the source 9 transmits via a path 14 to receiver 11 and via a different path 15 to receiver 11. As in the sensor arrangement of figure 1, the absorbing or scattering species attenuates a different proportion of the radiation in path 12 to that in path 13, and similarly for paths 14 and 15. The receivers are connected to means 16 and 17 respectively, in each of which the signal received from one source may be subtracted from the signal received from the other source and the difference between them accurately sensed. Each difference signal is used separately by the control means 18 as the basis for controlling the ratio of the energies emitted by the sources, at different times during the sensor operation. In succession the signals from the two receivers are approximately balanced and the difference signals measured.

The result of the foregoing is that two separate measurements of the relative attenuations in respective pairs of paths may be made. If the ratios of the radiation transmitted by each source into its associated paths is accurately maintained, errors in the relative emission efficiencies of the sources may be fully or partly corrected. It will also be understood that other benefits will accrue from there being two active paths. For example a relatively large change detected in one pair of paths which is not matched in the other pair of paths may be construed as being due to an object, such as an insect which has penetrated the sensing chamber, rather than the presence of an absorbing or scattering species.

Preferred embodiments of the source, receiver and control circuitry are shown schematically in figures 3 and 4. These will be suitable for use in both the arrangement of figure 1 and of figure 2, at visible or near infra-red wavelengths (500nm to 1000nm), convenient for the sensing of smoke. For clarity only those parts of the circuitry are shown which are essential to the understanding of the present invention.

Figure 3 shows a source control circuit. Sources 19 and 20 are LEDs, such as GaAlAs devices available from a number of suppliers, which emit radiation efficiently at a wavelength around 880nm. LEDs convert electrical energy directly into radiation energy, the intensity of the radiation emitted being approximately proportional to the electrical current which is passed through them. A constant current source 21, passes a current I, which is switched for a time (t1) into a capacitor 22, then switched for another time (t2) into a second capacitor 23. Charge accumulated on capacitor 22 (I.t1) is subsequently discharged for a time (t3) shorter than t1 through source 19 via a transistor 24. Charge accumulated on capacitor 23 (I.t2) is discharged for a time (t4) shorter than t2 through source 20 via transistor 25. This process is repeated at an approximately constant rate until an equilibrium is reached, with almost exactly the same charge flowing into the capacitors 22 and 23 as is discharged respectively into the sources 19 and 20 during each charge and discharge cycle.

The sources may be pulsed simultaneously, with the times t3 and t4 being identical, and this may be preferred with some receiver configurations. For use in a smoke detector it is preferred that the sources are pulsed in sequence. In this case the times t3 and t4 may be different, and in order to further improve the temperature stability it is found to be desirable that the discharge (pulse) time for each source is a near constant ratio of the charge time, ie t1/t3 and t2/t4 are maintained approximately constant. The times t1, t2, t3 and t4 are controlled by the microcomputer 26, but it will be understood that this could also be realised by other electronics means.

Figure 4 shows a receiver circuit, specifically disposed for use with the LED sources which emit pulses in sequence. The receiver 27 is a silicon photodiode which may be electrically connected in either polarity through a switching circuit 28 across the input connections of an operational amplifier 29 having a capacitor 30 connected between the inverting input and the output. The switches are controlled by the microcomputer 31 such that the receiver current is integrated on the capacitor 30 while radiation is being received from one source and then the switch connections are changed so that the receiver current is integrated in the opposite polarity while radiation is being received from the other source. The voltage at the output of amplifier 29 is amplified using a second operational amplifier 33, configured as a voltage amplifier, and any change in the amplified voltage resulting from the double integration is measured using an analogue to digital convertor 32, or by other electronic means.

If the receiver were always connected in one given polarity while radiation was being received from a given source, errors such as offsets in the operational amplifiers could result in an apparent change in the sensed obscuration. In order to overcome this, the receiver is connected in a given polarity for some instances of radiation being received from a given source, and is connected in the opposite polarity for other instances of radiation being received from the same source. By separately analysing the difference signals resulting from the two instances errors may be corrected.

The switching circuits of the above embodiments may be conveniently realised using CMOS transmission gates, such as the 4053B type available from a number of suppliers. The operational amplifiers may conveniently be a TLC27M2 type supplied by Texas Instruments. The microcomputer may conveniently be a device selected from the MC68HC05 range supplied by Motorola. A phototransistor may be employed instead of a photodiode by using an alternative receiver circuit. It will be understood that the principle of operation is not fundamentally dependent on the detailed circuitry, or on the specification of the components used, and could be realised using a wide variety of electronics means. It will also be understood that for the construction of a practical smoke detector the circuitry of figure 3 and figure 4 would be combined, as would the microcomputer 26, the microcomputer 31, and the analogue to digital convertor 32, and known features in addition to those shown would also be required. The principle described could be employed for applications other than smoke detection and for operation at other wavelengths, but changes in the detail of the embodiments may be necessary.

The times t1 and t2 may be typically controlled by a single chip microcomputer to a time resolution corresponding to one count of its internal timer. Because both t1 and t2 are derived from the same microcomputer clock, the ratio will be predictable and will not drift significantly with changes in the clock frequency. For a typical sensor, capable of operating with a power consumption suitable for use in a point obscuration fire detector, the internal timer could conveniently count every 16 microseconds and the times t1 and t2 could each be approximately 100 milliseconds. Using an 8-bit analogue to digital convertor to measure the difference signal would give a potential resolution better than 1 part in 1 million of the zero obscuration signal, at least 2 orders of magnitude better than the 0.02% in the specification. Second order effects within the electronics and opto-electronic components are likely to be present in practice which will result in the maximum theroretical performance not being achieved. It will be understood that that other measures may be taken in the design of the optics, electronics, and in the signal processing within the microcomputer to minimise or correct for these.

Embodiments of the sensor could utilise a wide variety of known optical techniques and physical arrangements. In practice it is found particularly convenient to expose both active and reference paths to smoke and to make the paths dissimilar in length. In order to maximise the difference in length at least one of the paths could be folded.

Although this is preferred for some applications, folding does presents additional problems in a very low cost product with the quality of the reflectors or prisms and with the overall mechanical stability of the enclosure. In preferred embodiments for use in a point obscuration smoke detector more direct paths are used. The paths must be efficient and have a consistent performance, in order to prevent additional errors being introduced into the measurement of the absorption co-efficient. The embodiments described in the following text are given as examples which are found to offer good stability, together with a convenient mechanical arrangement.

Figure 5 shows an embodiment of sensor components for the arrangement in figure 1. An LED 34 and a lens 35 constitute one source, and an LED 36 and a lens 37 constitute the other source. Radiation impinges on a receiver photodiode 40 via a long path 38 and a short path 39. The lenses 35 and 37 may have different focal lengths in order to more nearly equalise the radiation energies, or lens 37 may be omitted entirely.

Figure 6 shows a first embodiment of sensor components for the arrangement of figure 2. The sources comprise LEDs 41 and 42, and the receivers photodiodes 43 and 44. Beam splitting devices 49 and 50 result in two longer paths 45 and 47 and two shorter paths 46 and 48. The longer paths 45, 47 are combined for part of their length, but it may be arranged for the effect of insects present on the surface of one of the beam splitters to be resolved by the different effect on the pairs of beams. A second embodiment is shown in figure 7. The same components are shown with the (optional) addition of lenses 51 and 52. The principle is identical to that in the previous embodiment, but in this case the paths 45 and 47 are separated. In both embodiments the beam splitters may be constructed from etched metal grids, from arrays of plastic prisms in an injection moulded acrylic plate, or by other techniques.

Figure 8 shows a possible arrangement of the sensor embodiment of figure 7 within the envelope of a point smoke detector. The sensor assembly mounted between a member 53 and a member 54 enclosed within an outer case 55 provided with apertures 56. A screen 57 excludes insects and other larger objects. The LEDs and photodiodes are connected to a printed circuit board 58, which would also mount the necessary electronic circuitry. Other components (not shown) would permit the unit to be mounted on a surface and would provide an electrical interface to a fire detection and alarm system, as necessary. The mechanical components would be of injection moulded plastics, or metal as appropriate to the detailed design.

Claims

1. A sensor for sensing the presence of species in a medium which absorb or scatter radiation wherein visible or infra-red radiation is transmitted from at least two sources to a receiver along paths so arranged that the absorbing or scattering species attenuate a different proportion of the radiation transmitted along each path, characterised in that means are operable to subtract the signals resulting from the radiation received from one source from the signals resulting from the radiation received from another source and to sense the resulting difference signal, and wherein the ratio of the average energies radiated from the sources may be controlled by means of passing through the sources quantities of charge determined by gating a given current for times in a known ratio, so as to maintain the difference signal at zero or at a small proportion of the signal from one source, and wherein the ratio of the gating times, and the difference signal are analysed in order to permit changes in the quantity of radiation attenuated by the species to be calculated.

2. A sensor according to claim 1 containing two sources (8 and 9) and two receivers (10 and 11), wherein the first source (8) transmits to the first receiver (11) along a first path (12) and to the second receiver (10) along a second path (13), and wherein the second source (9) transmits to the second receiver (10) along a third path (14) and to the first receiver (11) along a fourth path (15), and wherein the said species attenuates a greater proportion of the radiation in the first path (12) than in the second path (13) and in third path (14) than in the fourth path (15), and wherein means are operable in conjunction with each receiver to subtract the signals resulting from the radiation received from one source from the signals resulting from the radiation received from the other source and to sense the resulting difference signal, and wherein the ratios of the average energies radiated from the sources may be separately controlled so as to maintain the difference signal for each receiver at zero or a small proportion of the signal from either source, and wherein the ratios of the said gating times and difference signals are analysed in order to permit errors due to variations in the emission efficiencies of the sources to be substantially corrected for.

3. A sensor according to claim 1 or claim 2 wherein the said species attenuates a different proportion of the radiation transmitted along paths by virtue of paths being of different lengths.

4. A sensor according to claim 1 or claim 2 wherein the said species attenuates a different proportion of the radiation transmitted along paths by virtue of paths being differently exposed to the species.

5. A sensor according to claim 1 or claim 2 wherein the said species attenuates a different proportion of the radiation transmitted along paths by virtue of sources transmitting radiation at different predominant wavelengths.

6. A sensor according to any one of claims 1 to 5 wherein the sources are semiconductor light emitting diodes which are pulsed in sequence, and wherein the means by which the ratio of the average energies radiated from a pair of sources is controlled comprises a capacitor which is charged with an electrical current (I) for one time (t1) the accumulated charge (I.t1) then being passed for the duration of the pulse through one source, and another capacitor which is charged with a virtually identical electrical current (I) for another time (t2) the accumulated charge (I.t2) then being passed for the duration of the pulse through the other source, and wherein the ratio of the charge times (t1/t2) may be controlled by a microcomputer or by other electronic means.

7. A sensor according to claim 6 wherein the pulse time for each source is a near constant ratio of the charge passed through the source, such that the sources are driven with similar pulse currents and exhibit similar emission characteristics.

8. A sensor according to any one of claims 1 to 7 wherein at least one receiver is a photodiode or a phototransistor, and wherein the means to accurately subtract the signals resulting from the radiation received from a pair of sources is to pulse the sources in sequence and to integrate the receiver current on a capacitor while radiation is being received from one source and subsequently to integrate the receiver current in the opposite polarity while radiation is being received from the other source, and to amplify the resultant change in the voltage present across the said capacitor and to measure it using an analogue to digital convertor or other electronic means.

9. A sensor according to claim 8 wherein the said receiver current is integrated in a given polarity for some instances of radiation being received from a given source and is integrated in the opposite polarity for other instances of radiation being received from the same source and in which the said difference signals resulting from the two instances are separately analysed, such as to permit offset errors in the receiver electronics to be substantially corrected for.

10. A sensor according to any one of claims 1 to 9 contained within a mechanical enclosure suitable to be disposed on a surface such as a ceiling and into which the ambient atmosphere may ingress through a screen which excludes certain insects, suitable for use as a fire detector of the point type.

Figure 1

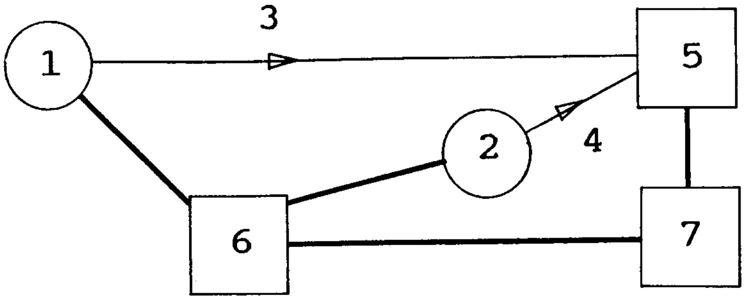


Figure 2

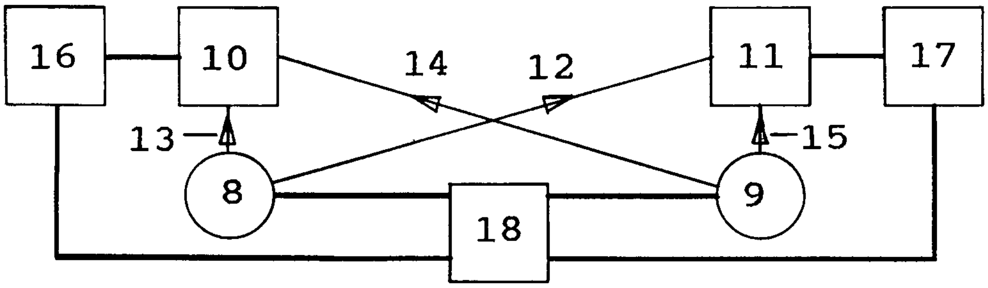


Figure 3

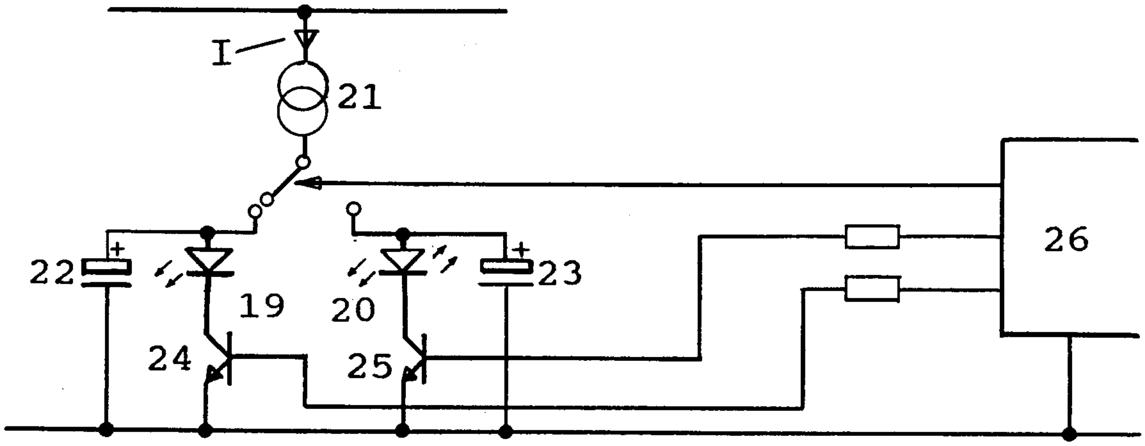


Figure 4

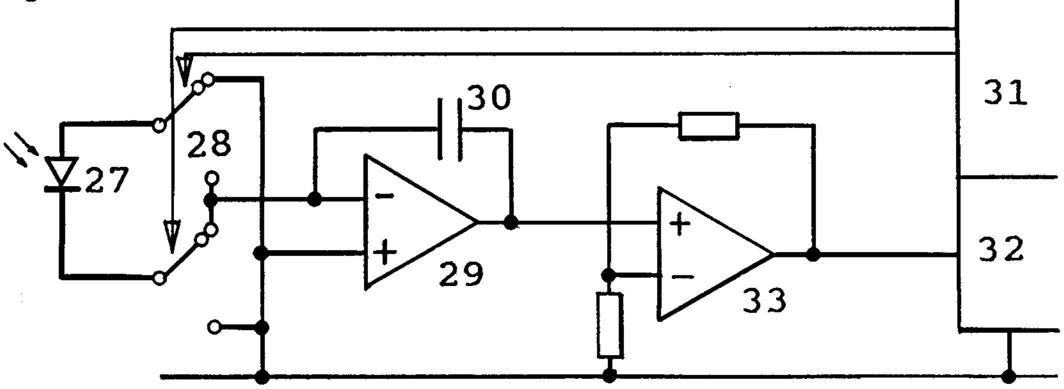


Figure 5

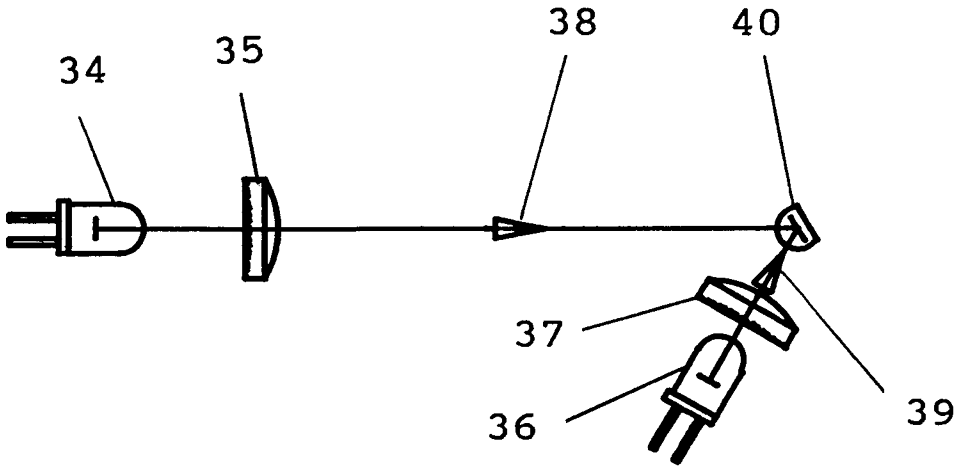


Figure 6

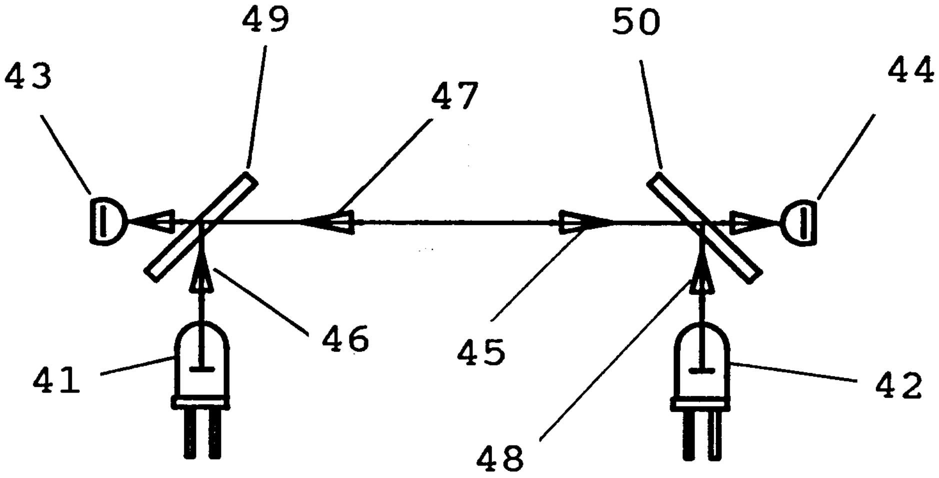


Figure 7

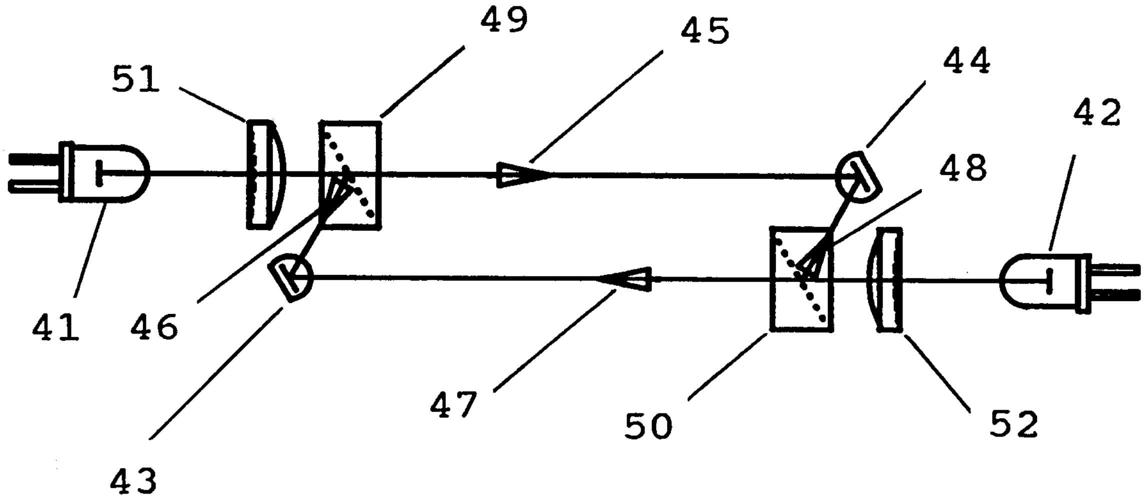
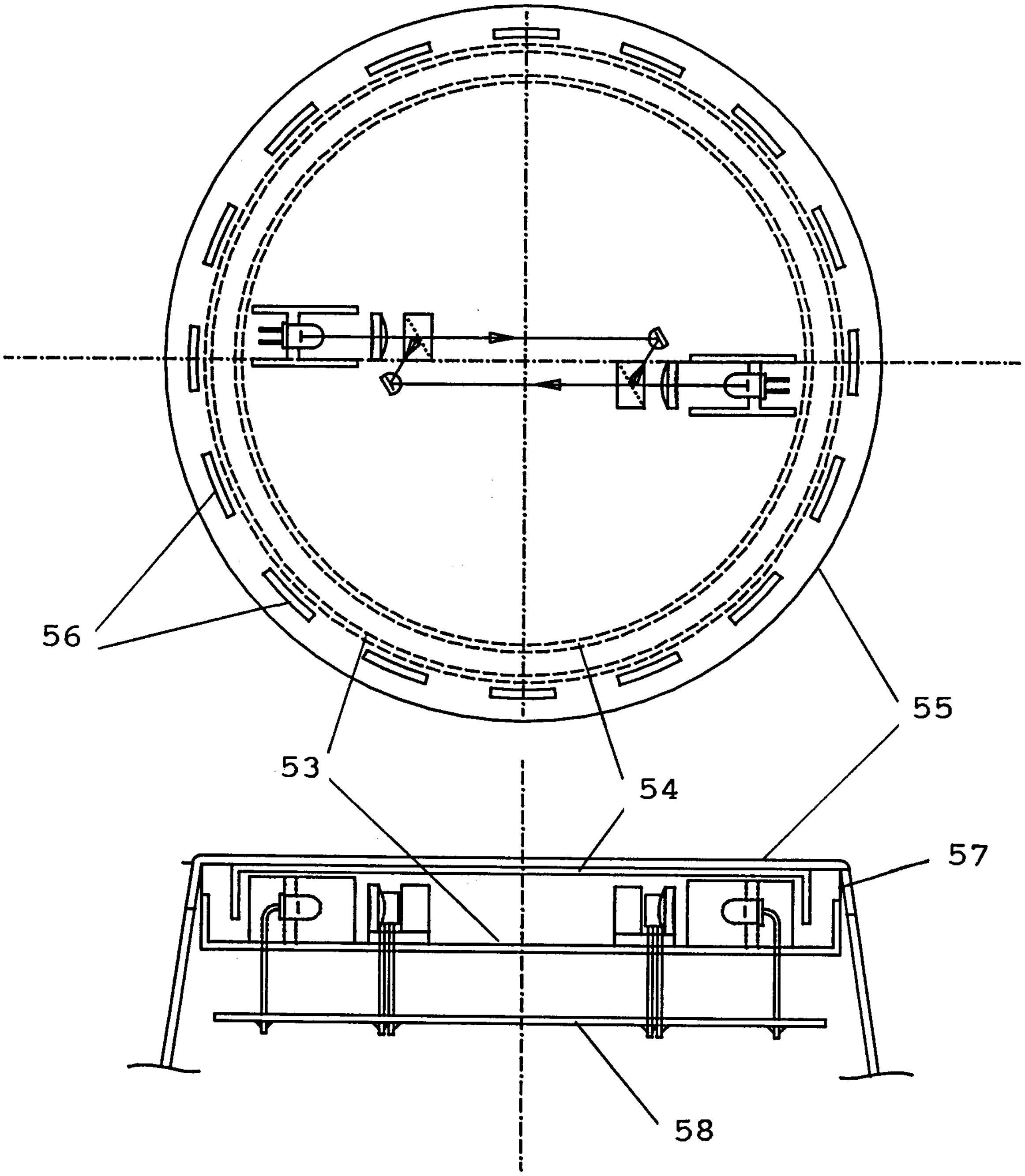


Figure 8



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EUROPEAN SEARCH REPORT

Application Number
EP 93 31 0263

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	PATENT ABSTRACTS OF JAPAN vol. 6, no. 34 (P-104) (912) 2 March 1982 & JP-A-56 153 239 (FUJI DENKI SEIZO) 27 November 1991 * abstract *	1,3	G08B17/103
Y	US-A-4 237 453 (W. J. MALINOWSKI) * column 3, line 5 - line 65; figure 1 *	1,3	
Y	US-A-4 838 698 (HIROMITSU ISHII ET AL) * abstract; figures 1,6 *	1,10	
Y	EP-A-0 119 618 (ERWIN SICK) * abstract; figure 1 *	1,10	
A	US-A-4 017 193 (L. LOITERMAN) * abstract; figures 1,7 *	1,2	
A	CH-A-643 061 (ZELLWEGER USTER) * claim 1; figure 1 *		**TECHNICAL FIELDS SEARCHED (Int.Cl.5)**
A	WO-A-81 02633 (BAXTER TRAVENOL LABORATORIES) * abstract; figure 1 *	5	G08B G01N
A	DE-A-36 15 259 (G. KRIEG) * abstract; figure 1 *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	6 September 1994	Breusing, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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