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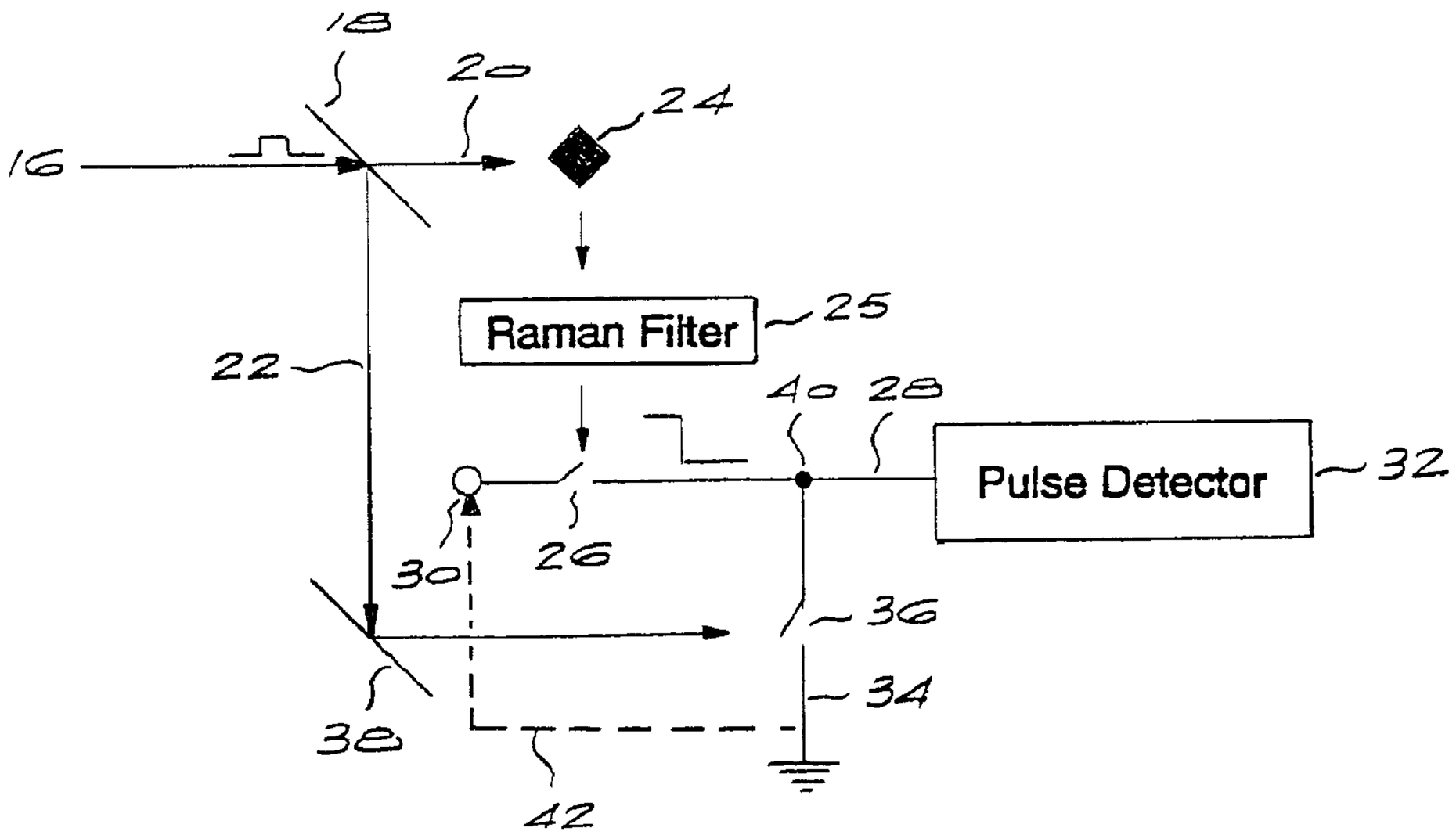
(54) Titre : METHODE ET APPAREIL DE CLASSIFICATION DE PARTICULES
(54) Title: PARTICLE CLASSIFICATION METHOD AND APPARATUS



(57) Abrégé/Abstract:
The invention concerns a method and apparatus for classifying particles, and in particular for classifying particles according to whether they are diamond or non-diamond particles. In the method each particle (24) is irradiated with a pulse of monochromatic light capable of causing Raman spectral activation in certain particles. Light emitted by the particle is filtered to remove components which are outside a band including a characteristic Raman spectrum for the relevant class of particles. The filtered light is direct onto a light sensitive switch (26) which is arranged to close on receipt of filtered light of predetermined intensity. On closure of the light sensitive switch, an electrical pulse is generated and directed towards a pulse detector (32). The particle is classified according to whether or not the pulse detector (32) detects an electrical pulse within a predetermined time window. The original pulse of monochromatic light can be split into a test portion, used to irradiate the particle, and a control portion used to control a time gating apparatus which sets the time window. The method can be used in a particle sorting method in which, typically diamond and non-diamond particles are separated from one another.

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ABSTRACT

The invention concerns a method and apparatus for classifying particles, and in particular for classifying particles according to whether they are diamond or non-diamond particles. In the method each particle (24) is irradiated with a pulse of monochromatic light capable of causing Raman spectral activation in certain particles. Light emitted by the particle is filtered to remove components which are outside a band including a characteristic Raman spectrum for the relevant class of particles. The filtered light is direct onto a light sensitive switch (26) which is arranged to close on receipt of filtered light of predetermined intensity. On closure of the light sensitive switch, an electrical pulse is generated and directed towards a pulse detector (32). The particle is classified according to whether or not the pulse detector (32) detects an electrical pulse within a predetermined time window. The original pulse of monochromatic light can be split into a test portion, used to irradiate the particle, and a control portion used to control a time gating apparatus which sets the time window. The method can be used in a particle sorting method in which, typically diamond and non-diamond particles are separated from one another.

"PARTICLE CLASSIFICATION METHOD AND APPARATUS"

BACKGROUND TO THE INVENTION

THIS invention relates to a particle classification method and apparatus.

One of the major problems encountered in the use of a Raman spectroscopy technique in the detection of a particular particle is the fact that the Raman component of the radiation emitted by the particle can be swamped, and hence rendered difficult to detect, by other secondary radiation, typically reflection and luminescence. For accurate detection of the Raman component it would accordingly be beneficial to eliminate the other secondary radiation effects.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a method of classifying a particle, the method comprising the steps of:

- irradiating the particle with a pulse of monochromatic light capable of causing Raman spectral activation of particles of a certain class,
- filtering light emitted by the particle to remove components which are outside a wavelength band including a characteristic Raman waqvelength for particles of the certain class,
- directing the filtered onto a first light sensitive switch which is arranged to close on receipt of filtered light,
- on closure of the first light sensitive switch, generating an electrical pulse and directing such electrical pulse towards a pulse detector, and
- classifying the particle according to whether or not the pulse detector detects an electrical pulse within a predetermined time window.

Thus the particle is classified according to whether it has a Raman response indicative of a certain class of particle.

The method preferably comprises the steps of:

- splitting the pulse of monochromatic light into a test portion and a control portion;
- irradiating the particle with the test portion of the pulse of monochromatic light; and

- using the control portion of the pulse of monochromatic light to activate a time gating means which operates to allow the pulse detector to detect only an electrical pulse which reaches the pulse detector within the predetermined time window.

The control portion of the pulse of monochromatic light may be directed onto a second light sensitive switch which is arranged to close on receipt of such light and thereafter to prevent an electrical pulse from reaching the pulse detector. In one embodiment, the electrical pulse is diverted to earth by the second light sensitive switch when that switch is closed. In another embodiment, the electrical pulse is diverted into a closed circuit by the second light sensitive switch on closure thereof.

In an application of the method, the particle is classified according to whether it is a diamond or non-diamond particle. The invention is applicable to on-line sorting of particulate, diamondiferous material, in which case a plurality of particles are irradiated in turn and particles for which the pulse detector detects an electrical pulse are sorted from other particles for which the pulse detector detects no electrical pulse.

According to a second aspect of the invention there is provided a particle classification apparatus comprising:

- irradiation means for irradiating the particle with a pulse of monochromatic light capable of causing Raman spectral activation of particles of a certain class,
- a filter for filtering light emitted by the particle to remove components which are at wavelengths outside a wavelength band

containing a characteristic Raman wavelength for particles of the certain class,

- a first light sensitive switch arranged to receive light filtered by the filter and to close on receipt of filtered light of predetermined intensity,
- an electrical pulse generator arranged, on closure of the first light sensitive switch, to generate an electrical pulse,
- an electrical pulse detector arranged to detect an electrical pulse generated by the pulse generator, and
- time gating means operating to prevent an electrical pulse generated by the pulse from reaching the pulse detector unless the pulse reaches the pulse detector within a predetermined time window,

the response of the pulse detector being indicative of whether or not the particles is a particle of the certain class.

The apparatus may comprise a light splitter for splitting the pulse of monochromatic light into a test portion with which the particle is irradiated and a control portion which activates the time gating means.

Preferably, the time gating means comprises a second light-sensitive switch which is arranged to receive the control portion of the pulse of monochromatic light and to close on receipt of such control portion.

The apparatus may be arranged to classify the particle according to whether it is a diamond or a non-diamond particle. In this case, the filter is arranged to filter out light components outside a band including a characteristic Raman spectrum for diamond.

The apparatus may be a sorting apparatus in which case means are provided for locating a plurality of particles one by one in an irradiation zone where they are irradiated in turn, and means for sorting diamond particles, for which the pulse detector detects an electrical pulse, from other particles, for which the pulse detector detects no electrical pulse.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 graphically illustrates the different rise times for Raman, luminescence and reflected light spectra; and

Figure 2 diagrammatically illustrates the present invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

The graph seen in Figure 1 has relative intensity and time on the vertical and horizontal axes respectively. The graph shows three curves 10, 12 and 14 which are respectively representative of the spectra for reflected light, the Raman spectrum for a diamond particle irradiated with monochromatic laser light, and the luminescence or fluorescence spectrum for the same particle. It will be noted that the reflected light spectrum rises more rapidly than the Raman spectrum and that the Raman spectrum rises more rapidly than the luminescence spectrum.

As explained previously, a difficulty with particle classification based upon detection of the Raman spectra of particles is the fact that the luminescence spectrum can swamp the Raman spectrum if it is allowed to rise to a high enough intensity level, i.e. if sufficient time is allowed to go by before spectral analysis takes place.

Figure 2 illustrates an apparatus which exploits the different rise times of the Raman and luminescence spectra to classify the particle as a diamond particle or as a non-diamond particle. Referring to this Figure a pulse 16 of monochromatic light capable of causing Raman spectral activation of a diamond particle is directed at a beam splitter 18 which transmits a test portion 20 of light and reflects a control portion 22 of light. The test portion 20 is used to irradiate a particle 24 which it is desired to classify.

The light emitted by the particle can take various forms. Firstly there may be a reflected light spectrum. Secondly, there may, in the case of a diamond particle, be a Raman spectrum. Thirdly, there may be a luminescence spectrum. With a view to eliminating or reducing secondary radiation effects, the emitted light is passed through a narrow band pass filter 25 which filters out light components except those in a bandwidth including a characteristic Raman wavelength for diamond.

Light passing the filter 25 is directed onto an optical switch 26 located in an electrical circuit 28 between a pulse generating power source 30 and a pulse detector 32. Light which falls on the switch 26 and which is accordingly indicative of the presence of a Raman spectrum, causes it to close momentarily and complete the electrical circuit.

An electrical pulse therefore travels, from left to right in Figure 2, from the pulse generating power source to the pulse detector. The apparatus also includes a short circuit line 34 in which a second optical switch 36 is located and which, in the illustrated example, extends to earth.

The control portion of the original light pulse is directed by the beam splitter 18 onto a mirror 38 which in turn directs it onto the optical switch 36. Like the switch 26, the switch 36 closes when light falls on it. It will be appreciated that it takes a first, finite and calculable period of time for the test portion of light to travel from the beam splitter 18 to the particle 24 and for the emitted radiation to travel from the particle 24 to the switch 26.

It takes a second, finite and calculable period of time, after closing of the switch 26, for the electrical signal to travel from the power source to the junction point 40. It takes a third, finite and calculable period of time for the control portion of light to travel from the beam splitter 18 to the mirror 38 and from the mirror 38 to the switch 36.

It will also be recognised that if the third period of time is shorter than the sum of the first and second periods of time, the switch 36 will close before the electrical signal has reached the junction point 40. In this situation, any electrical pulse from the power source is connected to earth and does not reach the pulse detector 32. The pulse detector 32 therefore has a nil response. If, on the other hand, the electrical pulse has reached the junction point 40 before the switch 36 closes, the pulse detector will have a positive response.

The operating parameters and particularly distances are set such that a positive response is indicative of a diamond particle, i.e. so that the intensity of the Raman component of the radiation emitted by the particle reaches a level high enough for the switch 26 to close, and for the electrical pulse to reach the point 40, before the switch 36 closes.

If the detector has a nil response, this is indicative of a non-diamond particle for which the emitted radiation contains no Raman component characteristic of diamond. In this case, the parameters are such that the relatively slow rise time of the luminescence spectrum prevents the electrical signal from reaching the junction point 40 before the switch 36 closes, with the result that the electrical pulse goes to earth.

Thus only those electrical pulses attributable to the diamond-characteristic Raman spectrum are detected by the pulse detector. Those pulses attributable to the slower luminescence spectrum, and which are generated later in time, are shorted to earth along the earth line.

It will be appreciated that the success of the technique as described above is dependent on the sensitivity and speed of closing of the switches 26 and 36. Currently available solid state switches with pico-second reaction times are capable of suitably rapid operation.

In one application, the apparatus and technique described above are incorporated in an automatic sorting system. In such a system, a mass of particles which is to be sorted is manipulated such that the particles pass one by one through the test location seen in Figure 2, where irradiation takes place.

The particles may, for instance, fall in free flight through the test location after being projected from the end of a conveyor belt. Whenever a desired particle, such as a diamond particle in the example described above, is detected a microprocessor connected to the pulse detector classifies the particles as a desired particle, i.e. a diamond, and causes that particle to be separated from other non-selected particles.

This may, for instance, be done using an air blast ejector which is activated to issue a short duration blast of air, at the appropriate moment, at the falling stream of particles, thereby to deflect the diamond particle away from the general particle stream for collection apart from the other particles.

In the above example, the electrical pulse from the source 30 is removed by the earth connection if the switch 36 has closed before the pulse reaches the point 40. In another embodiment of the invention, the earth connection may be replaced by a closed circuit, such as that indicated by the numeral 42, around which the electrical pulse will travel without resulting in a positive pulse detection by the pulse detector 32.

It will be appreciated that the switch 36 acts, in essence, to control a time window which only allows the pulse detector to detect a pulse from the source 30 if that pulse is attributable to impingement, on the switch 26, of the rapidly rising Raman spectrum characteristic of a desired particle, such as a diamond in the case of a diamond sorting apparatus.

Although specific reference has been made to diamond, it will be appreciated that the principles of the invention are applicable to the classification and sorting of other particulate materials as well.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:-

1.

A method of classifying a particle, the method comprising the steps of:

- irradiating the particle with a pulse of monochromatic light capable of causing Raman spectral activation of particles of a certain class,
- filtering light emitted by the particle to remove components at wavelengths outside a wavelength band including a characteristic Raman wavelength for particles of the certain class,
- directing the filtered light onto a first light sensitive switch which is arranged to close on receipt of the filtered light,
- on closure of the first light sensitive switch, generating an electrical pulse and directing such electrical pulse towards a pulse detector, and
- classifying the particle according to whether or not the pulse detector detects an electrical pulse within a predetermined time window.

2.

A method according to claim 1 comprising the steps of:

- splitting the pulse of monochromatic light into a test portion and a control portion,
- irradiating the particle with the test portion of the pulse of monochromatic light, and

- using the control portion of the pulse of monochromatic light to activate a time gating means which operates to allow the pulse detector to detect only an electrical pulse which reaches the pulse detector within the predetermined time window.

3.

A method according to claim 2 wherein the control portion of the pulse of monochromatic light is directed onto a second light sensitive switch which is arranged to close on receipt of such control portion and thereafter to prevent the electrical pulse from reaching the pulse detector.

4.

A method according to claim 3 wherein the electrical pulse is diverted to earth by the second light sensitive switch when that switch is closed.

5.

A method according to claim 3 wherein the electrical pulse is diverted into a closed circuit by the second light sensitive switch when that switch is closed.

6.

A method according to claim 1 wherein the particle is classified according to whether it is a diamond or non-diamond particle.

7.

A method according to claim 6 wherein a plurality of particles are irradiated in turn and wherein particles for which the pulse detector detects an electrical pulse are sorted from other particles for which the pulse detector detects no electrical pulse.

8.

A particle classification apparatus comprising:

- irradiation means for irradiating the particle with a pulse of monochromatic light capable of causing Raman spectral activation of particles of a certain class,
- a filter for filtering light emitted by the particle to remove components at wavelengths outside a wavelength band containing a characteristic Raman wavelength for particles of the certain class,
- a first light sensitive switch arranged to receive the filtered light and to close on receipt of the filtered light,
- an electrical pulse generator arranged, on closure of the first light sensitive switch, to generate an electrical pulse,
- an electrical pulse detector arranged to detect an electrical pulse generated by the pulse generator, and
- time gating means operating to prevent an electrical pulse generated by the pulse from reaching the pulse detector unless the pulse reaches the pulse detector within a predetermined time window,

the response of the pulse detector being indicative of whether or not the particles is a particle of the certain class.

9.

An apparatus according to claim 8 comprising a light splitter for splitting the pulse of monochromatic light into a test portion with which the particle is irradiated and a control portion which activates the time gating means.

10.

An apparatus according to claim 9 wherein the time gating means comprises a second light-sensitive switch which is arranged to receive the control portion of the pulse of monochromatic light and to close on receipt of such control portion.

11.

An apparatus according to claim 10 wherein the second light-sensitive switch is arranged when closed to divert an electrical pulse generated by the pulse generator to earth.

12.

An apparatus according to claim 10 wherein the second light-sensitive switch is arranged when closed to divert an electrical pulse generated by the pulse generator into a closed electrical circuit.

13.

An apparatus according to claim 8 which is arranged to classify the particle according to whether the particle is a diamond or a non-diamond particle.

14.

An apparatus according to claim 13 wherein the filter is arranged to filter out light components at wavelengths outside a wavelength band including a characteristic Raman wavelength for diamond.

15.

An apparatus according to claim 8 and comprising means for locating a plurality of particles one by one in an irradiation zone where they are irradiated in turn, and means for sorting diamond particles, for which the pulse detector detects an electrical pulse, from other particles, for which the pulse detector detects no electrical pulse.

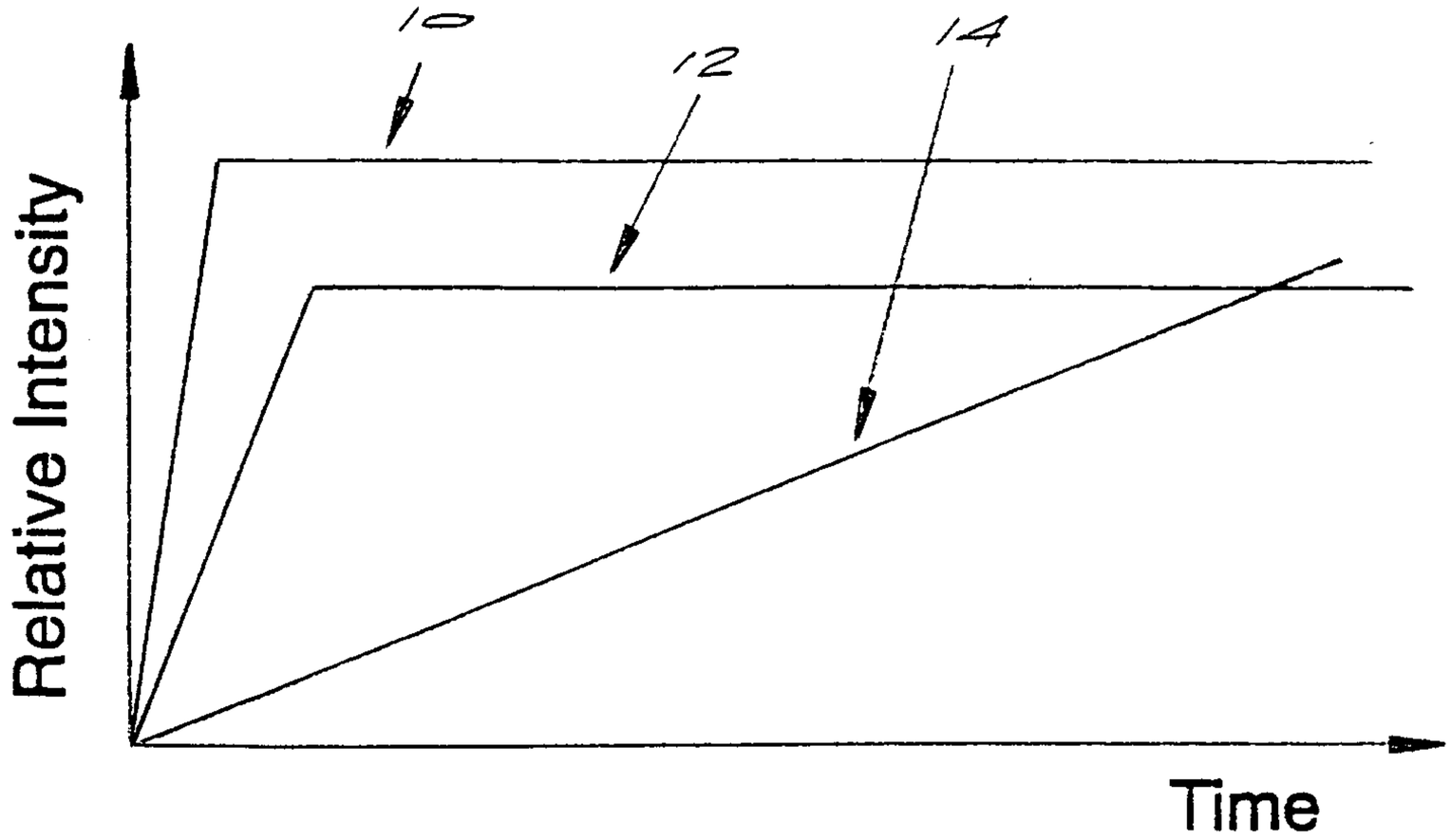

10
12
14
Relative Intensity
Time

Fig. 1

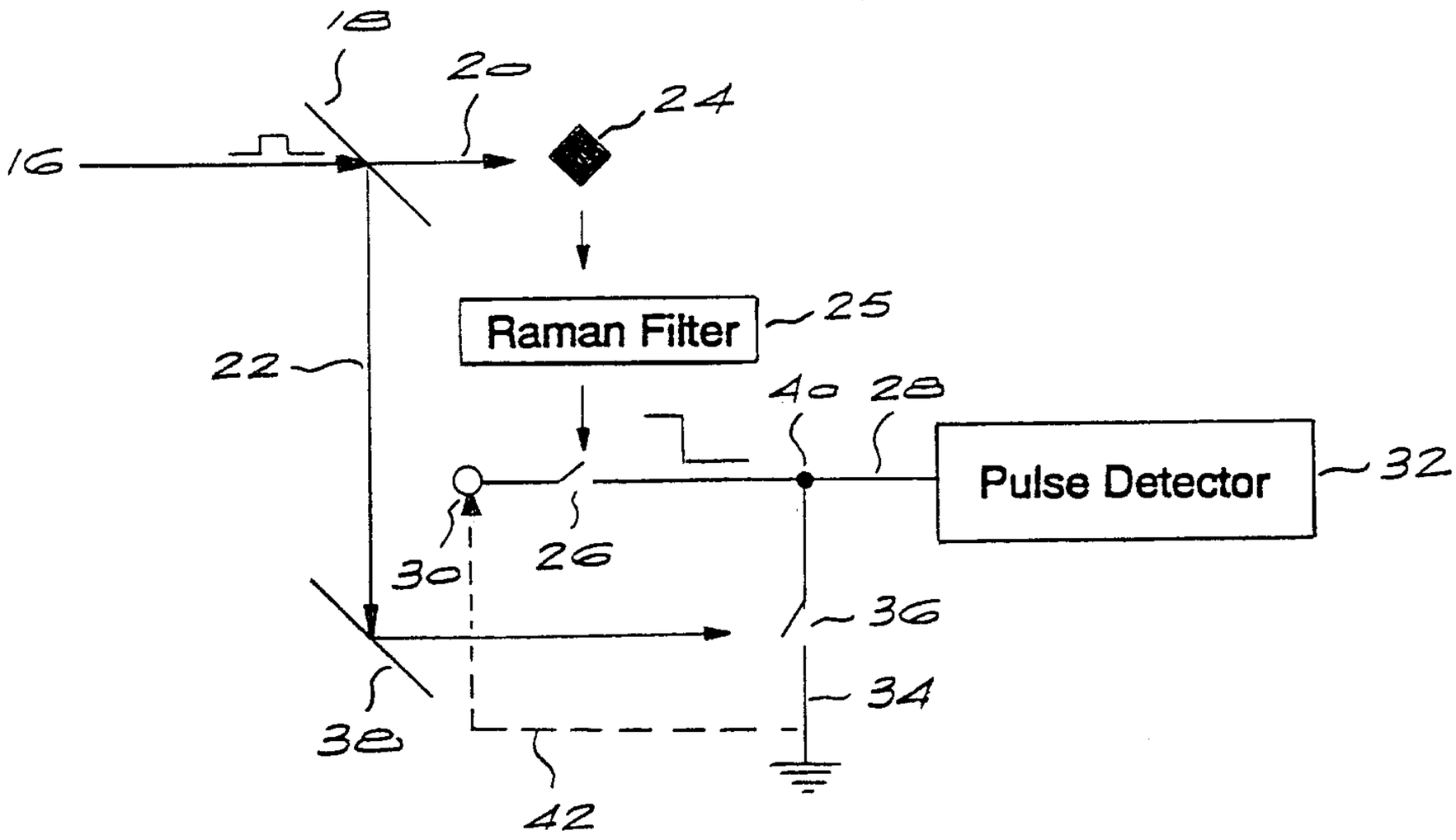
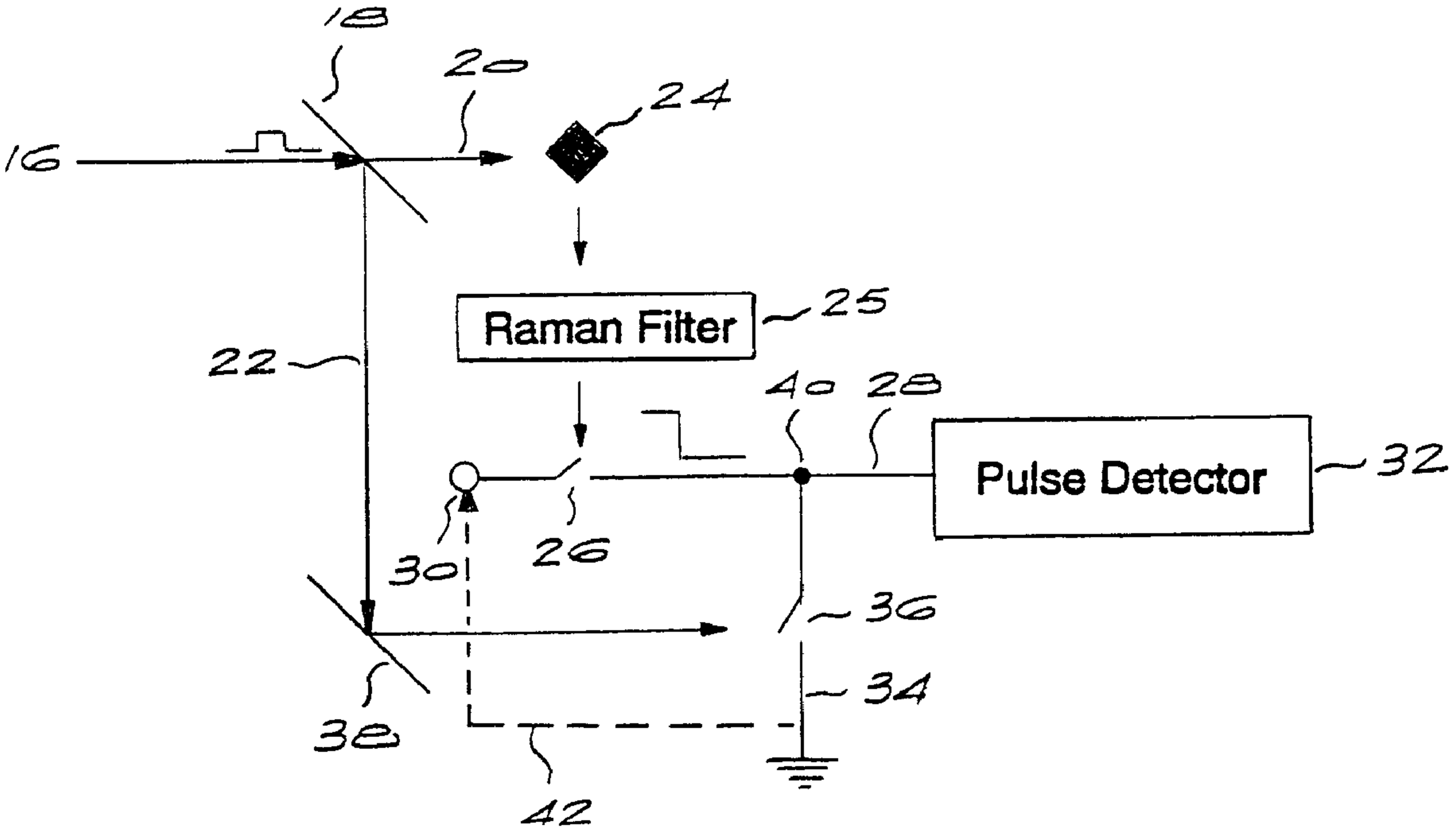

18
20
24
16
Raman Filter
25
22
40
28
Pulse Detector
32
30
26
36
34
38
42

Fig. 2


18
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16
Raman Filter
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Pulse Detector
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