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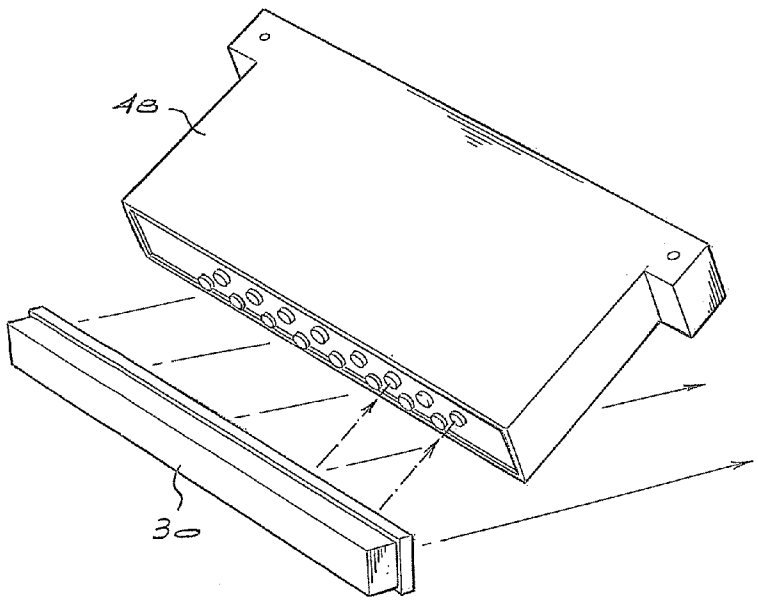
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(54) **Title:** A LIGHT DETECTING MODULE FOR A SORTER



(57) **Abstract:** A light detecting module for a sorter includes a housing including a plurality of openings therein. A primary collimator is located in each of the openings in the housing, the primary collimator having an inner surface that is not smooth to eliminate reflections off this surface. A filter is located in each of the openings behind each of the primary collimators. A secondary collimator is located in each of the openings in the housing, the secondary collimator having an inner surface that is not smooth to eliminate reflections off this surface. Finally, a light detector is located in each of the openings behind the secondary collimator.

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A LIGHT DETECTING MODULE FOR A SORTER

BACKGROUND

THIS invention relates to a light detecting module for a sorter, for example for a diamond sorter.

About 92% of diamonds in all alluvial gravels are less than 3mm or ½ a carat in size. Almost all these stones are never recovered on the operating mines in Southern Africa and the world due to the amount of time needed to identify these small stones among diamond bearing gravel. Mine operations with conventional sorting processes, like hand and grease sorting cannot afford the time needed to sort these small sizes.

When wet, these small stones are extremely difficult to spot with the naked eye. This means that there is a need for advanced high volume sorting machines which can identify these small stones. Current X-Ray Sorting machines available to diamond operations do not have the capabilities to recover these small low luminescence stones at high volume feed rates.

Laser sorting devices are also used but these are limited by the nature of the laser device to sorting larger diamonds and are difficult if not impossible to use to detect smaller sized stones.

The present invention seeks to address these drawbacks by providing a light detecting module capable of being used in such a sorter.

SUMMARY

According to a first embodiment there is provided a light detecting module including:

a housing including a plurality of openings therein;

a primary collimator located in each of the openings in the housing, the primary collimator having an inner surface that is not smooth to eliminate reflections off this surface;

a filter located in each of the openings behind each of the primary collimators;

a secondary collimator located in each of the openings in the housing, the secondary collimator having an inner surface that is not smooth to eliminate reflections off this surface; and

a light detector located in each of the openings behind the secondary collimator.

The filter may be a Raman filter.

The first and second collimators are designed to reflect light incident on their upper and lower surfaces at an angle of more that 5 degrees relative to a longitudinal axis of the opening.

The primary collimator may be formed integrally with the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of a diamond sorter;

Figure 2 shows the diamond sorter of Figure 1 from a different angle;

Figure 3 shows an example of a Raman shift for a diamond;

Figure 4 shows an example of a single light emitter and a light receiver;

Figure 5 shows an example of a bank of light emitters;

Figure 6 shows an example of a bank of light receivers;

Figure 7 shows an example exploded view of an illuminating module for use in the sorter of Figure 1;

Figure 8 shows an the illuminating module of Figure 7 assembled;

Figure 9 shows an example schematic illustration of the layout of lasers in the illuminating module;

Figure 10 shows an example laser holder for use in the illuminating module;

Figure 11 shows an example of a housing for a detection module; and

Figure 12 is a cross section through one of the openings of the housing of Figure 11.

DESCRIPTION OF PREFERRED EMBODIMENTS

This invention relates to a detecting module for use in a sorter.

For the purpose of this description the apparatus will be described with reference to a diamond sorter. It will be appreciated that the apparatus

could be used to sort crystals, jewel stones or quarts to name a few examples.

An example of a sorter in which the illuminating module of the present invention could be used is illustrated in Figures 1 and 2. A sorter 10 includes an illuminating module including a plurality of light emitters 12 and a plurality of light receivers 14.

In the illustrated embodiment the plurality of light emitters 12 are lasers and the plurality of light receivers 14 are photon multiplier tubes (PMT).

A feeding system 16 is used for feeding diamond containing material 18 between the plurality of light emitters 12 and plurality of light receivers 14. The feeding system includes at least one vibratory feeder.

A processor (not shown in Figures 1 and 2) receives signals from the light receivers 14 and uses the signals to detect diamonds within the diamond containing material 18.

A sorting mechanism 20 is responsive to the processor to remove diamonds from the diamond containing material 18.

In the illustrated embodiment, the sorter included at least one Raman filter (not shown in Figures 1 and 2) located in front of the lighter receivers 14.

Furthermore, in the illustrated embodiment, the sorting mechanism includes an air pressure system which directs jets of air pressure onto detected diamonds thereby to blow the diamonds out of the diamond containing material 18.

The sorting mechanism also includes a receiving container 22 positioned to receive diamonds which have been blown out of the diamond containing material.

The sorter of the illustrated embodiment uses the Raman Effect.

At the molecular level photons can interact with matter by absorption or scattering processes. Scattering may occur either elastically, or inelastically. The elastic process is termed Rayleigh scattering, whilst the inelastic process is termed Raman scattering. The electric field component of the scattering photon perturbs the electron cloud of the molecule and may be regarded as exciting the system to a 'virtual' state. Raman scattering occurs when the system exchanges energy with the photon and the system subsequently decays to vibrational energy levels above or below that of the initial state. The frequency shift corresponding to the energy difference between the incident and scattered photon is termed the Raman shift.

Depending on whether the system has lost or gained vibrational energy, the Raman shift occurs either as an up- or down-shift of the scattered photon frequency relative to that of the incident photon. The down-shifted and up-shifted components are called respectively the Stokes and anti-Stokes lines. A plot of detected number of photons versus Raman shift from the incident laser energy gives a Raman spectrum. Different materials have different vibrational modes, and therefore characteristic Raman spectra. This makes Raman spectroscopy a useful technique for material identification.

For diamond, the energy absorbed by the crystal from a monochromatic light source relates to an emitted signal with a Stokes shift of 1332 cm-1.

This is illustrated in Figure 3.

Figure 4 shows an example configuration of one of the light emitters and light receivers.

A laser beam 12 emits a specified wavelength of 638nm (nanometers), for example, which passes through an optical clean-up filter 24. This clean-up filter 24 forces the laser beam into a predetermined wavelength.

The laser beam enters a diamond 26 and instantaneously vibrates the diamond to emit the Raman Effect. The emitted light then travels at the speed of light into a Photon Multiplier Tube (PMT) 14.

A Raman filter 28 in front of the PMT 14 blocks the reflective laser light from entering the PMT 14. The Raman filter 28 only allows the Raman light, which is higher in wavelength, to enter the PMT. The photons from the Raman light are then transformed from photons in vacuum to a small 0-10 volt signal.

Referring to Figures 7 and 8 an illuminating module for use in such a sorter includes a housing 30 and a plurality of lasers 12 located in the housing 30.

The housing has a top, a bottom, a first and a second side. Although the housing illustrated is rectangular in shape, the housing could be any other shape such as square, triangular or round to name but a few examples.

The plurality of lasers 12 are arranged at different distances from the first and second sides so that the lasers emit beams of light parallel to the first and second sides, and wherein at least some of the lasers are arranged at different distances to the top and the bottom from at least some of the other lasers.

In the illustrated embodiment, the plurality of lasers 12 are arranged in a plurality of rows and wherein each row includes a plurality of lasers located adjacent one another.

The lasers in each row are staggered relative to the lasers in an adjacent row so that each laser emits a beam of light that is adjacent to the beam or beams of light emitted by the laser or lasers closest to it in the adjacent row.

This is arranged to obtain maximum coverage. It will be appreciated that the width of a laser diode module is more than the width of the laser beam emitted by the module. Thus, merely placing a plurality of laser beam

modules side by side will mean that there will be a distance between the beams through which diamonds could fall undetected. To address this, further lasers are placed in different horizontal planes to obtain maximum coverage. The number of lasers used and the spacing of the lasers can be varied depending on the width of the laser modules and on the smallest size of the diamonds that are required to be detected.

In an example embodiment, the total width of the laser module is 8 mm, whilst the width of the beam emitted by the laser is 2 mm. Therefore if the lasers would simply be placed side by side there would be a gap of 6 mm between the laser beams and diamonds of this size could fall through these gaps undetected.

Referring back to the illustrated embodiment, where the housing 30 is oriented as in the illustrated embodiment, this means that each laser will emit a beam of light that is in a different horizontal and vertical plane relative to the laser or lasers closest to it in an adjacent row.

Although any number of rows could be used, in the illustrated embodiment, three rows of lasers are used 32, 34 and 36.

The spacing of the lasers in a particular row relative to the laser adjacent to it is such to obtain the maximum coverage. It will be appreciated that the diamond containing gravel falls across the face of the illuminating device in the sorter (see Figure 1). In order to get maximum coverage, as much of the face of the illuminating device needs to have laser coverage. For practical purposes, it does not matter that the lasers are in different horizontal planes as the gravel will be falling vertically past the illuminating device.

It will also be appreciated that in the illustrated embodiment between each of the lasers of the top row 32, there is located one laser of the second row 34 and another laser of the third row 36. This can more clearly be seen in Figure 9 which is a schematic representation of the layout of the lasers.

Although it is most convenient to arrange the lasers in rows, the pattern of the lasers could be another pattern if the lasers are arranged so that in each vertical axis there is a laser which may or may not be in the same horizontal axis as one or more lasers of the plurality of lasers.

Each laser is located in a laser holder 38 illustrated in Figure 10.

The housing includes a plurality of openings therein, wherein each opening is sized to receive a laser holder 38.

The laser holder 38 includes power control circuitry (not shown) to control the power transmitted from a power source to the laser.

In the illustrated embodiment, each laser module consists of a laser diode located inside a laser holder 38 in the form of a metal housing, typically brass. The module further includes an optical focusing lens 40 and a small pc driver board (not shown). All these components are assembled into a module of diameter 8mm by 30mm long with two leading wires 42 to a 5V power supply (not shown).

In addition, each laser holder 38 includes a temperature sensor (not shown) located inside the laser holder 38 to sense the temperature of the laser.

Laser diodes are very temperature dependant as high temperatures shifts the specified laser wavelength. In Raman systems a stable laser wavelength is essential as the Raman emission shifts with the laser wavelength. Thus the laser assembly temperature needs to be controlled to ensure a stable wavelength.

The illuminating module of the present invention includes a cooling system to address these heat issues.

The cooling system of the illustrated embodiment includes a plurality of channels or tubes 44 running through the housing through which a cooling agent can be passed.

The cooling agent could be chilled water, frozen liquid gas, chilled liquid gas, refrigerated gas, ice, chilled liquid substance gel, refrigerated water, chilled anti freeze coolant, refrigerated anti free coolant, chilled air, refrigerated air or cold conditioned air pumped to name a few examples.

In the example of the cooling agent being water, the illuminating module includes a water cooling system (not shown) to cool the water and to pump the cooled water through the plurality of channels or tubes thereby to cool the lasers.

It will be appreciated that in order for the cooling system to operate efficiently, the housing needs to be made from a material that transmits heat efficiently such as a metal or suitable plastic to name but a few examples.

The illuminating module further includes a clean-up lens 24 located in front of the housing and a laser beam collimator plate 46 located in front of the housing. In the prototype of the present invention the clean-up lens 24 was implemented from four large filters to cover the bank of lasers. The join between the four large filters was specifically located so that the no laser projected through the join. The clean-up lenses are connected to the collimator plate 46.

The glass or crystal clean-up filter/s 24 arrangement placed in front of the laser modules can be rectangular, round or shaped to profile stability of the laser emitted light or radiation to a specific wavelength. The clean-up filters are mounted between the front-end of the laser housing block and accurately positioned with machined locating surfaces on the collimator plate (described below). The filters are secured in place and sealed from external dust penetration to the surface of the clean-up filters.

The clean up filters 24 are designed to allow a predetermined wavelength band through and block all other light wavelength. The laser modules emit 638nm, the clean up filter will only allow laser light to pass between 630nm and 648nm. Laser modules inherently have a second low emission at

around 690nm which if not blocked by the clean up filter is detected as a Raman shift.

The laser beam collimator plate 46 has holes the size of the laser beam focused at that point of entry to the collimator plate, is attached to the front of the housing. Typically these holes would be between 2mm and 4mm in diameter. The purpose of the collimator plate is to reduce reflection from the laser clean-up filter.

The beam collimator plate 46 only allows the strong or 80% strength of the laser beam to exit the collimator to allow for maximum strength of laser cover. This reduces the amount of background light. Because of the system layout where the detection module has a direct view of the laser bank, all particles falling through the laser beams create reflection in all directions. The holes in the collimator plate 46 prevents the reflected light from the particles to be reflected directly back via the clean up filter front surface, into the detection system as different wavelength light.

During manufacture, the housing is first formed with the openings and the laser modules 38 described are inserted into the openings. In the prototype of the system, the tolerance between the outer housing of the laser holders and the holes into which the laser holders slide was to within 0,05mm to ensure that the lasers are parallel.

These laser holders 38 can be secured in the block by means of glue, threaded bolting, grab screws, pinned, cast, soldered or epoxy type securing, for example.

The laser modules 38 need to be in full contact with the cooled assembly housing to ensure stable temperature control. Thus, thermal cream, silicone or thermal conductive paste can be inserted into the holes to ensure full thermal contact to the housing block.

The housing 30 can be machined, cast, formed, pressed or molded into an accurate housing, for example.

The housing block can be coated, painted, anodized, or molded in colour to reduce reflection within the laser detection system.

Finally, a non reflective clear glass plate is mounted on the front end of the laser beam collimator plate to prevent dust or moister entering the laser emitting system. In one example embodiment, tear off strips of clear film are stacked to the clear glass and torn off when dirt or excessive dust has collected on the film. The optical glass is made from special anti reflection type coatings to prevent reflections from the glass back to the particle and the reflection being up shifted into the Raman wavelength.

In the example embodiment, solid-state laser diodes are used to generate the Raman shift within the diamonds. Although Helium neon (HeNe) lasers are more commonly used in Raman generation application due to their stable wavelength laser beams. These lasers are very costly and typically only one laser per system would be used.

A laser beam of strength 30mW or more is required to generate enough Raman shift to be of use to the Photon Multiplier Tubes (PMT), the "eyes" of the laser sorter.

In one example embodiment, 150 laser diodes are used in the laser assembly to achieve a full laser coverage area of 350mm in width. This allows for a high amount of concentrate to pass through the detection system.

As the Raman Effect in diamonds for a multi channel system can only be achieved with a laser system consisting of multiple lasers and detectors in the shortest possible distance from the laser generation point, single laser systems with optic fiber cables do not supply enough energy to the diamond for detection. The illustrated sorter utilises a total of 150 x 5V solid state laser beams with a laser power of 38mW per laser to radiate the concentrated laser beams. These beams are focused at 200mm for optimal strength and spaced 1mm apart.

The laser beams are elliptical in shape with a 2mm x-axis and 1mm y-axis. In order to achieve strong Raman signal level, the detection system can only work with individual laser beams with focus abilities to achieve maximum power of the beam. The laser diode therefore requires accurate focusing. Advanced beam analyser allows the supplier to preset the beam as specified for this application.

The clean up filters 24 allow a wavelength of light between 630nm and 650nm to pass through. The solid state laser diodes used in a prototype example embodiment emitted a specified laser wavelength of 638nm but laser diodes may emit a small amount of light at around 700nm. This spillage is in the same range as the Raman signal. Thus to limit the spillage the clean-up filter 24 is placed between the laser 12 and the PMT 14.

The wavelength of the Raman filter 28 is determined by the wavelength of the laser diodes. The Raman shift stays constant as 1332cm-1 away from the laser wavelength. Special Raman filters are required to block the laser emitted light with an actual manufactured optical density of 6 or more. These filters should require a narrow bandwidth transmittance of at least ninety five percent or higher for Raman detection by the PMT's 14. Only a few global companies can achieve these specific specifications. Raman filters with these specifications have a workable light approach angle of 0 to 5 degrees. In multiple detection systems this angle becomes the most important parameter to have an operational detection system.

A small amount of photons clear the Raman filter to identify the diamond from the rest of the material passing through the lasers. These photons reach the PMT 14. The light or photon in the vacuum of the PMT 14 is then transferred into a small electrical voltage. A programmable logic controller system (PLC) interprets the voltage signal as an input for further programmable parameters to interpret.

In the illustrated embodiment, sixteen 30mm diameter PMTs 14 detect the diamonds. The +15 /-15 volts PMTs 14 are set at 950 volt to achieve a 1 to 3 detection ratio. The staggered horizontal layout ensures a full coverage in the detection area. All magnetic, cell and static interferences from external sources are shielded away from the PMTs 14 and signal transfer cables to eliminate false detection signals. A high voltage power supplier supplies the 950 volt required by the PMT 14.

Figure 11 shows the receiver housing 48 in more detail. The housing 48 includes sixteen PMT's 14 housed inside a solid machined aluminium block 48. It will be appreciated that any other number of PMTs could be used with the main purpose being full receiver coverage.

The housing ensures accurate alignment and positioning of the detectors. The housing 48 can be made of metal, non metal, thermo-plastic, plastic and/or solid form to house the detectors. The housing can be machined, cast, formed, pressed or molded into an accurate housing.

In any event, the PMTs are staggered to provide full horizontal detection area cover.

In the illustrated embodiment, the openings are equally spaced or spaced to form a matrix in order to provide a full coverage area.

The PMTs 14 can be secured in the housing by means of glue, threaded bolting, grab screws, pinned, cast, soldered or by an epoxy type securing.

The length of the detector housing is directly related to the diameter of the detection area of the detectors. To ensure the detectors only view and detect directly in front of the detector and not in the peripheral view, the detectors are positioned a distance away from the opening of the primary collimator opening to ensure the detector detect in a tunnel view. This prevents detectors detecting objects from other adjacent channels.

In other words, the PMTs see light as a human eye would. This means that any light in the peripheral view of the detector would be seen as Raman once passed through the Raman filter. Bearing in mind that the light from the Raman filter is only of Raman wavelength at 0 degree impedance, the housing and position of the PMT ensures that any light outside of 3 degrees from the horizontal and vertical plans are not "seen" by the PMT and only the Raman signal would be treated as Raman. The position also ensures accurate positioning of a particle in free space. Capturing the position of a particle in free space within the peripheral view of the PMT would be impossible, therefor there is a need to ensure tunnel view to the PMT to capture accurate positioning along the laser illumination area.

The aluminium housing 48 ensures accurate alignment and positioning of all PMT's. The tolerance between the outer housing of the detectors and the openings into which the PMTs slide is typically within 0,05mm, to ensure the axes of the center lines of the PMTs are parallel.

The housing 48 is matt black anodized to prevent any reflection of laser light.

Also located in each of the openings is a primary collimator 50 having an inner surface with a raised screw thread. This raised screw thread eliminates reflections off these surfaces. This raised screw thread could also be implemented in other ways such as by raised concentric circles with sharp edges, for example.

In the illustrated embodiment the primary collimator 50 is formed integrally with the housing. Thus the walls of each opening include a thread shaped edge to form the primary collimator 50 that eliminates reflections from flat surfaces.

Raman filters with special layering only function to specification when light penetrates the filter at substantially 0 degrees. Any angle more than 5 degrees allows light wavelengths to penetrate outside the designed

specifications, thus the importance of eliminating reflection of surfaces, as this would indicate a possible diamond to the PMT.

The diameter of the primary collimators are smaller in size to align with the open clear area of the Raman or similar filters. This ensures all light traveling down a detection channel is relayed to the detector without any interference. The length of the primary collimator is determined by the diameter of the detector in conjunction with the peripheral view calculation of the detector as mentioned above.

In each opening, behind the primary collimator 50 is located a Raman filter 24 as described above.

Behind the Raman filter 24 is a secondary collimator 52. The secondary collimator 52 has upper and lower surfaces that are not smooth to eliminate reflections off these surfaces.

Two collimators are required for the following reason. The Raman filter cannot be placed right up against the PMT as a glare appears at the edges of the Raman filters due to the huge amount of background light created by the matrix of lasers. To eliminate the glare which is seen by the PMT as a diamond the second collimator is added to move the Raman filter away from the PMT. If any light penetrate the Raman filter at an offset angle then it would bounce off the secondary collimator inner surface.

The secondary collimator 52 can be manufactured from metal, non metal, thermo plastic or plastic. In the illustrated embodiment, the secondary collimator 52 was not formed integrally with the housing as it contains the Raman filter.

The length of the secondary collimator 52 in the prototype embodiment was at least 50mm. The diameter can be the same as the detector but not limited to this size and could therefore be bigger but not smaller.

The secondary collimator 52 can be coated, painted, anodized, or molded in black or another surface finish that will eliminate reflection within the collimator.

The secondary collimator 52 has a reassess machined in the front end of the collimator housing to accommodate the Raman or similar filter. The filter is secured by means of a small grab screw. The collimator assembly with filter in place is then assembled into the detector housing by sliding the collimator assembly from behind into the detector hole.

Finally, the PMTs 14 are located behind the secondary collimator 52.

The diameter of the inlet holes in the example prototype were 25mm. The Raman filter was then placed inside the secondary collimator 50mm away from the front of the PMT. The filter is placed 50mm away from the PMT to eliminate the glare effect that appears when the filter is placed right against the PMT. This effect reduces the detection of smaller Raman signals and therefor the detection of smaller diamonds.

After inserting all secondary collimators 52 into the housing, each detector is then slide in from behind with a positive location to the back end of the secondary collimator 52 to prevent any light seepage.

A clear optical type glass can be mounted on the front end of the primary collimator openings to prevent dust or moister entering the detector system. Tear off strips of clear film can be stacked to the clear class and torn off when dirt or excessive dust has collected on the film. The optical glass is made from special anti reflection type coatings to prevent reflections from the glass back to the particle and the reflection being up shifted into the Raman wavelength.

The processor in the form of a Programmable Logic Controller (PLC) controls the adjustable time settings from detection to ejection. The background noise ratio 3 to 1, which means the diamond signal, is three times stronger as the gravel falling in front of the PMT's 14. A threshold

level of 15mV is set. This means diamonds will have a stronger signal than 15mv and any signal above this will be seen as a diamond. When the PMT detects the diamond, a 0-10v signal is sent to the PLC. Once the PLC receives the signal, 19 ms lapse before three air jets directly below and one on either side of the activated PMT are opened by their air jet solenoid valves for 23 ms to blast the diamonds and surrounding gravel into the second stage sorter. The second stage sorter will be described in more detail below.

High speed data networking and computer processors are required to process and send signals to various components. The particle drop is S = 250 mm and the beam width is d = 2 mm. The time taken to traverse the beam of width d = 2 mm is, since d << S,

$$t = d / (2 g S)0.5$$

Taking g = 9.8 m/s then t = 0.9 ms for the above parameters. Thus the Raman effect from the diamond is visible for only 1mille second in a 2mm diamond. During the past three years affordable Industrial PLC with a 1 mille second loops time become available. Loop is the time the computer requires processing incoming data and responding to the command

Fiber optic data network is the only communication network capable of achieving 1ms loop time required between the PLC and the components.

The laser bank is placed such that the lasers do not shine directly into the optical block or collimators. Direct laser light of the strength used could penetrate the filter as the optical density of any filters of current design cannot cut all the light from the laser beam.

The laser block is placed 250mm away from the optical block or PMT housing and above the top surface of the optical block. Alignment brackets are then used to ensure the laser beams shine 1 mm below the bottom surface of the optical block. This allows for a laser curtain in front of the PMT housing based on the angle of the laser block, this angle can be

adjusted to allow for a thicker material feed curtain. As the PMT housing block is also adjustable in the horizontal axis, the laser block needs re-adjustment when the PMT block is adjusted backwards.

This allows for a fully adjustable set-up to accommodate high material feed settings. Also the size of the material or rocks can vary from 1mm to 65mm is square mesh size, when feeding large size material the PMT block needs to be moved back in the pipe housing to allow for more area of material feed between the laser bank and the PMT housing.

Two magnetic vibratory feeders are used in the feeding system. These two feeder are placed at right angles to each other to deliver an evenly spread of material. The first feeder tray acts as a feeding valve to the machine, as soon as the vibration start the material in the pipe that feed the machine starts flowing onto the feeder tray. The feeder tray is fully covered for security reasons and to prevent dust from entering the sorting facility.

The material in the primary feeder tray slopes drown from the entry point to he exist point, the secondary feeder is set at a higher feed setting, this allows for an even spread across the secondary tray. Once this is achieved the material falling thought the laser beam is then at is optimal presentation to the laser beam and detection from the PMT.

As the speed of the feeder trays increase so the point of entering the laser beams moves forward due to excel rate material falling from the tray, this action is counter act by adjusting the gap between the laser block and the PMT housing.

The ejector block below the PMT housing also allows for horizontal adjustment. These two are adjusted together when the machine is set up for larger material sizes. This process takes approximately 15 minutes, the machines are preset in the factory for small or large size materials.

Reference was made above to a secondary stage sorter. The second stage sorter is the same as the main sorter but with a single channel

detection and ejector. It includes the same components which are controlled by the main PLC system.

Thus the sensed diamonds are ejected from the diamond containing material by the first stage together with some of the diamond containing material and the further sorting process then further sorts these diamonds from any diamond containing material which may have been separated along with the diamonds by the first stage sorter.

To balance the plant feed, the raw material is prepared by washing and pre-sizing the washed material. For every 100 tons of virgin material fed into the first stage of the plant 10% to 20% of the 100 tons will be diamond bearing material for sorting. Of the diamond concentrate the ratio between the small and big size fraction is 30% small and 70% in the large size fraction. Thus for every 100 tons fed into the plant per hour, 6 tons of size fraction 1-8mm will be fed into the sorting machines or storage bins.
The feed rate or the amount of material flowing through the machine is controlled by voltage controllers on each of the vibration conveyor feeder trays. These settings are determined for a specific feed rate. Once set the feed rate stays constant. The feed rate of the machine can be adjusted to a low of 2,7 ton per hour on the size fraction 1-4mm with a mono layer curtain and 99% recovery or a high of 6,0 ton per hour at 97% recovery. The setting will be determined by the grade of the diamonds and the carat price. Between 4-8mm the feed rate can be adjusted from 3 to 8 tons per hour.

Feed rate for the 8-32mm size fraction can be adjusted from 10 tons to 18 tons per hour with a recovery of 99% at 10 ton per hour or 97% at a higher feed rate. The same grade decision applies for the smaller diamonds. Because of the simplicity and the hand off approach, the system can be operated 24 hours a day. Thus an average of 100 ton per day can be achieved between the small and big size fraction. The amount of hours can also be adjusted to meet the production figures per day. Storage bins in the process allows for the plant to have human interface during the day and prepare enough concentrate for the plant to run on a 24 hour cycle with minimum standby staff of 2 per night shift.

CLAIMS:

1. A light detecting module including:

   a housing including a plurality of openings therein;

   a primary collimator located in each of the openings in the housing, the primary collimator having an inner surface that is not smooth to eliminate reflections off this surface;

   a filter located in each of the openings behind each of the primary collimators;

   a secondary collimator located in each of the openings in the housing, the secondary collimator having an inner surface that is not smooth to eliminate reflections off this surface; and

   a light detector located in each of the openings behind the secondary collimator.

2. A light detecting module according to claim 1 wherein the filter is a Raman filter.

3. A light detecting module according to claim 1 or claim 2 wherein the first and second collimators are designed to reflect light incident on their upper and lower surfaces at an angle of more that 5 degrees relative to a longitudinal axis of the opening.

4. A light detecting module according to any preceding claim wherein the primary collimator is formed integrally with the housing.

5. A light detecting module according to any preceding claim wherein the filter is located in the secondary collimator.

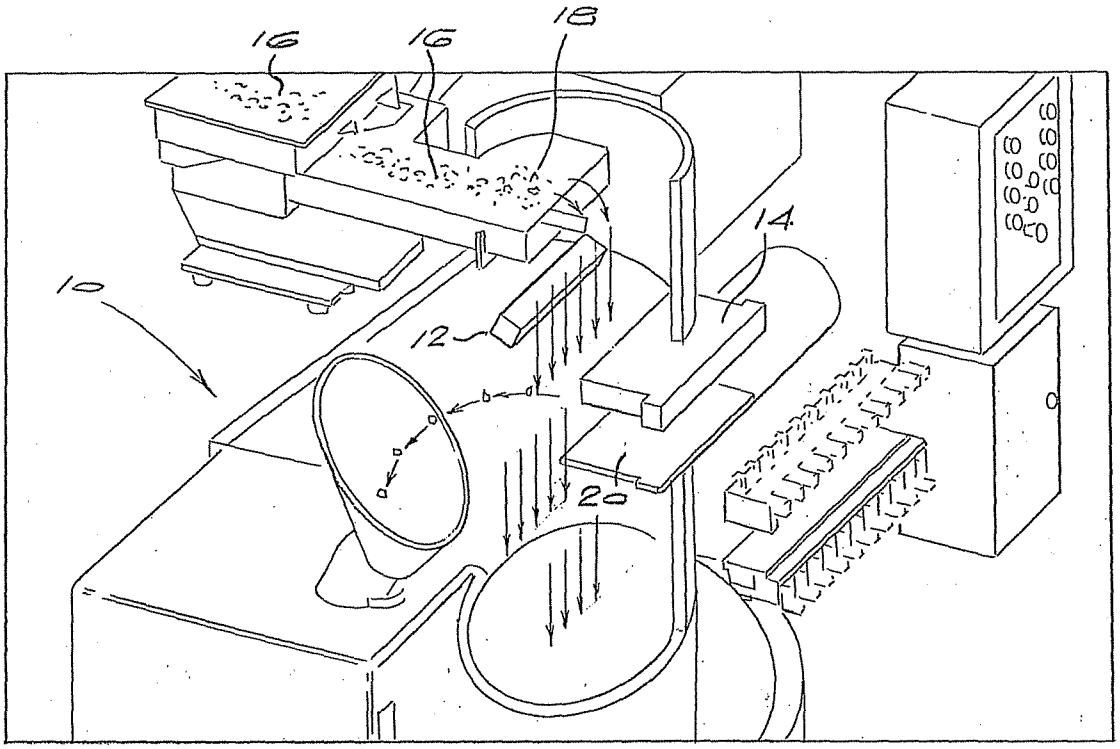


Fig.1

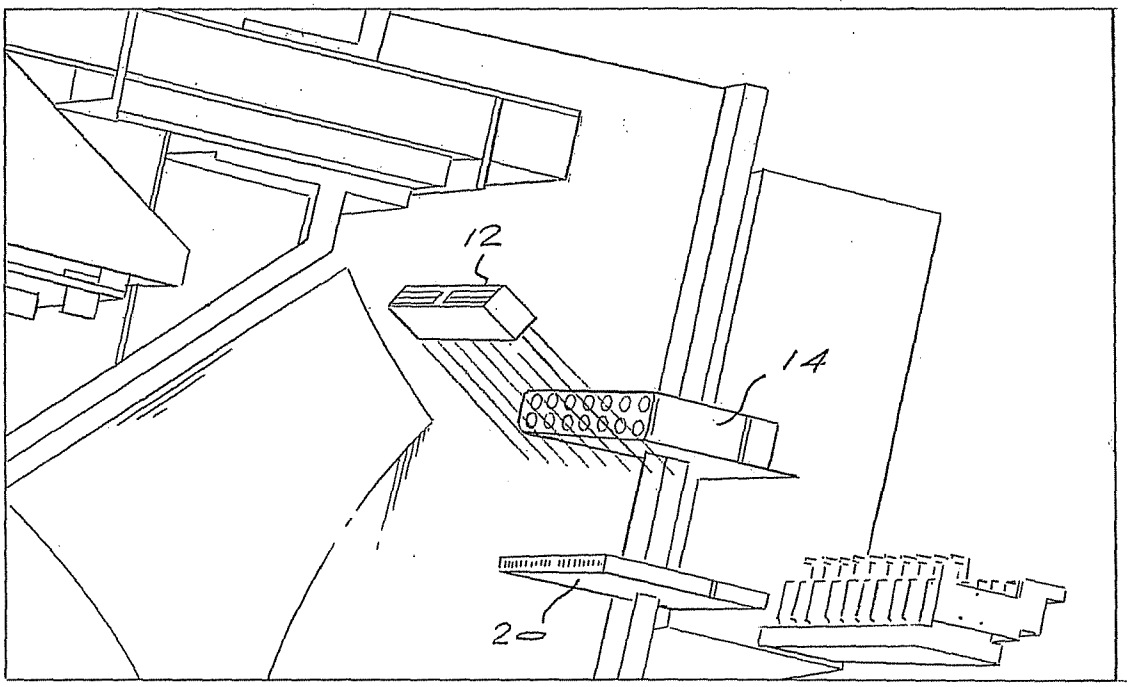


Fig.2

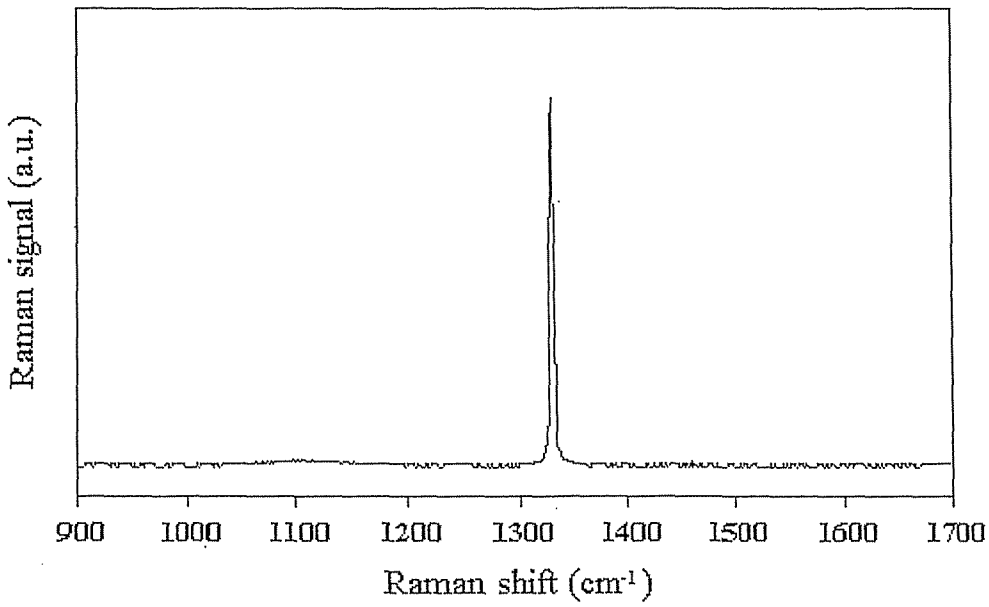

Raman signal (a.u.)
900
1000
1100
1200
1300
1400
1500
1600
1700
Raman shift (cm-1)

Fig.3

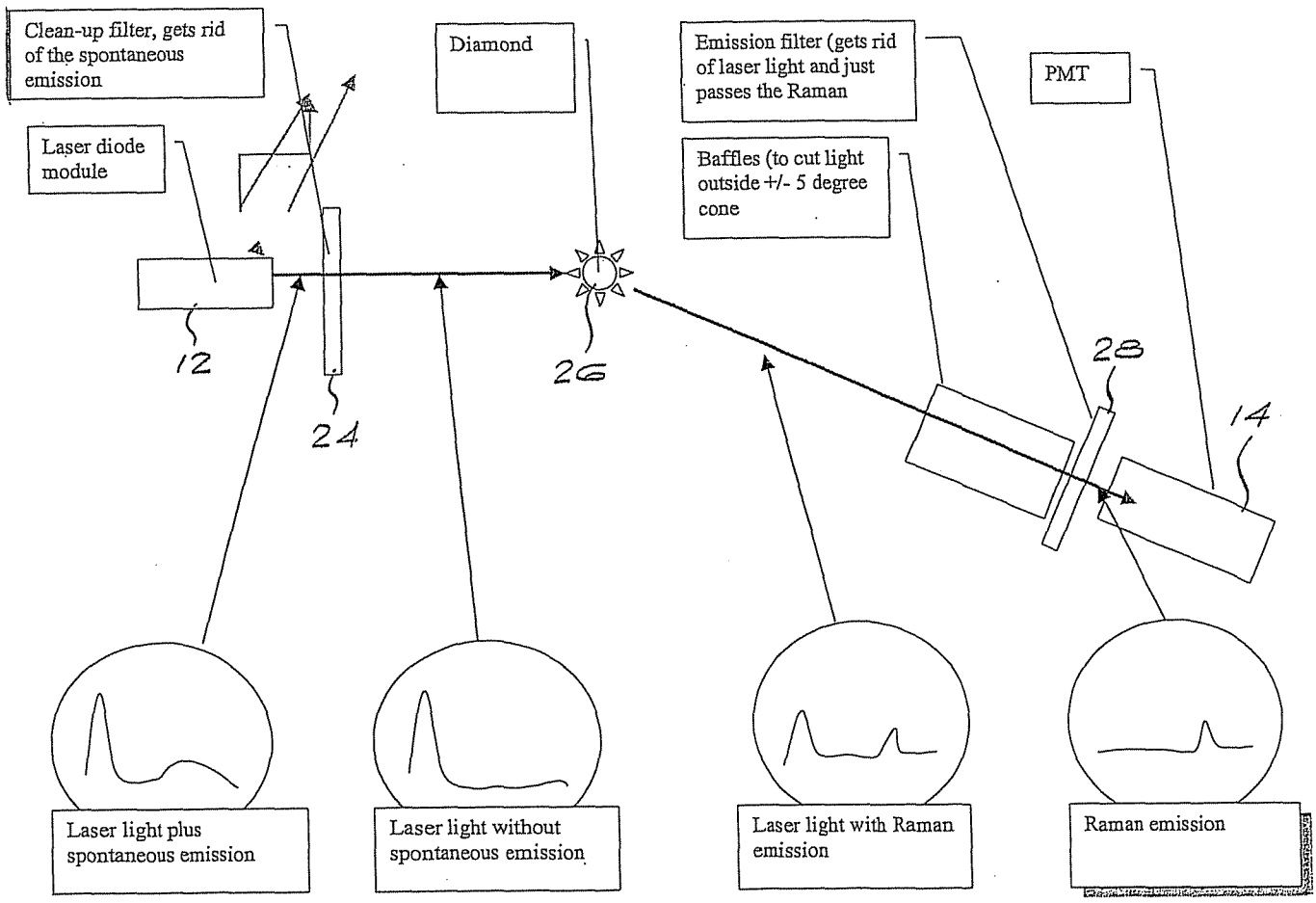

Clean-up filter, gets rid of the spontaneous emission
Laser diode module
Diamond
Emission filter (gets rid of laser light and just passes the Raman
PMT
Baffles (to cut light outside +/- 5 degree cone
12
24
26
28
14
Laser light plus spontaneous emission
Laser light without spontaneous emission
Laser light with Raman emission
Raman emission

Fig.4

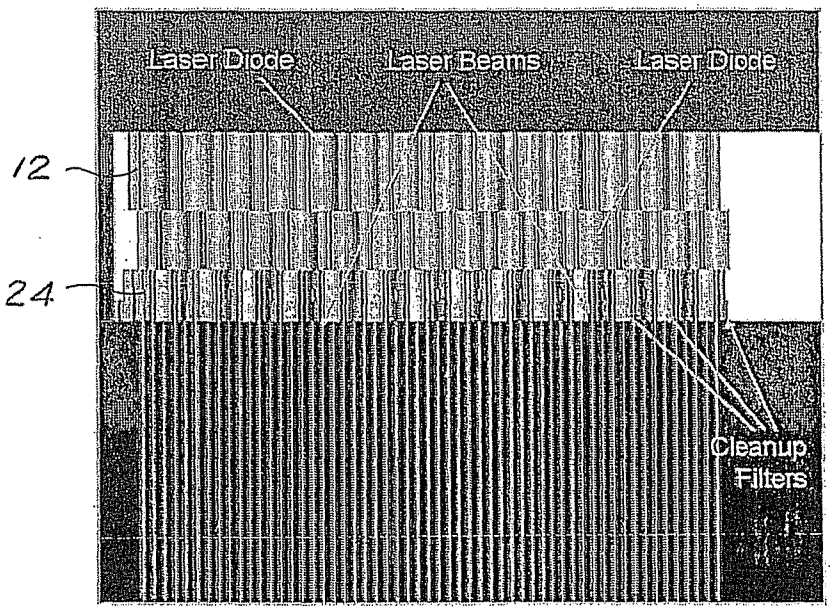

Laser Diode
Laser Beams
Laser Diode
12
24
Cleanup Filters

Fig.5

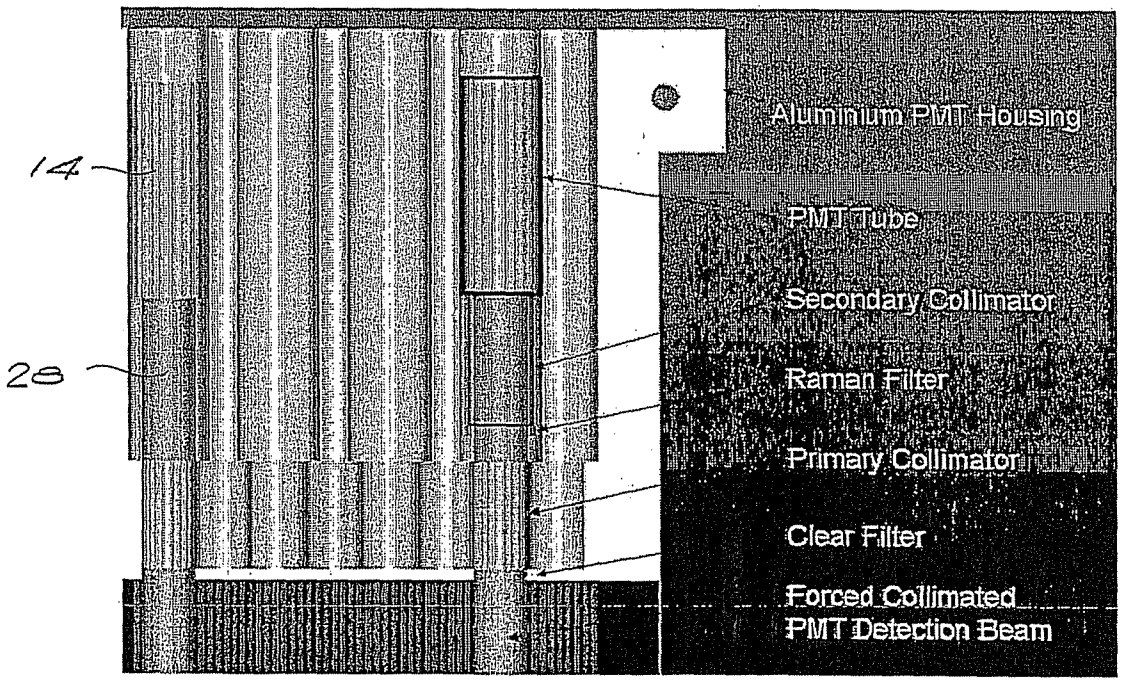

14
20
Aluminium PMT Housing
PMT Tube
Secondary Collimator
Raman Filter
Primary Collimator
Clear Filter
Forced Collimated
PMT Detection Beam

Fig.6

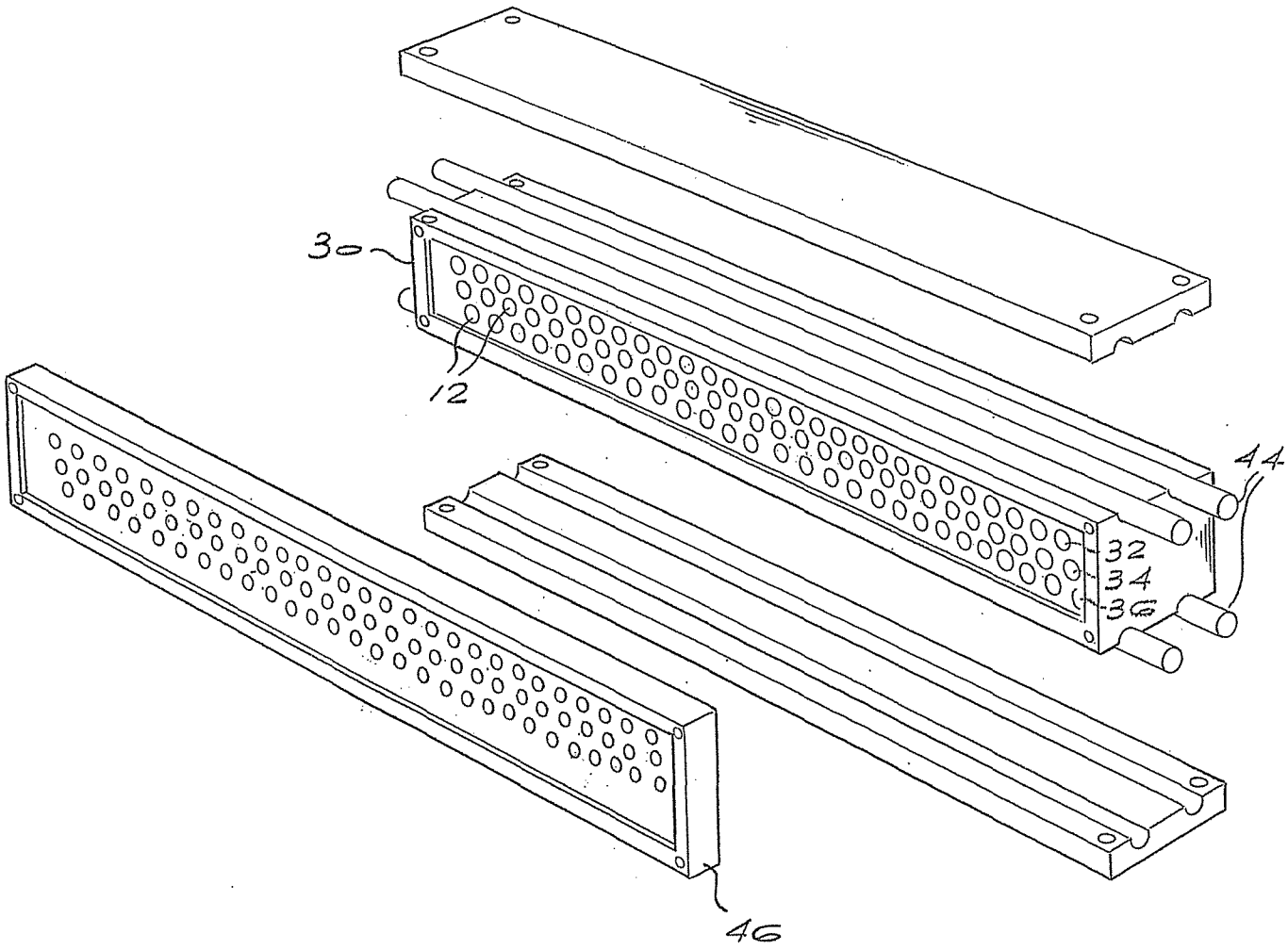


Fig. 7

Fig. 8

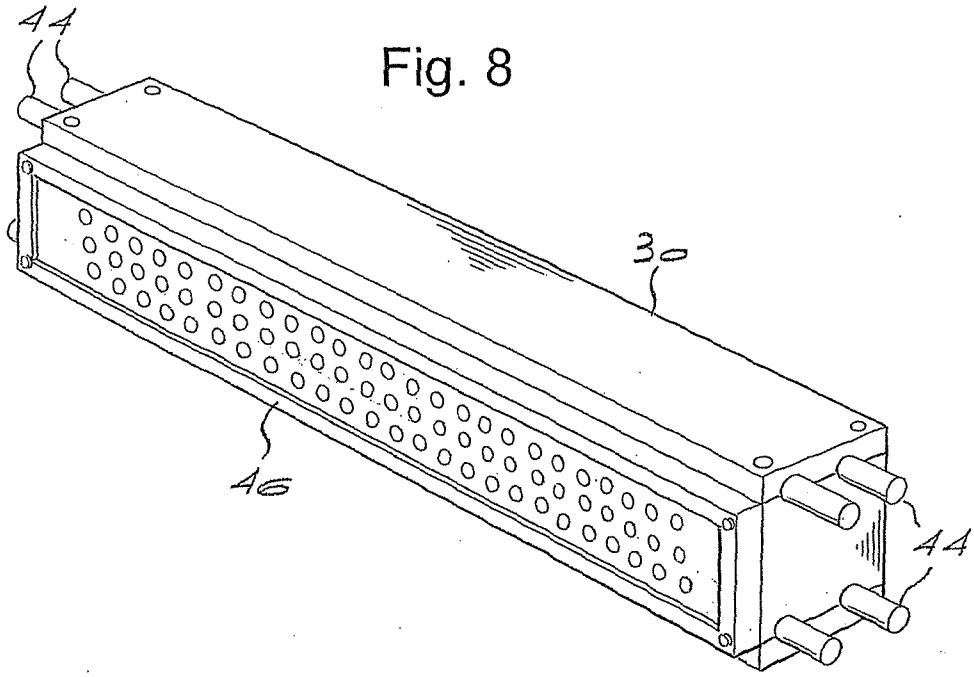


Fig. 9

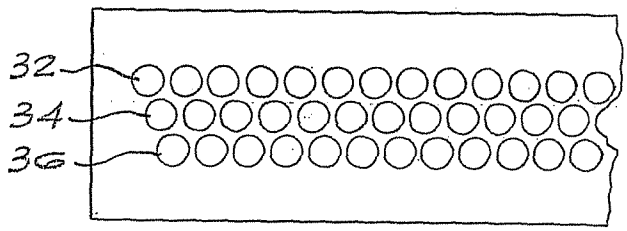
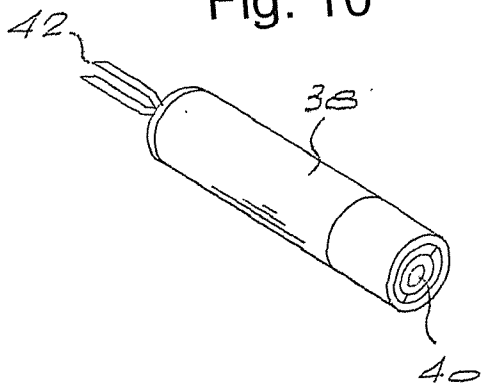


Fig. 10



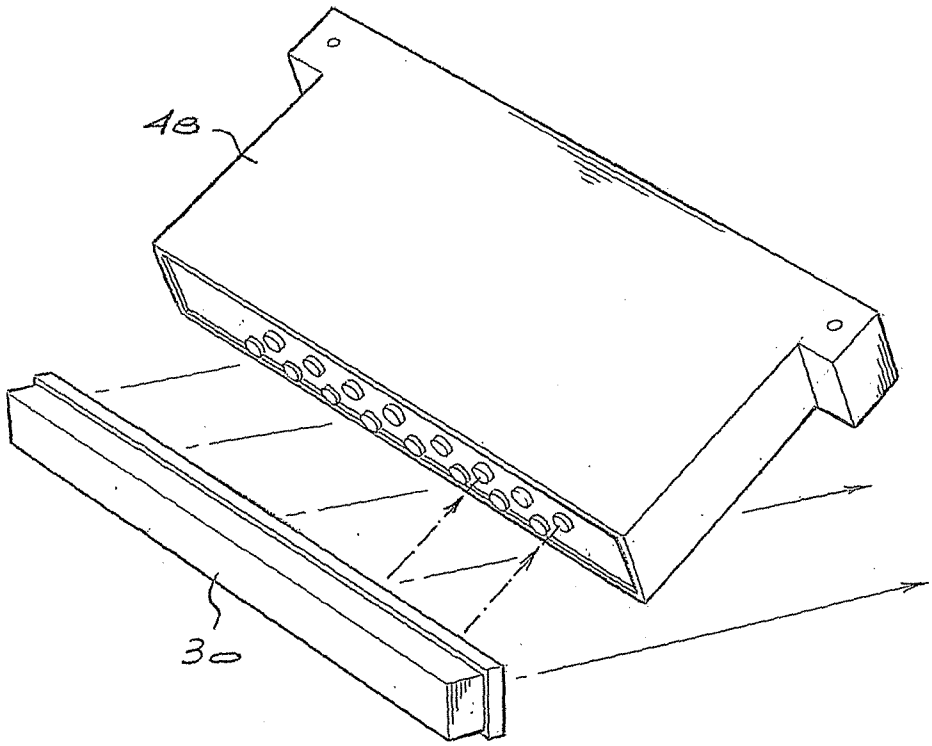
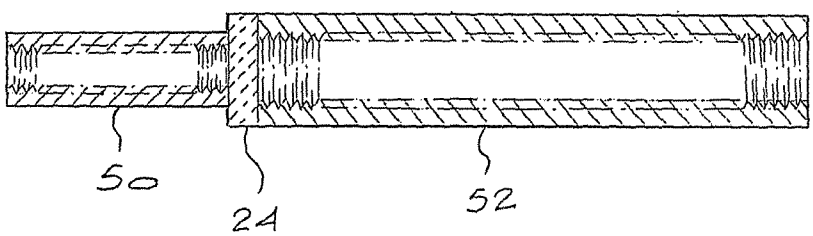


Fig. 11

Fig. 12



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/051534

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N21/65

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N G01J B07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 784 486 A (VAN WAGENEN RICHARD A [US] ET AL) 15 November 1988 (1988-11-15) column 14, line 22 - column 16, line 66 column 17, line 54 - line 62 figures 2,5	1-5
X	EP 0 299 606 A (HOCHSTEIN PETER A) 18 January 1989 (1989-01-18) figure 1 column 3, line 38 - line 58 column 7, line 31 - line 50	1-5
A	US 3 469 103 A (ERPEL ADOLPH C) 23 September 1969 (1969-09-23) column 2, line 58 - line 65 column 3, line 36 - line 48 figure 4	1-5

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 September 2007	01/10/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	D'Alessandro, Davide

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2007/051534

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 110 262 A (MILES LAB [US]) 13 June 1984 (1984-06-13) page 6, line 12 - line 32 figure 1 -----	1-5
A	US 4 368 980 A (ALDRED PHILLIP J E [GB] ET AL) 18 January 1983 (1983-01-18) figure 1 column 2, line 55 - line 68 -----	1-5

INTERNATIONAL SEARCH REPORT

Information on patent family members

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