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(54) **FIBER OPTICAL ASSEMBLY FOR FLUORESCENCE SPECTROMETRY**

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(60) Provisional application No. 60/748,523, filed on Dec. 7, 2005.

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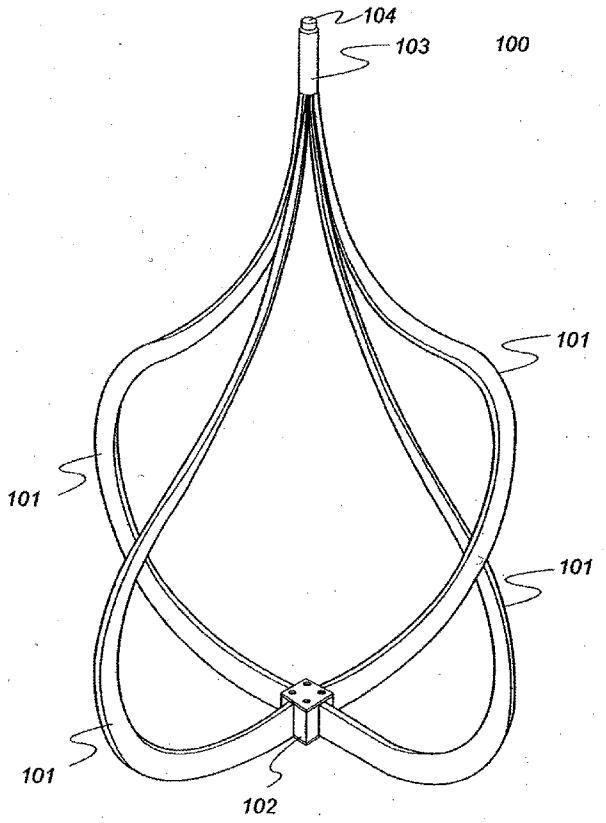
(57) **ABSTRACT**

System and method for analyzing a sample for the presence of an analyte in a sample, the system comprising a sample holder for containing the sample; an excitation source in optical communication with the sample, wherein radiation from the excitation source is directed to the sample, and wherein the radiation induces a fluorescence signal; and at least one linear array comprising a proximal end disposed in proximity to the sample holder and an end port distal from the proximal end; a plurality of optical fibers extending from the proximal end to the end port and having a first end and a second end, wherein the first ends of the individual optical fibers are substantially coplanar and adjacent to one another, and wherein the second ends of the optical fibers form a non-linearly arranged bundle, and wherein the plurality of optical fibers transmits the fluorescent signal from the proximal end to the end port; and an end port assembly optically coupled to the end port, the end port assembly comprising a single photo-detector, wherein the photo-detector detects the fluorescent signal and converts the fluorescent signal into an electrical signal.



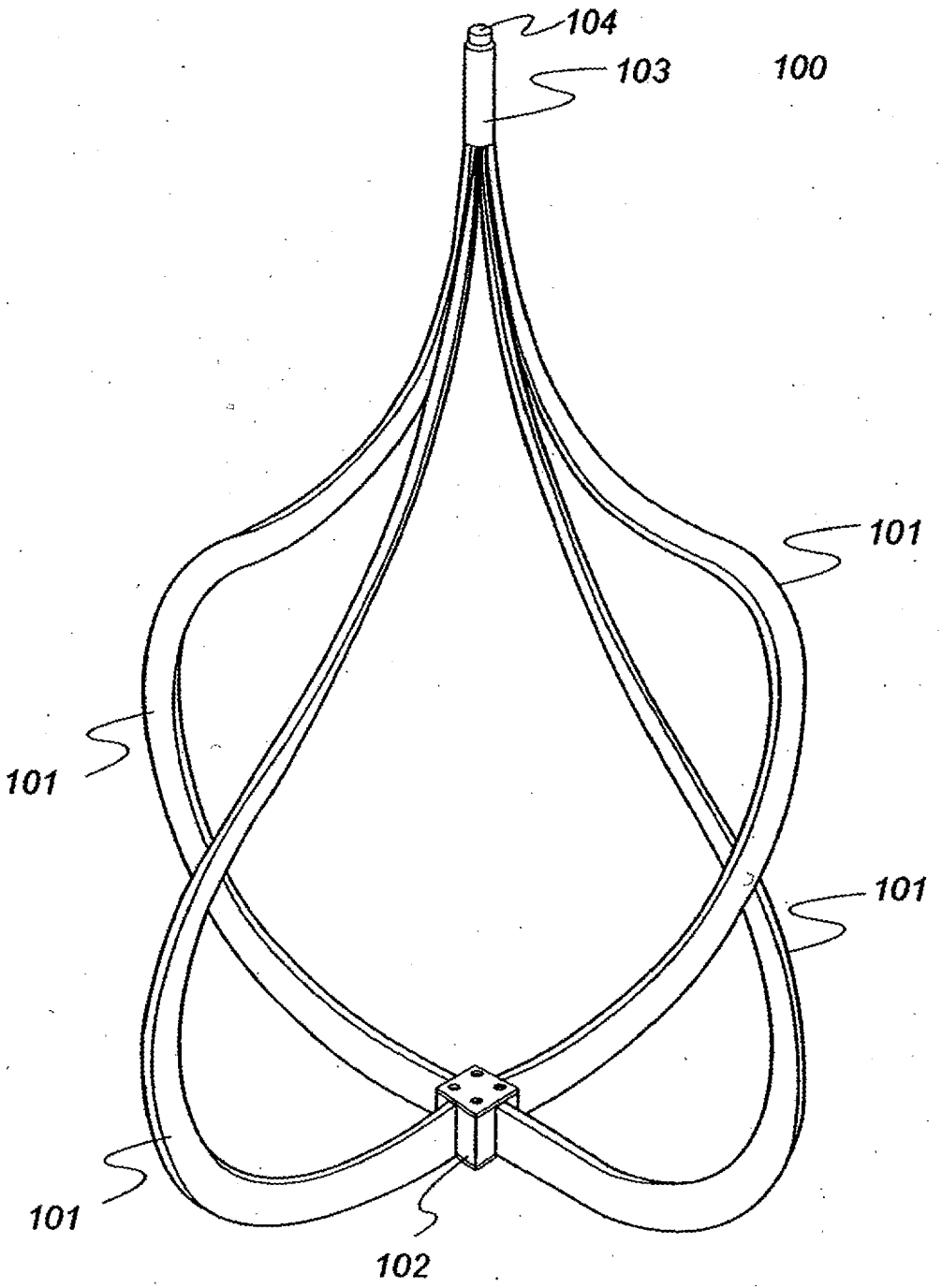
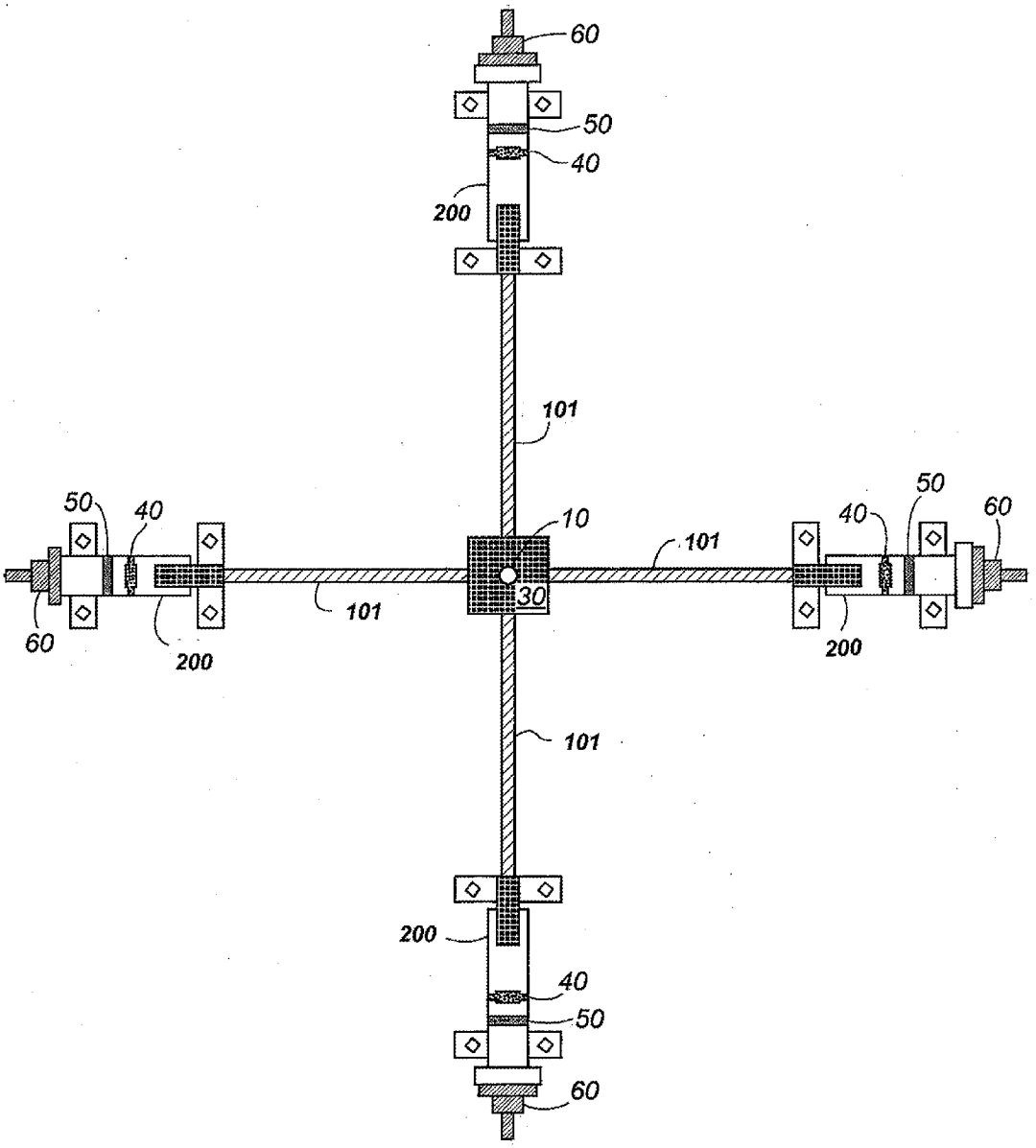


Fig. 1


60
50
40
200
101
50
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101
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101
200
40
50
60

Fig. 2

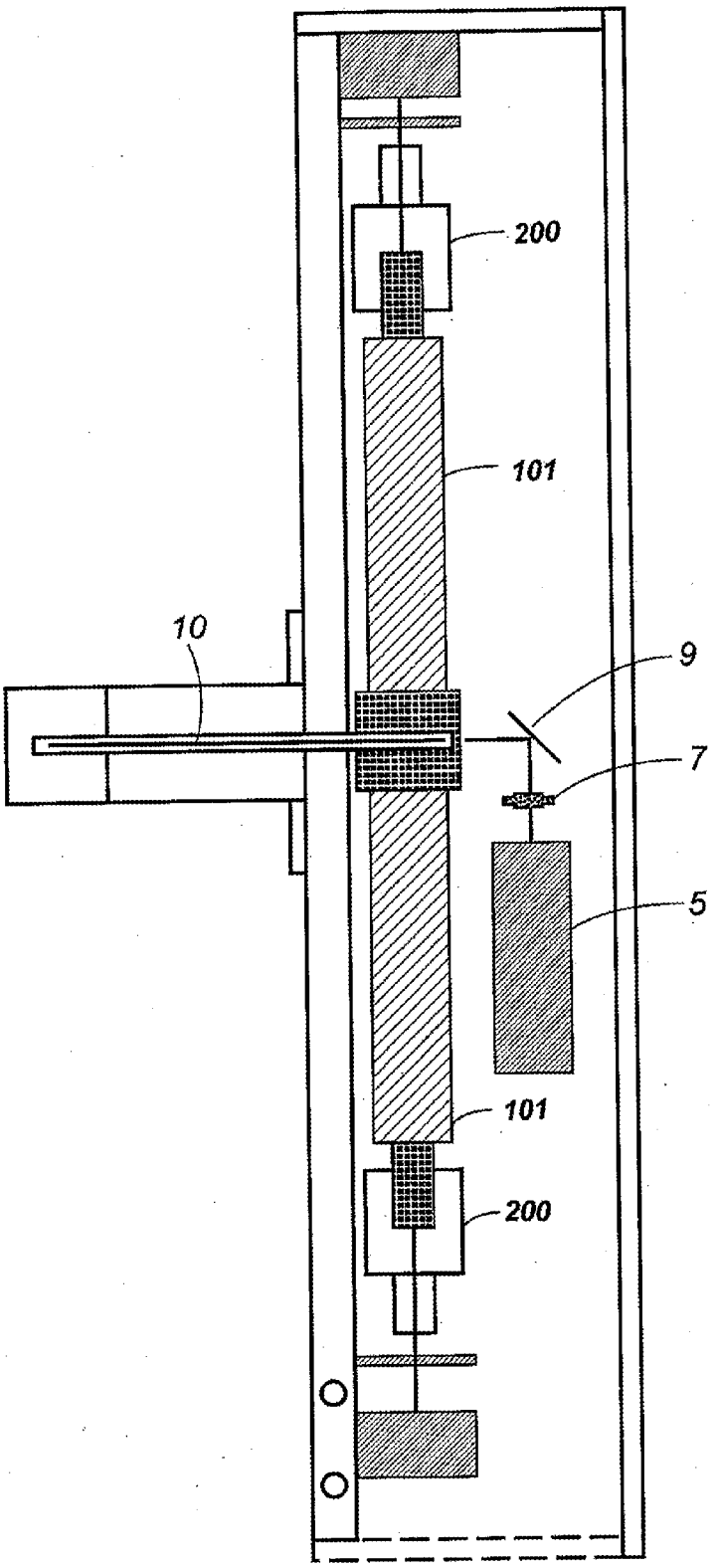

Fig. 3

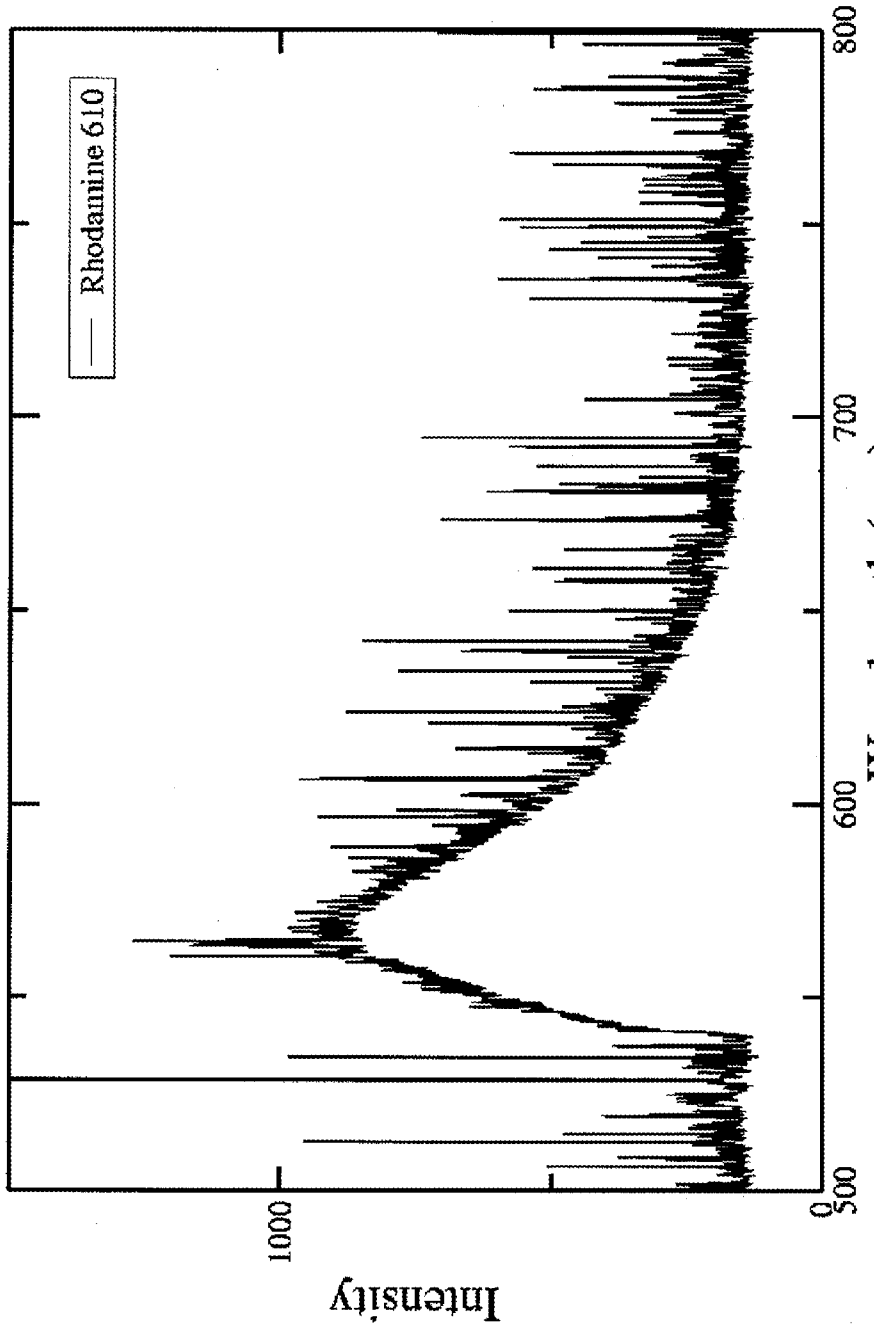
Rhodamine 610
Intensity
0
1000
500
600
700
800
Wavelength (nm)

FIGURE 4

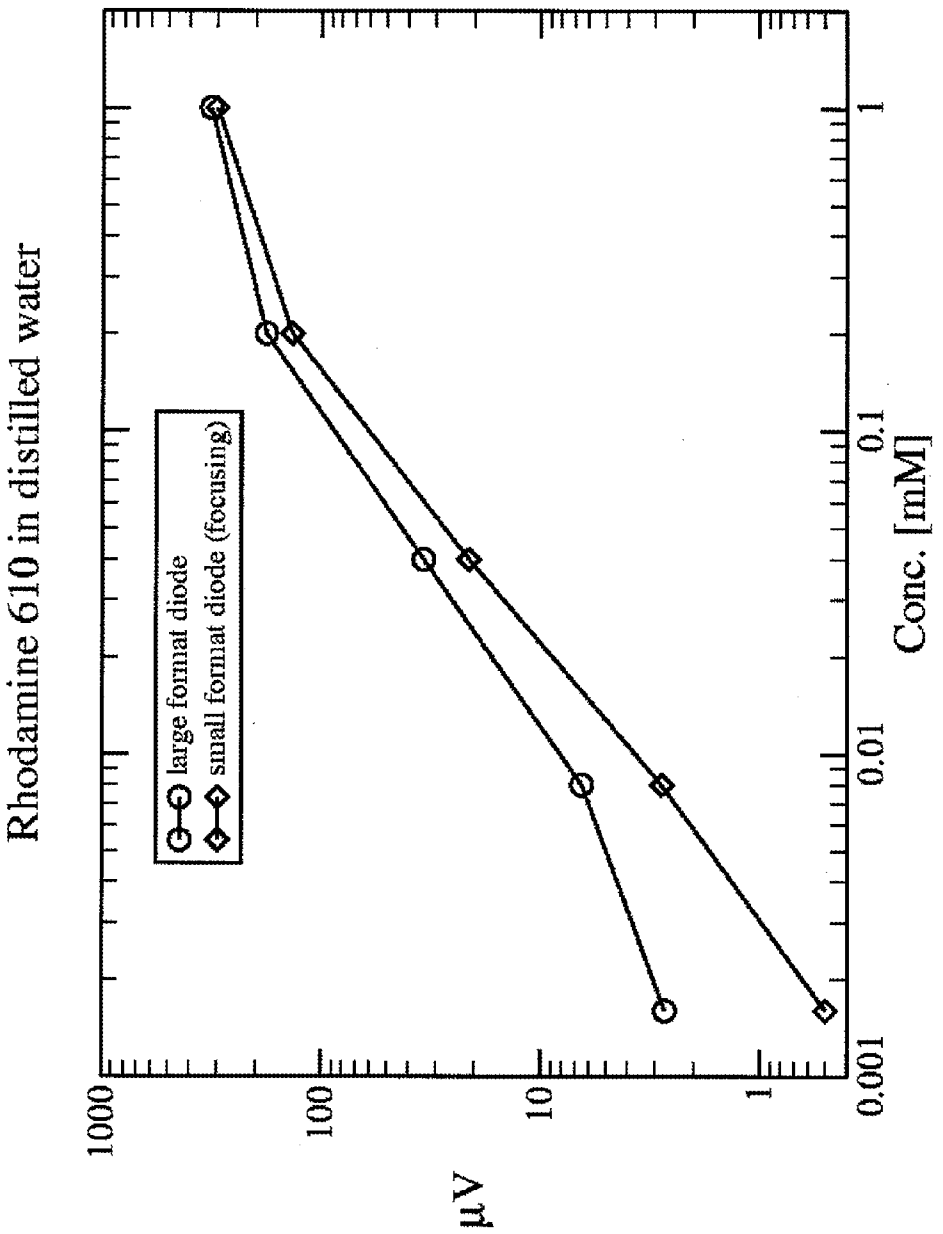
Rhodamine 610 in distilled water
large format diode
small format diode (focusing)
μV
1000
100
10
1
0.001
0.01
0.1
1
Conc. [mM]

FIGURE 5

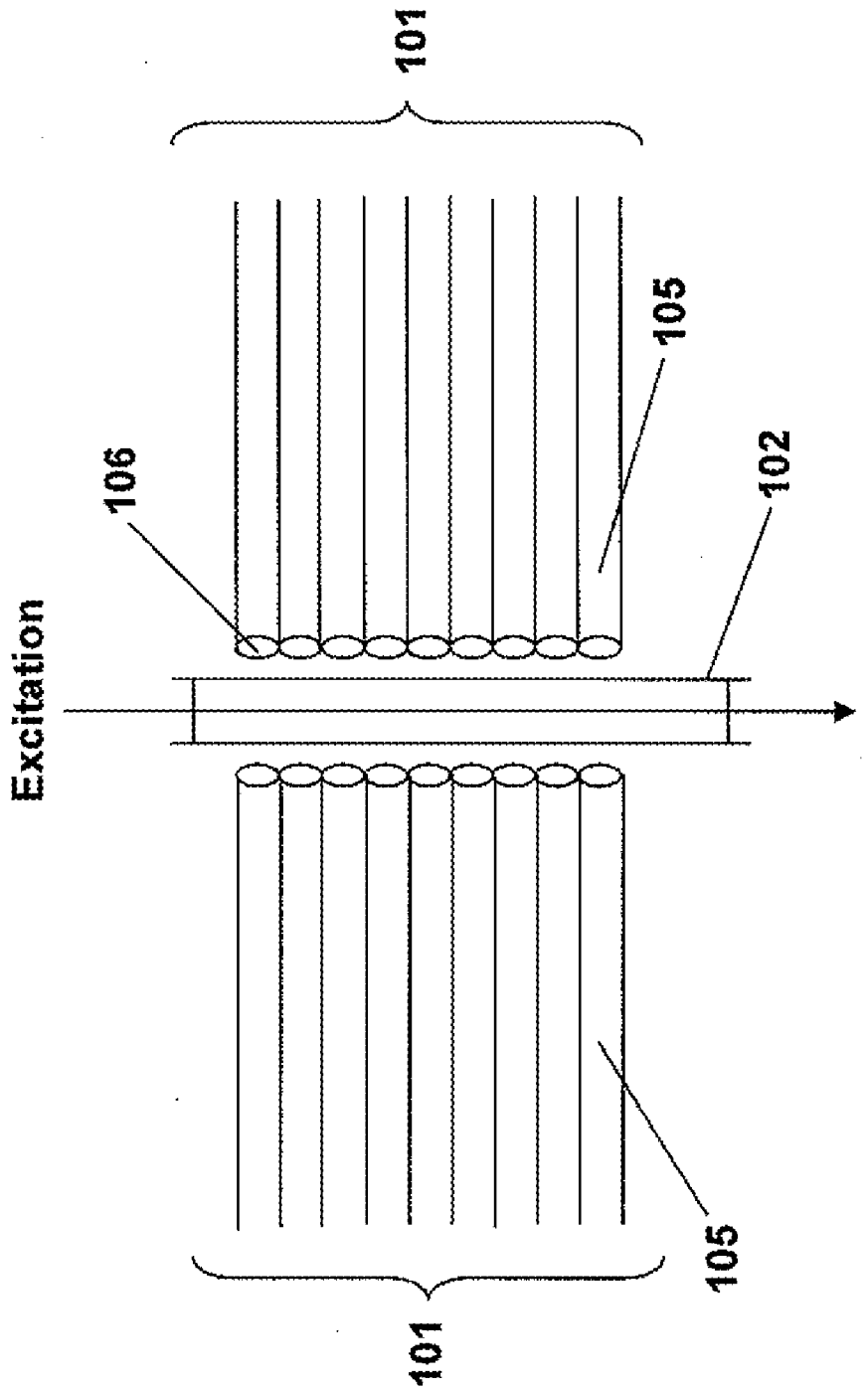

FIGURE 6

FIBER OPTICAL ASSEMBLY FOR FLUORESCENCE SPECTROMETRY

REFERENCE TO PRIOR APPLICATION

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 11/634,546, filed Dec. 5, 2006, which in turn claims the benefit of U.S. Provisional Application No. 60/748,523, filed Dec. 7, 2005.

STATEMENT REGARDING FEDERAL RIGHTS

[0002] This invention was made with government support under Contract No. DE-AC 52-06 NA **25396**, awarded by the U.S. Department of Energy. The government has certain rights in the invention.

BACKGROUND OF INVENTION

[0003] The present invention relates generally to an apparatus and method for improved optical geometry for enhancement of fluorescence and spectroscopic detection in fluids. More particularly, the invention relates to an apparatus and method of fluorescence detection in fluids of marker proteins and analytes.

[0004] The conventional method of performing laser induced fluorescence measurements is to use a small transparent laboratory vessel known as a cuvette to contain the sample to be analyzed. A standard cuvette has dimensions of 1 cm×1 cm and is about 3.5 cm in height and sealed at the bottom. The cuvette is usually made of fused quartz or optical quality borosilicate glass. The cuvette is optically polished and sometimes has an antireflective coating. The cuvette is filled from an upper, open end that is usually equipped with a ground-in glass stopper.

[0005] To perform a measurement, the cuvette is filled with the liquid to be investigated and then illuminated with a laser focused through one of the cuvette's faces. A lens is placed in line with one of the faces of the cuvette located at ninety degrees from the input window to collect the laser-induced fluorescence light. Only a small volume of the cuvette is actually illuminated by the laser. This small volume produces fluorescence once affected by the laser, which is detrimentally reduced by the fact that the lens only picks up approximately ten percent of the fluorescence signal because of solid angle considerations. This is the current state of the art. It has been used for at least seventy-five years; even before the laser existed when conventional light sources were used to excite the fluorescence.

SUMMARY OF INVENTION

[0006] The present invention solves the problem of low collection efficiency as embodiments collect nearly all of the fluorescence light produced from the sample that is analyzed. This is an advance in the state of the art as it increases the amount of fluorescence signal by approximately a factor of ten over conventional apparatus.

[0007] The following describe some non-limiting embodiments of the present invention.

[0008] According to one embodiment of the present invention, a system is provided for analyzing a sample for the presence of an analyte in a sample, the system comprising a sample holder for containing the sample; an excitation source in optical communication with the sample, wherein radiation from the excitation source is directed to the sample, and wherein the radiation induces a fluorescence signal; and at least one linear array comprising a proximal end disposed in proximity to the sample holder and an end port distal from the proximal end; a plurality of optical fibers extending from the proximal end to the end port and having a first end and a second end, wherein the first ends of the individual optical fibers are substantially coplanar and adjacent to one another, and wherein the second ends of the optical fibers form a non-linearly arranged bundle, and wherein the plurality of optical fibers transmits the fluorescent signal from the proximal end to the end port of the linear array; and an end port assembly optically coupled to the end port, the end port assembly comprising a single photo-detector, wherein the photo-detector detects the fluorescent signal and converts the fluorescent signal into an electrical signal.

[0009] According to another embodiment of the present invention, a linear array for detecting a fluorescent signal generated by a sample is provided, comprising a proximal end and an end port distal from the proximal end, wherein the end port is optically polished, and wherein the proximal end is disposed in proximity to the sample; a plurality of optical fibers having a first end and a second end, wherein the first ends are substantially coplanar and adjacent to one another, and wherein the second ends of the optical fibers form a non-linearly arranged bundle which is in contact with the endport, and wherein the optical fibers transmit the fluorescent signal from the sample to the endport; and an end port assembly optically coupled to the optical end port, the end port assembly comprising a single photo-detector, wherein the photo-detector detects the fluorescent signal and converts the fluorescent signal into an electrical signal.

[0010] According to yet another embodiment of the present invention, a method of analyzing a sample for the presence an analyte is provided, the method comprising providing a sample comprising the analyte to a sample holder; disposing a proximal end of at least one linear array in proximity to the sample holder; directing radiation from an excitation source to the sample, wherein the radiation causes the sample to generate a fluorescent signal; receiving the fluorescent signal from the sample at the proximal end; transmitting the fluorescent signal to a photo-detector in the linear array; detecting the fluorescent signal with the photo-detector; converting the fluorescent signal to an electrical signal; and analyzing for the presence of the analyte based on the electrical signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a schematic representation showing one embodiment of the system of the present invention.

[0012] FIG. **2** is a schematic representation showing a four linear array embodiment.

[0013] FIG. **3** is a schematic representation of a side view of a two linear array embodiment showing how a laser is focused into the sample to be analyzed.

[0014] FIG. **4** shows a spectrum of rhodamine 610 in water with Nd:YAG laser excitation at 532 nm.

[0015] FIG. **5** shows a single detector dilution measurement of rhodamine 610 in distilled water.

[0016] FIG. **6** depicts a two linear arrays of the present invention radially disposed in proximity to a sample holder.

DETAILED DESCRIPTION

[0017] Referring to the drawings in general, it will be understood that the illustrations are for the purpose of

describing a particular embodiment of the invention and are not intended to limit the invention thereto.

[0018] The present invention is a spectroscopic—or light gathering—apparatus and corresponding method for rapidly detecting and analyzing analytes in a sample. The sample is irradiated by an excitation source in optical communication with the sample. The excitation source may include, but is not limited to, a laser, a flash lamp, an arc lamp, a light emitting diode, or the like. Irradiation of the sample causes the sample to fluoresce, or emit a fluorescent signal. The fluoresced light correlates to the presence and concentration of the analyte in the sample.

[0019] In one embodiment, the invention is used for detecting and analyzing analytes in either a fluid or a supporting media such as, for example, a gel. When the sample is a fluid, the sample holder may be a thin capillary, which is open at both ends and thus allows the excitation source to pass freely through the sample holder (see FIG. **6**). Examples of such supporting media include agarose or acrylamide gel. In another embodiment, the invention is capable of detecting and analyzing analytes in a self-supporting sample such as; a thin solid, a needle- or whisker-like crystal, or the like. In particular, the present invention may be used to rapidly detect the abnormal form of the prion protein PrP^{sc} (from the normal form, PrPc) in samples of bodily fluids such and blood or urine. PrP^{sc} is the marker protein used in diagnostics for transmissible spongiform encephalopathies, examples of which include bovine spongiform encephalopathy in cattle, scrapie in sheep, and Creuzfeld-Jakob disease in humans. Currently, no rapid means exists for the ante mortem detection of PrP^{sc} in the dilute quantities in which it usually appears in bodily fluids. The present invention has the advantages of requiring little sample preparation, and allowing for electronic diagnostic equipment to be placed outside of the containment area.

[0020] FIG. **1** depicts one embodiment of the system **100** of the present invention. In this embodiment, four linear arrays **101** extend from a sample holder **102**, which houses an elongated, transparent sample container which is open at both ends, to an end port **103**. The distal end of the endport **104** is inserted into an end port assembly **200**. The linear arrays **101** comprise a plurality of optical fibers having a first end and a second end, the plurality of optical fibers optionally surrounded by a protective and/or insulating sheath. The optical fibers are linearly arranged, meaning that they are substantially coplanar with respect to one another so as to form an elongated row of fibers. "Linear array," as used herein, is thus understood to mean that the first ends of the individual fibers are adjacent and substantially coplanar with respect to one another, so as to form a substantially linear arrangement, capable of extending along the length of the capillary (see FIG. **6**). The number of fibers may vary, and in one embodiment is from about 10 to about 100, alternatively is from about 25 to about 75, and alternatively is about 50. The number of linear arrays in a system may vary. The maximum number of linear arrays is dependent upon the size of the sample holder in that the sample holder must be large enough to afford sufficient space for the first ends of the optical fibers to be in proximity to a sample container. Herein, "proximity" is understood to mean a distance of from about 1 mm to about 1 cm between the first ends and the sample holder. In one embodiment, the number of linear arrays is from 2 to 10, alternatively is from about 4 to 6, and alternatively is 4. In one embodiment, the linear arrays are radially disposed about the sample holder, wherein "radially disposed" is understood to mean that the individual arrays (which extend along the length of the sample holder and remain substantially coplanar to one another), extend outward from, and are substantially perpendicular to, the sample holder, similar to elongated spokes on a wheel. "Radially disposed" is not understood to mean that a single array is placed around the circumference of the sample holder. The adjacent linear arrays may be oriented substantially equidistantly from one another and surrounding the sample holder, as shown in FIG. **1**. For example, when the number of linear arrays is two, the linear arrays may be placed on opposing sides of the sample holder. When the number of linear arrays is three, the adjacent linear arrays may be oriented at 120 degree angles with respect to each other; when the number is four, the adjacent linear arrays may be oriented at 90 degree angles with respect to each other, etc.

[0021] The length of the optical fibers within a linear array may vary widely and is dependent upon the number and nature of the optical fibers. The length must be sufficient to allow bundling of the optical fibers from each linear array without compromising the integrity of the optical fibers. In principle, there is no upper limit on the length of the optical fibers, which would allow for a sample to be located remotely from the diagnostic equipment used to analyze the sample. This remote analysis is made possible by the low optical attenuation in the fibers.

[0022] In one embodiment, the second ends of the optical fibers are bundled together to form a single end port (see FIG. **1**, **103**). In other words, a given length of the second ends of the fibers from one or more linear arrays are arranged in a non-linear manner (e.g., in a round or oblong shape) to form a single bundle. If the second ends of multiple linear arrays are bundled, preferably the second ends of the fibers from each linear array are randomly interspersed within the bundle. The bundle comprising the second ends of the optical fibers is then placed in contact, or inserted into, an endport assembly **200**. In one embodiment, the endport assembly **200** comprises a single detector. The plurality of optical fibers receives the signal emitted from the analyte of interest and transmits the signal from the first ends of the fibers to the end port comprising the second ends of the fibers. The fibers have a high numerical aperture (NA), which correlates to sine $\theta/2$, where θ is the angle of accepted incident light (optical acceptance angle). In the present invention, the NA may range from about 0.20 to about 0.25 and the optical acceptance angle of from about 20 degrees to about 45 degrees. The optical acceptance angle is chosen such that substantially all of the emitted signal may be intercepted by the plurality of fibers. This ensures optimum collection efficiency of the signal from dilute analytes, such as PrP^{sc}.

[0023] FIG. **6** depicts linear arrays **101** radially disposed about a sample holder **102**. The first ends **106** of the individual optical fibers **105** are disposed in proximity to the sample holder **102**, are substantially coplanar with respect to one another, and in one embodiment extend substantially perpendicularly outward from the sample holder **102**. The second ends of the optical fibers **105** (not shown) are bundled and inserted into endport **104**.

[0024] In one embodiment, the optical fibers comprise fused silica. The fibers may have a diameter of from about 50 micrometers to about 400 micrometers. The bundling of the optical fibers from each linear array offers several advantages. Rather than separate detectors for each linear array being required, a single detector may be used. For a system

comprising four linear arrays, this results in a detection area having one-quarter the size of four individual detectors. The background noise thus is dramatically decreased, which in turn increases the signal to noise ratio and thus lowers the limit of detection. In one embodiment, the size of the detector is from about 0.5 mm×0.5 mm to about 1 mm×1 mm. The limit of detection of the system of the present invention is at least 0.1 attomole of analyte, alternatively is at least 200 attomole, alternatively is from about 0.1 attomole to about 1.0 micromole, alternatively is from about 0.1 attomole to about 1 nanomole, and alternatively is from about 0.4 to about 1.0 attomole of analyte. Alternatively, the limit of detection of the system is at least 0.1 attogram of analyte, and alternatively is at least 10 attogram of analyte.

[0025] FIG. **2** depicts an alternative embodiment of the present invention, wherein the second ends of the optical fibers are not bundled, but are each connected to a separate detector. In FIG. **2**, each linear array **101** is located in close proximity to sample **10** on one end and is connected to end port assembly **200** at the opposite end. Each linear array **101** is optically polished to form a robust, high quality optical output end port. Thus, the fluoresced signal ("fluorescent signal") that is incident on array **101** from sample **10** is transmitted through the fibers to end port assembly **200**. The optical acceptance angle (related to the numerical aperture) of the optical fibers in arrays **101** are chosen such that essentially the entire fluorescent signal that exits sample **10** is intercepted by the plurality of optical fibers. This ensures optimum collection efficiency of the scarce fluorescence photons from dilute analytes, such as PrP^{sc}, within sample fluids.

[0026] End port assembly **200** is a mounting structure that is designed to hold in alignment with one or more lenses **40**, one or more optical filters **50**, photo-detector **60**, or at least one optically dispersive element. Note that lens **40** is optional, but is used in one particular embodiment to focus the light signal and increase detection efficiency. Filters **50** may be used to reject laser light outside of the detection bandwidth of the sample analyte of interest. Photo-detector **60** may comprise detectors such as, but not limited to: photon detectors, including photo-diode detectors, photo-multipliers, charge-coupled devices, a photon-counting apparatus, optical spectrometers; and the like. In one embodiment, the fluorescent signal is transmitted to a spectroscopic apparatus having a dispersive element that analyzes the sample for the presence of the analyte based upon the spectral signature. Photo-detector **60** may also be optimized for the fluorescence spectral region of interest.

[0027] In one embodiment, multi-spectral analysis of the sample may be achieved by providing a plurality of linear arrays, each having a different type of photo-detector. For example, a first linear array may be coupled to a spectroscopic apparatus, an second linear array may be coupled to a photo-diode detector, a fourth linear array may be coupled to a charge-coupled device, and a fourth linear array coupled to a photomultiplier tube.

[0028] The fluorescent signal that is captured is converted to an electrical signal by photo-detector **60** and transmitted to an analyzer (not shown), which receives the electrical signal and analyses the sample for the presence of the analyte. The analyzer may include a lock-in amplifier, which enables phase sensitive detection of the electrical signal, or any other means known in the art for analyzing electric signals generated by the different types of photo-detectors described herein. The output of the analyzer may take the form of digital data, visual data (such as an oscilloscope trace or strip charts), or the like.

[0029] Referring now to FIG. **3**, radiation emanating from excitation source **5** is focused through lens **7** and directed off reflector **9** into sample fluid **10**. Alternatively, radiation from excitation source may be directed into sample **10** through the optical fibers of at least one linear array **101**. Any energy source that can excite the sample to produce fluorescence or scattered light may be used as excitation source **5**. In the embodiment shown in FIG. **3**, excitation source **5** is a laser that is amplitude modulated or "chopped", so that the resultant fluorescent signal has a known modulation incorporated within. As previously mentioned, excitation source **5** may also be a flash lamp, an arc lamp, a light emitting diode, or the like. The resultant fluorescent signals from all photo-detectors **60** may either be linearly combined for maximum amplitude or, if embodiments of two or more arrays are used, combined in quadrature to reduce common-mode noise. A phase-sensitive detector (sometimes called a "lock-in" detector), gated at the amplitude modulation frequency of excitation source **5** may be employed to further reduce electrical noise by "narrow-banding" around the selected modulation frequency.

[0030] One embodiment of a method of use includes first acquiring a sample of fluid to be investigated. The sample is loaded in a fresh 100 microliter capillary with at least 50 microliters of fluid. The capillary is then inserted into the fiber optical assembly frame, making sure that the filled section of the capillary is within the range of the fiber arrays. Then, the laser is aligned such that the output is focused into the capillary. A "chopper" (square wave amplitude modulator) reference output is then connected to the reference input of a phase sensitive detector (not shown). In this embodiment, each fiber optical array optical output port that is used is equipped with an appropriate optical filter, lens (if appropriate), and photo-detector. Each of the photo-detectors may then be connected. The photo-detectors may be connected in pairs to the quadrature input of the phase sensitive detector for noise reduction. Finally, the fluorescent signal is then measured using the phase sensitive detector.

[0031] The advantages of such a detection array are numerous. Primarily, it permits the use of very small samples at low concentration to be optimally interrogated using the laser-induced fluorescence technique. This fiber based detection system is adaptable to existing short-pulsed detection hardware that was originally developed for sequencing single DNA molecules. The geometry is also amenable to deployment for short pulse laser single molecule detection schemes, as described below. The multi-port geometry of the system allows efficient electronic processing of the signals from each arm of the device. Finally, and perhaps most important, fiber optical cables are essentially 100% efficient in optical transmission, having an attenuation less than 10 db per kilometer). Thus, once deployed for use in a facility, only the capillary assembly needs to be located in the facility, as the fluorescence information can be fiber-optically transmitted to a remote location where data processing and analysis can be performed.

[0032] The following example illustrates the features and advantages of the invention, and are in no way intended to limit the invention thereto.

Example 1

[0033] A large area PIN diode (OSI type 10s-DP/Sb, 11.28 mm diameter active area) detector was initially installed in an

end port assembly with a single lens to pick up the light from the distal end of the fiber optic collector, with a notch filter to eliminate additional 532 nm laser light from a frequency doubled Nd:YAG laser. The performance of this configuration was evaluated, and it was found that the noise was too high for the intended application. The optics were then redesigned to employ basic focusing of the light onto a PIN diode (OSI type 040DP/SB, 0.81 mm diameter active area) having a much smaller area and lower noise.

[0034] The performance of this assembly was directly compared to the original detector using a series of measurements of dilute dye solutions. A rhodamine **610** solution having a concentration of 5 mM was prepared in reagent grade methanol. The solution was then diluted with distilled de-ionized water. Dilution curves were obtained from both detector designs on the same samples using different legs of the O-leg fiber optic (linear array) assembly. FIG. **4** shows the spectrum of one of rhodamine **610** dilutions, obtained with a 30 mW Nd:YAG excitation source and an Ocean Optics spectrometer (Ocean Optics HR2000). The dye produces a broad fluorescence, with a peak near 570 nm. The additional sharp features seen in FIG. **4** are Raman peaks associated with the plastic sample vial. This dye is similar to Texas Red dye.

[0035] The entire fluorescence band was used for dilution measurements, although in final practice an optical band pass filter would be used to minimize interference from protein auto-fluorescence: The detectors were attached to a Stanford Research Systems RS830 DSP lock-in amplifier, and measurements were made in differential mode (common-mode noise rejection, A-B).

[0036] Control measurements were made using distilled, de-ionized water in 100 ml micro-pipettes. These showed no apparent signal (~0.1 mV with no phase-lock on the lock-in amplifier) on the new detector assembly, whereas a small (~5 mV) signal on the large area PIN diode assembly (with defined phase-lock of the signal by the lock-in amplifier) was observed. The latter indicated that a small amount of scattered laser light was leaking past the blocking filter or was at high enough angle of incidence to pass through the filter.

[0037] Samples were prepared by diluting the 5 mM solution of rhodamine **610** in methanol with distilled de-ionized water with five-fold serial dilution. Samples were loaded into 100 ml micro-pipettes and measurements made with each detector on the same sample. The excitation source for these measurements was a 30 mW Nd:YAG laser modulated with a chopper at 115 Hz (Signal Recovery Inc. model 651 chopper). FIG. **5** shows the results of the dilution measurements for comparison of detector performance. The signal from the original large format diode detector is consistently higher, although not by a factor of ten, which is the difference in active area between the two detectors. This indicates that most of the light is being gathered with the newer focusing optics and the small area diode. It also indicates that the small area diode is either being over-filled or some fine focus is needed on the small area detector. Both detectors give low measurements at 1 μM concentration, indicating the sample is optically dense at this concentration. The response is reasonably linear for both detectors down to the 10 μM concentration level, below which the large format detector becomes dominated by scattered light. The small area detector response remains linear down to the 1 μM concentration range.

[0038] Whereas typical embodiments have been set forth for the purpose of illustration, the foregoing description should not be deemed to be a limitation on the scope of the invention. Accordingly, various modifications, adaptations, and alternatives may occur to one skilled in the art without departing from the spirit and scope of the present invention.

1. A system for analyzing a sample for the presence of an analyte in a sample, the system comprising:
- a. a sample holder for containing the sample;
- b. an excitation source in optical communication with the sample, wherein radiation from the excitation source is directed to the sample, and wherein the radiation induces a fluorescence signal; and
- c. at least one linear array comprising:
  - i. a proximal end disposed in proximity to the sample holder and an end port distal from the proximal end;
  - ii. a plurality of optical fibers extending from the proximal end to the end port and having a first end and a second end, wherein the first ends of the individual optical fibers are substantially coplanar and adjacent to one another, and wherein the second ends of the optical fibers form a non-linearly arranged bundle, and wherein the plurality of optical fibers transmits the fluorescent signal from the proximal end to the end port; and
  - iii. an end port assembly optically coupled to the end port, the end port assembly comprising a single photo-detector, wherein the photo-detector detects the fluorescent signal and converts the fluorescent signal into an electrical signal.

2. The system according to claim **1**, further comprising an analyzer electrically coupled to the photo-detector, wherein the analyzer receives the electrical signal from the photo-detector and analyzes the sample for the presence of the analyte based upon the electrical signal.

3. The system according to claim **1**, wherein the linear array comprises from about 10 to about 100 optical fibers.

4. The system according claim **1**, wherein the system comprises at least two linear arrays.

5. The system according to claim **4**, wherein the linear arrays are disposed about the sample holder radially and substantially equidistantly with respect to each other.

6. The system according to claim **1**, wherein the excitation source is a laser.

7. The system according to claim **5**, wherein the laser is amplitude modulated.

8. The system according the claim **2**, wherein the analyzer is a phase-sensitive detector.

9. The system according to claim **1**, wherein the end port assembly further comprises at least one optical filter, wherein the at least one optical filter rejects radiation from the excitation source that is outside a detection bandwith of a predetermined analyte.

10. The system according to claim **1**, wherein the photo-detector is a photo-diode or a photo-multiplier.

11. A linear array for detecting a fluorescent signal generated by a sample, the linear array comprising:
- a. a proximal end and an end port distal from the proximal end, wherein the end port is optically polished, and wherein the proximal end is disposed in proximity to the sample;
- b. a plurality of optical fibers having a first end and a second end, wherein the first ends are substantially coplanar and adjacent to one another, and wherein the second ends of the optical fibers form a non-linearly arranged bundle

which is in contact with the endport, and wherein the optical fibers transmit the fluorescent signal from the sample to the endport; and

c. an end port assembly optically coupled to the end port, the end port assembly comprising a single photo-detector, wherein the photo-detector detects the fluorescent signal and converts the fluorescent signal into an electrical signal.

12. The linear array according to claim **11**, further comprising an analyzer electrically coupled to the photo-detector, wherein the analyzer receives the electrical signal from the photo-detector and analyzes the sample for the presence of the analyte based upon the electrical signal.

13. The linear array according to claim **12**, wherein the analyzer is a phase-sensitive detector.

14. The linear array according to claim **11**, wherein the end port assembly further comprises at least one optical filter, wherein the optical filter rejects radiation from the excitation source that is outside a detection bandwith of a predetermined analyte.

15. The linear array according to claim **11**, wherein the photo-detector is a photo-diode or a photo-multiplier.

16. The linear array according to claim **11**, wherein the linear array comprises from about 10 to about 100 optical fibers.

17. A method of analyzing a sample for the presence an analyte, the method comprising the steps of:

a. providing a sample comprising the analyte to a sample holder;

b. disposing a proximal end of at least one linear array in proximity to the sample holder;

c. directing radiation from an excitation source to the sample, wherein the radiation causes the sample to generate a fluorescent signal;

d. receiving the fluorescent signal from the sample at the proximal end;

e. transmitting the fluorescent signal to a photo-detector in the linear array;

detecting the fluorescent signal with the photo-detector;

g. converting the fluorescent signal to an electrical signal; and

h. analyzing for the presence of the analyte based on the electrical signal.

18. The method according to claim **17**, wherein the linear array comprises a plurality of optical fibers having a first end and a second end, wherein the first ends are substantially coplanar and adjacent to one another.

19. The method according claim **17**, wherein at least two linear arrays are disposed in proximity to the sample holder.

20. The method according to claim **19**, wherein the linear arrays are disposed about the sample holder radially and substantially equidistantly with respect to each other.

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