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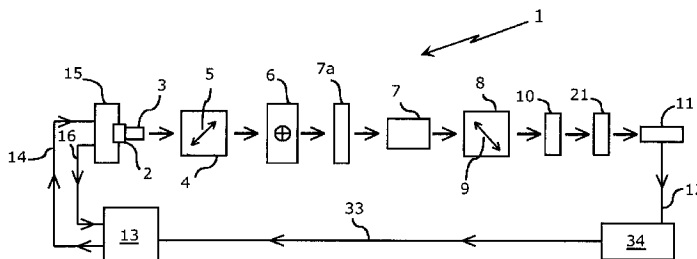


FIG. 1

(57) Abstract: Perioperative patient blood glucose concentrations are determined by imposing patient effluent ultrafiltrate through a sample cell incorporated in an automated polarimeter. The device includes an optical platform, fluid handling subassembly, controlling electronics, and integration software. A stable collimated light source of known intensity and distinct specified wavelength is passed through an optical platform including a polarizer, retarder, bandpass filters, sample flow cell, analyzer and detector. The angular rotation of the transmitted light resulting from the glucose contained in patient ultrafiltrate collected in the sample flow cell is recorded and provides a measure of the glucose concentration.

WO 2013/184584 A1

## AUTOMATED MEASUREMENT METHOD OF CHIRAL ANALYTE CONCENTRATION

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**Related Applications**

This application is related to and claims priority to a provisional application entitled "METHOD AND APPARATUS FOR AUTOMATED MEASUREMENT  
10 OF CHIRAL ANALYTE CONCENTRATION" filed June 5, 2012, and assigned Serial No. 61/655,806.

**Field of the Invention**

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The present invention relates to the measurement of physiological analytes and particularly to automated systems for the measurement of such analytes throughout major surgical procedures and the measurement of such analytes in the care of critically ill patients.

20

**Background of the Invention**

The detrimental effects of elevated perioperative blood glucose have been  
25 reported in a large and growing body of peer-reviewed medical publications. Pre-operative and intraoperative hypoglycemia and hyperglycemia have been reported as independent risk factors for postoperative complications, including infection and

death. In modern surgical suites there are limited space and personnel available for monitoring patient blood analytes, though studies have shown the importance for tightly controlled glucose during cardiothoracic and other major surgical procedures. The current method for monitoring patient blood glucose is to obtain a sample of the patient's blood and have it sent to the hospital lab for analysis, or to a nearby point-of-care laboratory system. These procedures lack sufficient accuracy, take too long, and require that limited staff take time away from critical functions to draw a blood sample, analyze it, or send it off to the hospital's lab for analysis (and wait for results). The time lag between sampling and delivery of results is detrimental to optimum blood glucose management.

The "Portland Protocol" (Furnary 2004), where insulin is continuously provided to the patient during open heart surgical procedures, was developed to keep blood glucose from rising above 180mg/dL, but does not address hypoglycemic (low blood glucose) conditions that lead to other postoperative complications. Tight glucose control, targeting concentrations between 80-120mg/dL has been shown in published studies to reduce postoperative complications. These complications include mediastinitis or deep sternal wound infection, loss of mental acuity, respiratory infections, and death. Reduced mortality, reduced morbidity, lower incidence of surgical site infections, enhanced long term survival, and reduction in lost mental acuity are benefits of maintaining blood glucose concentrations below 180mg/dL. Of the seventy-five percent of patients that lose some mental acuity during surgery about 50% regain normal function over the next year. Hypoglycemia during surgery has been associated with this loss, and more frequent monitoring of patients before, during, and after surgery

to maintain optimal blood glucose events will provide for faster healing and improved patient outcomes.

There are currently no automated blood glucose monitoring systems utilized  
5 to monitor critically ill patients or perioperatively. Some companies have developed implantable monitors for use in critical care settings, but none for intraoperative monitoring.

Prior art products include an implantable catheter that would be expected to  
10 add complexity to the number of attachment's (IV's, monitors, oxygen, etc.) to the patient. It is used in conjunction with an injectable compound that provides fluorescence in the presence of glucose. Little is known about how this might interact with the hemoconcentrator or heart-lung bypass process, in addition to a lack of measurement precision and sensitivity.

15 Another prior art product provides an implantable sensor that takes readings from interstitial fluid collected via microdialysis and transmits them via RFID to a monitor within five feet of the patient. It has received CE Mark as a Class II A medical device. It has been designed for use in clinical settings by healthcare  
20 professionals, but requires calibration with inaccurate and labor intensive fingerstick or laboratory analysis.

While continuous monitors based on microdialysis technologies for diabetic  
25 patients have been released to market in the United States, they are not stand-alone monitors, and require that the patient calibrate and make adjustments to treatment (insulin injection or medication) based on readings from old inaccurate existing

finger-stick method and monitor, or confirmation readings from clinical laboratory devices.

The current method for measuring glucose during surgery is to draw a blood  
5 sample and send it to the hospital's lab for analysis and wait for results to be  
returned to the surgical suite. Time between testing and receipt of results can be  
more than an hour, and presumably because of this, patient sampling is done at  
least on an hourly basis during cardiothoracic surgeries that last on average about  
six hours, which does not provide sufficiently frequent measurement to permit  
10 timely adjustment of insulin and/or glucose.

Over the past decade, the occurrence of one of the worst postoperative  
complications, namely deep sternal wound infection, has been increasing. Rates  
that used to be 1% or less are now occurring in 2-3% of cases, and in some hospital  
15 systems in more than 4%. The incidence of diabetes, and therefore the number of  
diabetic patients undergoing surgery has increased, pushing mortality, morbidity,  
and hospitals costs upwards.

A variety of clinical procedures have been implemented that have helped  
20 slow the increase in the incidence of deep sternal wound infections, but none has  
addressed it as sufficiently as shown in the clinical studies over the past four years.  
These measures include antibiotic treatments, wound care solutions (platelet rich  
plasma), hand washing, and reduction of surgical personnel moving in and out of  
the surgical suite.

Microdialysis based continuous monitors remain targeted at the much larger consumer monitor market, and have not yet been applied successfully to perioperative monitoring, and continue to be used as ancillary products to track trends as opposed to adjusting or directing treatment, due to their lack of sufficient accuracy and necessary precision.

The prior art includes an injectable product that glows in the presence of glucose, however the results obtained are general in nature and not sufficiently specific to provide guidance in therapeutic treatment. Microdialysis based monitors incorporate a minimally invasive sensor that is implanted in the skin of the patient. Most utilize RFID or Bluetooth technology to transmit measurement data to the monitors, again with high costs and insufficient measurement precision.

The prior art also includes a number of devices that measure blood glucose, none of which has been applied to the specifications or the working environment found in cardiothoracic and other major surgeries, or intensive care units. Most require too much hands-on effort, frequent calibration, implantables, transmission radio frequencies, or other issues that would preclude their providing the required accurate, safe, convenient, and automated real-time measurement system that displays results on-demand.

Conventional methods for relatively crude industrial measurement of chiral analytes (sugars such as glucose) are shown in US Patent No. 3,411,342. This polarimeter consisted of a light source, collimating lens, a primary polarizer to establish a reference point for measurement of optical rotation, a sample cell through which a continuous stream of crude syrup was circulated, and a measuring

circuit that determined the extent of optical rotation caused by the sample through an appropriate output signal. Visible light sources in the 400-700nm wavelength were typical with this type of polarimeter. The minute concentrations of glucose that are present in the human body are far below the sensitivity provided by such  
5 polarimeters.

It is well known that glucose in solution is an optically active material. Due to its molecular structure it will cause the plane of polarization of light to be passing through the solution to be changed. The quantitative relationship between  
10 the amount of polarization rotation, the glucose concentration, and the length of the optical path through which the light travels has been clearly established. This is expressed mathematically as:

$$\Delta\theta = \alpha * L * C$$

15

Where:

$\Delta\theta$  is the polarization change in degrees;

$\alpha$  is the specific rotation constant dependent on the specified glucose type and the wavelength of the light source;

20  $\alpha$  : 56.5 degrees per decimeter per gram per milliliter for  $\alpha$ -d-glucose at a wavelength of 633 nanometers;

L is the path length of the optical path containing the glucose solution in decimeters (dm) where (1 dm: 10cm, or 10 centimeters); and

25

C is the concentration of the glucose solution in grams (g) per 100 milliliters (ml) of solution or g/dL (from "Sugar Analysis" 3rd Edition, Browne & Zerban, John Wiley & Sons, 1941, page 263).

5 For the clinically meaningful glucose concentration of 40 to 400mg/dL (milligrams per deciliter) and a path length of 5cm (centimeters) the observed rotation ranges from about  $0.0112^\circ$  to  $0.11275^\circ$  for a wavelength of 633 nanometers (nm). As the wavelength of the light source is increased the specific rotation decreases, to a value of  $26.3^\circ$  per decimeter per gram per milliliter for  $\alpha$ -d-  
10 glucose at a wavelength of 900 nanometers. At that wavelength the rotation in the above case is reduced to  $0.0052$  and  $0.052^\circ$  respectively.

If the assumption is made that there is about a 10% change in the optical transmission through the 5cm path of a flow cell; then a 5cm path length through  
15 the flow cell should produce about  $0.0042$  to  $0.047^\circ$  of polarization rotation. Thus, a usable system must have a basic sensitivity on the order of about  $0.0042^\circ$  degrees, i.e., 14 arc-second, or 70 microradians, with a 5cm flow cell.

US Patent No. 5,209,231 by Cote, et al., describes a non-invasive glucose  
20 sensor which utilizes a pair of polarizers, a quarter wave plate and a motor driven polarizer which produces a constant amplitude phase modulated beam. This beam is split into two beams, one of which passes through the sample and the other which is employed as a reference. By phase demodulation of the two beams, each incident on a different detector, a measure of glucose concentration in an optical  
25 cell is determined. Measurements are proposed to be made transversely through the eye's anterior chamber. This approach suffers in sensitivity of measurement

(according to the authors) which is probably due to noise problems associated with the motor driven phase modulator as well as other unidentified problems.

"Multispectral Polarimetric Glucose Detection using a Single Pockels Cell",  
5 Optical Engineering, Vol. 33, pp 2746 ( 1994) by King, et al., describes a system which employs a pair of polarizers, a quarter wave plate, and a Pockels cell modulator which are configured as a polarization spectrometer. They employed the output from a lock-in amplifier which is "filtered using a leaky integrator" and then fed back to a compensator circuit which was eventually summed with the  
10 driver oscillator output and then input to the Pockels cell driver to null the AC signal in the system. Again, noise levels in the system represent the major problem in achieving the required sensitivity. The reported data show a scatter that is unacceptable for a working blood glucose sensor.

15 Similarly, Pockels cell modulation has been employed for differential analysis of chiral analytes in flow cells (US Patent No. 5,168,326). By applying oscillating voltage to the Pockels cell, alternating beams of circular and linearly polarized light are produced. Greater sensitivity is achieved through effectively removing noise by subtracting the rotation angles calculated for each of the beams.

20 The analysis techniques for chiral analytes such as glucose have been improved in the area of noise reduction. There are various single beam methods utilizing electronic or optical means to filter noise (as an example, WO 01/06918). Additional methods utilize dual beams either by comparison to a reference cell (US  
25 Patent No. 4,912,059), mixing out of phase sinusoidal signals (US Patent No. 5,477,327), switching between a signal and reference beam (U.S. Patent No.

5,621,528), or using a two frequency laser source with two orthogonal linear polarized waves (US Patent Nos. 5,896,198 and 6,327,037). Glucose measurement is based on ascertaining the change in optical rotation (transmission) from the optical null point.

5

The inventor has developed patented prior art utilizing modulated sources (US6999808, USRE39642, USRE40316, and US6370407) demonstrating methods and devices for precisely extracting signals out of the noise, and provided greater sensitivity and stability than required. The methods therein described suffer from a common problem of cost and complexity that reduce their commercial utility from a practical standpoint.

10

Thus, there remains a need to provide a more practical, cost effective, and accurate automated method for quantifying the change in optical rotation introduced by a chiral analyte, such as glucose, by reducing the noise associated with the measurement and moving away from predictive mathematics in favor of direct measurement.

15

## 20 **Objects of the Invention**

Accordingly, it is an object of the invention to provide a practical, reliable, affordable, and automated apparatus capable of accurately measuring the concentration of an optically active ingredient such as glucose in a sample.

25

It is another object of the invention to provide an automated device capable of accurately measuring the glucose concentration in a blood product acquired from patient blood before, during, and after major surgical procedures (perioperatively) and in critical care settings. During surgery, the device can  
5 monitor directly from ultrafiltrate effluent discharged from the hemoconcentrator without additional invasive measures or attachments to the patient (subject).

It is another object of this invention to provide a new very sensitive, stable, practical, and cost effective polarimeter which has applications in ellipsometry and  
10 in certain types of chemical analysis.

### **Summary of the Invention**

15 The present invention provides an innovative approach to generating and maintaining a very stable and robust monochromatic light source that incorporates a highly controlled level of emitted power intensity through intense and highly precise management of a plurality of electro-optical and thermal machine states. The signal provided from this source is utilized to make direct measurement of  
20 chiral analytes such as glucose without the need for predictive mathematics. Optimal operating conditions, as they relate to the measurement system as a whole, are maintained for each and every one of the mechanical, optical, thermal, and electro-optical components utilized in the system.

25 Briefly described, and in accordance with an embodiment chosen for illustration, the invention provides an automated system and method for measuring

the concentration of an optically active substance, for example glucose, in a measurement cell incorporated in the apparatus, by guiding a beam, preferably of collimated monochromatic light, through a polarizer oriented in a first direction to polarize the light in a first direction, through a retarder, and then through a calibration cell (fluid filled or solid optic), and then through a measurement cell which is intermittently filled with sample ultrafiltrate, calibration standard, or flush solution having no chiral analyte concentration or having a known concentration of chiral analyte, and then through the second polarizer (analyzer) which is oriented in a second direction to polarize the light in a second direction. The beam is then guided from the analyzer to a detector. The optical platform is "aligned" when the polarizer, a retarder, and analyzer are adjusted to minimize the amount of light passing to the detector assembly that may optionally include line filters, focusing lenses, and/or bandpass filters. In preferred embodiments once the platform is aligned an optical bias is imposed on the signal by adjusting the retarder, or either increasing or decreasing the output power of the light source to provide a specified electronic response at the detector. This describes the optical path through which monochromatic light is passed to provide a signal to the detector that is utilized to provide a measure of the optical rotation caused by the chiral analyte(s) that are delivered into the measurement cell. As indicated above the degree of rotation is dependent on the concentration of the chiral analyte, the length of the measured optical path, the wavelength and intensity of the light source, the quality of extinction in the polarizers, and the type of retarder utilized (half-, quarter-wave plate, etc.).

25 In the embodiment chosen for illustration the retarder, preferably a quarter-wave plate, is adjusted to provide a predetermined optical bias at the detector. The

difference between the amount of monochromatic light reaching the detector when a solution of known (or no) optical rotation is in the measurement cell and the amount that reaches the detector when passed through a sample represents the concentration of the glucose in the flow cell.

5

Alternatively, the optics may be adjusted to allow a maximum signal to reach the detector, and the reduction in signal received at the detector will represent the concentration of glucose in the flow cell.

10 The monochromatic light source in one embodiment is a laser diode or light emitting diode assembly with a known wavelength in the visual and near IR range. Applicant's system is presently designed for 635nm. This specific wavelength was utilized to permit "off-the-shelf" optics; however, the system has successfully been operated at 780nm although this range requires safety devices such as interlocks to  
15 protect operators. It was found that 780nm wavelength provided much better transmission, with less rotation, but negligible interference. The light source assembly is equipped with feedback temperature controller to stabilize the light source. The required stability of the monochromatic source received by the detector allows for fluctuations totaling not more than four percent of the range of  
20 response for glucose concentrations from 0mg to 400mg/dL (dynamic range), and preferably an order of magnitude below. As an example for operating parameters with a dynamic range of 240mV the tolerance for baseline fluctuations would be no greater than +/- 5mV.

25 The first polarizer is incorporated in the optical platform in front of the light source and is oriented to provide a specific state of polarized light. As in most

polarimetry and ellipsometry the optical components are selected to match the wavelength of the light source, and the optics have anti-reflective coatings of the same wavelength mounted on their surfaces. The resolution of the degree to which the optical signal can be managed is highly dependent on the extinction ratios of the polarizers. In the preferred embodiment extinction ratios range between 5 1:10,000 and 1:100,000 are obtained. This is described as an optical component through which one part of light in 10,000 to 100,000 of the light is incident on the detector; for a very carefully oriented polarizer and analyzer system the transmission is about 1 part in 100,000. The utilization of a retarder further 10 increases the precision by providing greater resolution of the signal of the basic polarimeter.

Sample ultrafiltrate, flush solution, or calibration standard of a known concentration of chiral analyte are delivered to the flow cell of the above described apparatus (polarimeter) by means of an electronic pump controlled by the device's 15 operating software. The individual bags of aqueous calibration standard and flush solution, gas eliminating valves, check valves, connectors, tubing, ultrafilter, self loading pump heads, waste line, waste reservoir, IV cannulae, and pressure, flow, and bubble sensors may be provided as a disposable unit to be utilized for each 20 patient undergoing surgery or in critical care settings where the apparatus is to be utilized.

### **Brief Description of the Drawings**

25 The present invention may more readily be described by reference to the accompanying drawings in which:

FIG. 1 is a schematic block diagram of an optical platform utilized in the system of the present invention.

5 FIG. 2 is a schematic block diagram of a modified optical platform utilized in the system of the present invention incorporating an automated retarder stage.

FIG. 3 is a schematic representation of the interconnections between subassemblies and components of a preferred embodiment of the invention.  
10

FIG. 4 is a schematic representation of the interconnections between subassemblies and components in an alternative embodiment of the present invention.

15 FIG. 5 is an illustration of the response amplitude of a quarter wave plate utilized as a retarder in the system of the present invention and useful in the description of the operation of the system.

FIG. 6 is a schematic representation of information flow among components  
20 of the system of the present invention to facilitate description of the system operation.

FIG. 7 is a functional flow diagram illustrating the interrelationship of fluid flow, sensors, and corresponding signals to and from the system processor.  
25

FIG. 8 is an illustration of the measurement method utilized in the present system to address the effects of drift in baseline response during the measurement cycle.

5 FIG. 9 is an illustration of a graphical user interface display employed in the system of the present invention showing trending of glucose measurements over time and the present glucose measurement and time.

10 In the drawings, bold lines interconnecting functional blocks indicate fluid connection such as blood, ultrafiltrate, and the like; light lines interconnecting functional blocks indicate electronic/electrical signal transmission.

### **Detailed Description of the Invention**

15

In one embodiment of the proposed device, light from a monochromatic source, such as an LED or laser diode, is collimated and polarized. This light beam is passed through a retarder and subsequently through a high quality optical quartz glass flow cell through which the sample ultrafiltrate, calibration standard or flush solvent are drawn by the device's pump and manifold system. The light emanating from the measurement flow cell is routed through the analyzer, and optionally through a focusing lens and/or bandpass filter of known wavelength, before it is directed onto the detector.

25 Referring to FIG. 1, a monochromatic light source (laser diode or light emitting diode) **2** is shown, the output of which is collimated by an optical

component **3** (if needed) and transmitted to a polarizer **4**. Applicant has found that the utilization of a 10mW, 635nm laser diode having an integrated, internal beam corrected optic is suitable. Double ended arrow **5** indicates the direction of polarization of light passing through polarizer **4**.

5

The resulting linearly polarized light passes through a retarder such as quarter wave or half wave plate **6**. The retarder **6** represents the capability of a quarter wave plate to modify the relative phases and or direction of polarized light to produce elliptically and/or circularly polarized light. The retarder **6** is followed by a calibration cell **7a** that can be a flow cell, fluid filled cell, or solid optical cell providing a known specified signal at the detector. Applicant has found that a suitable solid optical cell is available from Meadowlark<sup>®</sup> or Rudolph Research<sup>®</sup>, or a flow cell from Hellma<sup>®</sup> may be utilized with suitable calibration fluid. The light emanating from the calibration cell **7a** is passed through a measurement cell **7** through which the polarized light from the retarder and calibration cell **7a** passes on the way to the analyzer **8**. The double ended arrow **9** represents the direction of the polarization of light passing through of the analyzer **8**. Light emanating from analyzer **8** passes through focusing lens **10** and/or bandpass filter **21** and is focused onto a suitable detector **11** such as a silicon photodiode which produces an output signal **12** that represents the amount of light that is transmitted through the entire polarimeter. A suitable detector **11** may be obtained from ThorLabs, part No. PD55. For a very carefully oriented polarizer, retarder, and analyzer system, the transmission should be less than 1 part in 100,000 of light incident on the detector.

25

In the embodiment shown in FIG. 1, an optical platform **1** is shown including a collimating component **3** that is incorporated with the light source **2**,

and along with a thermo-electric controller **15** (TEC) to form a light source assembly. Applicant has determined that the thermo-electric controller TEC produced by Wavelength Electronics, part No. WTC3243, is suitable for use in the present invention. The TEC **15** and light source **2** are managed through command  
5 signals **14** from the light source driver/controller **13**, which are generated from feedback signals **12** received by the microprocessor **34** from the detector **11**. A suitable light source driver may be obtained from Wavelength Electronics and designated LDD200-2P 200mA laser driver. The microprocessor **34** sends signals  
10 **33** to the light source driver/controller **13** to precisely control the light source power output. This feedback loop increases or decreases the output power of the emitted light through signals driving the light source **2** in constant power mode to a specified level of electrical response at the detector. The stabilized monochromatic light emitted from the collimated component **3** is linearly polarized as it passes  
15 through the first polarizer **4** and elliptically/circularly polarized as it passes through the retarder **6**. The rotational position of the first polarizer **4**, retarder **6**, and analyzer **8** are adjusted to provide the desired signal at the detector **11** with no chiral fluid in the measurement cell **7** or with chiral fluid having a known concentration of chiral analyte. This then will allow a measurement of the concentration of a chiral molecule (such as glucose) based on the change in the  
20 signal, when the glucose solution replaces the non-chiral fluid in the measurement cell. The optical platform includes the monochromatic light source **2**, collimating element **3** (if needed), first polarizer **4**, retarder **6**, calibration cell **7a**, measurement cell **7**, analyzer **8**, focusing lens **10** (if needed) and/or bandpass filter **21** (if utilized), and finally the detector **11**. The first polarizer **4**, retarder **6**, analyzer **8**  
25 are readily available components and included a high precision polarizer and analyzer from Meadowlark<sup>®</sup> having an extinction ratio of 100,000 with a 635nm

anti-reflective coating. Similarly, the quarter wave plate was provided with a 635nm anti-reflective coating.

5           During the initialization of the instrument, or setup, the retarder **6** and analyzer **8** are removed from the optical path and the first polarizer **4** is rotationally adjusted to provide the maximum signal at the detector **11**. The analyzer **8** is then re-inserted in the optical path and adjusted to provide a minimum signal at the detector **11**. The direction of polarization **9** of the analyzer **8** is perpendicular to  
10 the direction of polarization **5** of the first polarizer **4** (crossed polarizers concept). The retarder **6** is re-installed in the optical path and rotationally adjusted to minimize the intensity to approach extinction of the polarized light at the detector **11**. The analyzer **8** is then adjusted to further minimize the intensity of light at the detector **11** followed by again adjusting the retarder. This process of adjusting the  
15 retarder **6** and analyzer **8** continues until the lowest intensity or extinction is obtained at the detector **11**. Upon recognizing this level of light (known as “extinction”) through the optical components at the detector **11**, the resulting signal now takes into consideration all effects of light absorption, reflection, refraction, and transmission. The initialization procedure includes the alternative inverted  
20 procedure wherein the first adjustment is to obtain a minimum signal at the detector and the subsequent adjustments are made to obtain a maximum signal at the detector. Then the retarder **6** is adjusted to the desired baseline signal (or bias). Alternatively, the system can be adjusted to obtain a desired bias electronically by changing (increasing or decreasing) the power to the light source resulting in the  
25 desired baseline optical response (or bias) at the detector.

Referring to the modification shown in FIG. 2, the retarder **6** (a quarter or half wave plate) is installed in an automated rotatory stage **20** in the optical path between the first polarizer **4** and the measurement cell **7**. Through operating software the rotatory stage **20** is rotated via automation to further extinguish light energy passing through the optical path to the detector **11**. The retarder **6** mounted in rotatory stage **20**, and the analyzer **8** are rotationally positioned (and locked in this "fixed" position) to allow the least amount of light possible to reach the detector **11**. A suitable rotary stage is available from Newport<sup>®</sup> identified as Agilis<sup>®</sup> X-100. This minimizing of transmitted light is referred to as extinction, and is a function of the quality of the optics and the precision of the rotational positioning of the optical components.

Once "extinction" has been achieved, the retarder **6** is repositioned through the proposed device's operating software to provide a known baseline response (or bias) represented by a specified electronic signal at the detector **11**. The retarder **6** is then locked in the position corresponding to the desired response bias. The optical platform is now optically aligned. In this embodiment the limiting factors are the quality of the polarizer **4**, analyzer **8**, and retarder **6**, the precision of the retarder stage **20**, the capability of determining the "position" of the intensity minimum (extinction) at the detector, and the ability of the light source driver/controller **13** to precisely maintain the intensity of the monochromatic light emitted from the light source **2** (that changes due to temperature change in the light source), and for the thermo-electric driver controller for the silicon photodiode detector to maintain the temperature of the detector. As temperature rises, frequency (wavelength) and/or intensity of the emitted light will change, as will the electronic response of the detector. It is imperative that stability of the light source

and detector response be automatically maintained very precisely by the operating software.

In one embodiment, setting and management of the "baseline response" can be addressed with a retarder **6**, that is set in a "fixed" position in its mount **20**. In this iteration the signals **12** from the detector **11** would be received by the processor **34** that sends signals to the light source driver/controller **13** that sends signals to light source **2** to adjust the power output of the light source up or down to very precisely maintain the specified "baseline response" automatically between measurements.

Alternatively, the issue of "baseline" stability is addressed through software that manages and rotates a precision rotatory stage **20** rapidly and precisely through detector response feedback signals **17** received by the rotary stage driver controller **18** that sends command adjustment signals **19** to the rotatory stage **20** to re-establish the programmed baseline (or bias) between measurements.

In either of these alternative embodiments the measurement is then provided by the delta (change) in light energy received by the detector **11** as a function of the concentration of chiral analytes and the "baseline" response, and/or bias that is programmed into the operating software and maintained through automated adjustments. The "baseline" response is now maintained through a feedback loop that compensates for the intensity fluctuations of the light source, electrical "noise", and signal drift inherent in the system as temperatures change.

For calibration, referring to FIGS. 1 and 2, the calibration cell **7a** is imposed in the optical platform **1** at a position between the retarder **6** and measurement cell **7**. The calibration cell **7a** can be a fluid filled optical cell (filled with a known concentration of chiral analyte), flow cell (filled with a known concentration(s) of chiral analyte), or optic capable of imposing rotation to the light passing through it equal to a known concentration of the analyte to be measured (glucose). The light passing through the calibration cell **7a** and the measurement cell **7** filled with distilled water is received at the detector **11** providing an electronic signal equal to a known concentration of chiral analyte (glucose). This method provides a simplified calibration of the device where changes in the optical baseline are always accounted for during and between measurement cycles. The concentration of the chiral analyte (glucose) in the sample will always be relative to the response for the known concentration provided by the calibration cell regardless of potential changes in intensity that may impact the baseline response. As an example, a calibration cell providing rotation equal to 75mg/dl, would provide an X response signal at the detector when distilled water is in the measurement cell, and that signal plus the response signal from the rotation for the sample or standard subsequently added to the measurement cell provides a measured value for the concentration of glucose in the measurement cell. That is, the concentration of glucose in the sample in the measurement cell would be a function of the response from the sample relative to the response from the calibration cell. For example:

Detector signal with calibration cell producing rotation equal to 75mg/dL and DI in measurement cell = X

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Signal produced when sample replaces DI in measurement cell = 250% X

(2.5 - 1) 75mg/dL = 112.5mg/dL concentration of glucose in sample

This method provides an externally manufactured calibration optic or  
5 component that can be imposed in the device for regulatory validation. Through  
this method the internal processor, thermal controller, light source driver, and  
detector feedback loops can be tested for their ability to maintain the system  
baseline response within expected specification limits for a known analyte  
concentration. The accuracy of measurement is then dependent solely on the  
10 system's ability to maintain that baseline response and addresses issues of "drift"  
that may occur during a measurement cycle. This calibration and measurement  
method provides a platform for direct measurement and moves the system away  
from the need for predictive measurements.

15 Referring to FIG. 3, a schematic representation of the interconnections  
among components, including fluid flow systems and electrical signals, for a  
preferred embodiment is shown. The system includes the optical platform **1**, the  
light source driver/controller **13**, fluid handling pump **29** and manifold **31**, sample  
pump manifold **44**, and graphical user interface/display **38** that are managed by the  
20 processor **34**. Blood from the patient or ultrafiltrate from other medical devices,  
such as a hemoconcentrator, dialysis machine, extracorporeal filtration unit  
referred to as the sample source **22**, flows into a an ultrafilter **30**.

In the case where the device is connected directly to a patient as the source  
25 **22**, ultrafiltrate is removed from the patient's blood by the ultrafilter **30** via the  
sample pump manifold **44**, and is directed to the measurement cell **7**. The blood

from the patient (source **22**), minus a small quantity of serum ultrafiltrate may then returned to the patient via the patient return cannula **48**. The system draws the ultrafiltrate through a main fluid manifold **31** being drawn (or pushed) by a pump **29** that fills the sample measurement cell **7** (it should be noted that the pump **29** can be incorporated either ahead of the flow cell to push fluid or after the flow cell to draw fluid through). The ultrafiltrate, flush solution supply **25**, or calibration standard supply **24** is selectively directed through manifold **31** in accordance with the discrete operation selected by the user (and defined in the operating software). On demand, point in time, measurement is made of the analyte concentration in the patient ultrafiltrate through quantifying the rotation of the light energy passing through the optical platform **1** based on the amount of light energy that is captured by the detector **11** (FIG. 1). The system may be utilized in conjunction with the hemoconcentrator in open-heart surgery, extracorporeal filtration devices, hemodialyzers in dialysis and renal replacement therapy, or to be utilized as a stand-alone monitor connected directly to the patient.

Referring to FIG. 4, is a schematic representation of the interconnections between sub-assemblies and components in an alternative embodiment is shown utilizing a rotary stage **20** and rotary stage driver **18** to maintain the response baseline. These include the optical platform **1**, the light source driver/controller **13**, rotatory stage driver/controller **18**, fluid handling pump **29** and main fluid manifold **31**, sample pump manifold **44**, and graphical user interface/display **38** that are managed by the processor **34**.

Blood from a patient undergoing open-heart surgical procedure on bypass (utilizing a heart-lung machine) flows through a hemoconcentrator. Ultrafiltrate

originating at the hemoconcentrator has been removed from the patient's blood and is normally directed to a waste receptacle. The blood flows through the hemoconcentrator and is then directed to the heart-lung machine to be processed prior to being returned to the patient.

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Inserting the present system into this procedure collects the waste ultrafiltrate at the sample source connection **22** and reroutes it through a secondary ultrafilter **30**, and a main fluid manifold **31** being drawn (pushed) by a pump **29** that fills the sample measurement cell **7** selectively with ultrafiltrate, flush solution  
10 supply **25**, or calibration standard supply **24** in accordance with the discrete operation selected by the user (and defined in the operating software).

On demand, point in time, measurement is made of the analyte concentration in the patient waste ultrafiltrate through quantifying the rotation of the light energy  
15 passing through the optical platform **1**, based on the amount of light energy that is captured by the detector **11** (FIGS. 1 and 2).

For the polarizer to make discrete measurements, the status of a number of machine and components must be controlled and managed very precisely. The  
20 subsystems that must operate in precise reproducible unison and accord are the light source **2**, light source thermo-electric temperature controller **15**, light source driver/controller **13**, rotatory stage **20** (if utilized), rotary stage driver **18** (if utilized), detector **11**, graphical user interface **38**, detector thermo-electric temperature controller **63** (if utilized - to be described) and detector  
25 driver/controller **64** (if utilized - to be described), multiple component power

supplies **39**, the sample pump manifold **44**, the main fluid control manifold **31**, main fluid control pump **29**, and the on-board processor **34**.

Measurement is achieved by quantifying the optical rotation of the  
5 monochromatic light passing through chiral analytes such as glucose in solution. In one embodiment of the device, once the optics have been aligned as previously described to "extinction", an optical bias is applied by rotating the retarder **6** until the desired bias is achieved through the detector **11**. In choosing the bias, an initial "slope" or "transmission curve" is plotted as shown in FIG. 5, and the peaks  
10 **42** and extinction points **43** noted. For a quarter wave plate retarder **6** there will be four peaks and extinction points. These peaks **42** and "valleys" **43** correspond to the fast and slow axes of the linearly polarized monochromatic light received from the first polarizer **4**. If a half wave plate is employed as the retarder **6**, there will be only two peaks and precision will be reduced by half.

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FIG. 5 illustrates the four peaks from a quarter wave plate transmission curve. These are shown to illustrate the difference in response amplitude between the fast and slow axis. There are advantages to take measurements on either the upward or downward directed slopes of the fast axis. There will be 90° of rotation  
20 between extinction points **43** in a quarter wave plate, and 180° between these points for a half wave plate. In the preferred embodiment of the device, the bias is set at a preferred position above extinction on the upward slope of the fast axis **41**. The optimum position in the slope provides the greatest linearity and dynamic range of the glucose measurements, though it must be noted that as the amplitude  
25 of the bias increases, there can be a proportional increase in noise. It is important to note that measurements can be taken on the upward or downward slope, with the

most important aspects being dynamic range of the signal and the linearity of response within that range.

The system is driven and managed by appropriate operating software that  
5 monitors and manages the various machine states to maintain the stability of the  
baseline response; draw specified fluids through the device on demand; capture,  
process, and display data, manage calibration functions, and other processes.  
Silicon based photodiode detectors provide a practical and cost effective  
component for capturing response data. Measurement accuracy and sensitivity are  
10 dependent on the stability of light sources and detectors that are temperature  
sensitive, it has been found that the control of temperature and management of  
drivers and controllers for these components by the operating software becomes  
critical.

15 Referring to FIG. 6, once the bias has been selected and set, the system  
software will maintain the intensity of the light source **2** through signals received  
by the light source driver/controller **13** from the processor **34** in response to signals  
**12** sent to said processor **34** by the detector **11**, the end result of which are signals  
**33** sent to the light source driver/controller **13** to adjust the light source power up  
20 or down and initiates signals **14** to the light source temperature controller **15** to  
adjust the temperature of the light source. The processor **34** may at the same time  
be acting on signals **12** received from the detector **11**, and sending signals **67** to the  
detector TEC driver controller **64** to adjust power to the detector TEC **63** to  
manage the temperature of the detector **11**.

In an alternative embodiment using a rotary stage **20**, the processor **34** is at the same time acting on the signals **12** received from the detector **11**, and sending signals **17** to the rotatory stage controller **18** that sends signals to the rotatory stage **20** to rotate clockwise or counter clockwise to realign optically to the set bias, or "baseline" response. The feedback loops between detector, processor, light source driver/controller **13**, and alternatively (or simultaneously) to the rotatory stage controller **18** provide a "baseline" controlling loop, ensuring that measurements are made as a function of the difference between the baseline and the rotation of the light in proportion to the concentration of glucose in the sample flow cell.

10

In a preferred embodiment the thermo-electric temperature controller **63** and controller driver **64** for the detector are managed via signals **67** and **68** provided to and from the system processor **34** and feedback signals **65** and **66** between the controller **63** and controller driver **64**. An inline fluid heater/cooler **71** is imposed in fluid handling system to maintain constant temperature of fluids delivered to the measurement cell as the temperature of the sample affects measurement. The inline fluid heater/cooler **71** is managed through signals **72** from the inline fluid heater/cooler controller **70** that operates in response to signals to **74**, and signals from **73** the processor **34**. The various signals and operating parameters described are built into, and managed by the operating software.

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FIG. 7 is a functional flow diagram illustrating the interrelationship of fluid flow, sensors, and corresponding signals to and from the processor **34**. The patient's ultrafiltrate from the system's ultrafilter **30** (which can be a hemodialyzer, hemoconcentrator, or other appropriately configured ultrafilter) is introduced to the main fluid manifold **31**. The system includes a circulating pump **45**, a vacuum

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pump **46**, patient connector or intravenous draw catheter **47**, an intravenous blood return catheter **48** an ultrafilter **30**, patient pressure/flow sensors (draw and return) **49** and **50**, vacuum line pressure/flow sensor **51**, tubing **55** connecting catheter **47** to ultrafilter **30**, tubing **56** connecting vacuum pump **46** to ultrafilter **30**, and  
5 tubing **57** connecting vacuum pump **46** effluent to the main fluid handling manifold **31**, as well as electronic connections between the pumps, sensors, power source, and main fluid handling manifold to the devices on board processor. In response to the appropriate signal **58** from the processor **34**, the circulating pump **45** is engaged and begins to draw blood from the patient (or ultrafiltrate from other  
10 devices such as heart-lung effluent ultrafiltrate, extracorporeal filtration ultrafiltrate, dialysis ultrafiltrate, etc.).

Blood returning to the patient from the circulating pump **45** can be returned via a secondary intravenous catheter **48** or through existing IV lines entering the  
15 patient. After a predetermined time has passed to allow “priming” of the ultrafilter and patient blood return line, a signal **59** from the processor **34** is sent to the vacuum pump **46** which begins to draw ultrafiltrate from the ultrafilter **30**.

In a preferred embodiment of the device the main fluid handling pump **29**  
20 may serve as the vacuum pump **46** to draw ultrafiltrate from patient blood or outside device effluent. This ultrafiltrate is delivered to the device’s main fluid handling manifold **31** that sends it to the measurement cell **7** in response to signals from the processor **34** during a defined measurement cycle.

25 The patient draw **55** and return **75** lines can be flushed with a saline solution incorporating an anticoagulant. Sensor signals **61** from patient draw, signals **60**

from patient return, and signal **62** from vacuum lines are provided to the processor **34** to maintain appropriate fluid flow without collapsing patient blood vessels, introducing bubbles to patient vascular system, or bubbles to the optical platform, as well as tracking fluid flow to the measurement cell. In the event of blockage or  
5 bubbles the processor would provide signals to disengage or reverse pumps. Signals **58** and **59** are provided to engage and disengage circulating pump **45** and vacuum pump **46** to provide ultrafiltrate samples to the optical platform.

In the preferred embodiment of the device a baseline response is obtained by  
10 measurement through a solution of known (or no) optical rotation which produces known (or no) optical rotation characteristics. Discrete measurements are performed by the system's operating software, and incorporates three measurements for each displayed result (FIG. 8). The system takes a "baseline" reading of a solution of known (or no) optical rotation in the sample measurement  
15 cell 7 (FIG. 3), then a signal from the processor turns on the pump **29** and makes the manifold **31** adjustment for either the patient ultrafiltrate, or the calibration standard (in the event of a calibration run to confirm for example the accuracy of measurements being made or to modify settings to compensate for any variations). The pump **29** then draws fluid (patient ultrafiltrate or calibration standard supply  
20 **24**) into the sample measurement cell 7, where it is allowed to dwell for a short period of time prior to taking readings of the amount of monochromatic light received by the detector. The pump **29** is then re-engaged and the manifold **31** selection set to flush solution supply **25** to flush the sample out of the cell and fill it with flush solution. After the sample measurement cell 7 has been flushed and is  
25 full, the fluid is allowed to "dwell" allowing all bubbles to clear the area where the monochromatic light passes through, and a second "baseline" reading is taken.

Referring to FIG. 8, two baseline readings are taken, and the difference between the average of the two baseline readings, one before sample measure and one after sample measure, and the readings taken for the patient ultrafiltrate or the calibration standard supply **24** provides the measure of the optical response representing the glucose concentration of the solution. This measurement method addresses "drift" in the baseline response during the measurement cycle. The software automatically returns the system to the specified baseline response (or bias) at the beginning of each measurement cycle. Referring to FIG. 8, the measurement method incorporated in the present invention is illustrated for four samples A-D. Baseline measurements are taken before and after each ultrafiltrate or calibration measurement; the before and after baseline measurements are averaged and the glucose concentration of the ultrafiltrate or calibration standard is then determined by reference to the average baseline reading.

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When utilizing an in-line calibration cell **7a**, measurements can alternatively be made as a function of the signal received at the detector **11** based on the rotation of the light passing through the calibration cell when a solution of known (or no) optical rotation **25** measurements are made and the measured response when calibration solution supply **24** or ultrafiltrate samples are in the measurement cell **7**. As an example, the average sample measurement response divided by the average responses for a solution of known (or no) optical rotation before and after the sample measurement provides a percentage from which the calibration concentration can be subtracted to provide the concentration of the sample or standard corrected for "drift", as well as, shifts in emitted light frequency and/or intensity.

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The operating parameters may be entered into the graphical user interface (GUI) 38, which doubles as a display where glucose readings are displayed numerically and graphically as shown in FIG 9. The display illustrated in FIG. 9 shows trending of the glucose measurements over time, and indicates whether or not the readings are within the glucose control levels programmed into the system as set by the medical professionals (between 80mg/dL and 150mg/dL).

It will be apparent to those skilled in the art that many commercial elements and off-the-shelf products are incorporated in the system of the present invention. For example, a variety of microprocessors may be found to be suitable; Applicant has determined that National Instruments microprocessor cRIO-9073 with Digital I/O, Analog I/O and Digital Capture Modules (part Nos. 9219, 9263 and 9474) were satisfactory for use in the present system. The programming of the microprocessor and controllers to perform the appropriate electronic functions, including control and monitoring of the system, is well known to those skilled in the art and need not be described here.

The present invention has been described in terms of selected specific embodiments of the apparatus and method incorporating details to facilitate the understanding of the principles of construction and operation of the invention. Such reference herein to a specific embodiment and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the embodiments chosen for illustration without departing from the spirit and scope of the invention.

**What is Claimed:**

1. Apparatus for measuring the concentration of a chiral analyte in a sample comprising:

- 5 (a) an optical platform having;
- i. a light source of monochromatic light,
  - ii. a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization,
  - 10 iii. a retarder positioned to receive polarized light from said first polarizer,
  - iv. a calibration cell positioned to receive light from said retarder,
  - v. a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral
  - 15 analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder,
  - vi. an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer, and
  - 20 vii. a detector for receiving light from said analyzer and generating an electrical signal proportionate to the light striking the detector,

whereby light from said light source is polarized in said first polarizer and passes through said retarder, calibration cell, measurement cell, and analyzer and strikes

25 said detector to produce an electrical signal proportional to the amount of light received from said analyzer, and

(b) a fluid flow system having:

i. an ultrafilter for receiving fluid having a concentration of chiral analytes to be measured, the output of which yields an ultrafiltrate, and

5 ii. means connecting said ultrafilter to said measurement cell for delivering said ultrafiltrate to said measurement cell,

whereby light from said light source is polarized and directed through said measurement cell containing said ultrafiltrate, through said analyzer to said detector to generate an electrical signal whose magnitude is a representation of the  
10 degree of rotation of polarized light resulting from the polarized light passage through said ultrafiltrate in said measurement cell.

2. The apparatus of Claim 1 wherein said light source comprises a light  
15 source assembly having a monochromatic light source and a thermo-electric controller for stabilizing and/or precision management of the light source temperature.

3. Apparatus for measuring the concentration of a chiral analyte in a sample comprising:

(a) an optical platform having;

5 i. a light source of monochromatic light,

ii. a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization,

iii. a retarder positioned to receive polarized light from said first polarizer,

10 iv. a calibration cell positioned to receive light from said retarder,

v. a measurement cell for selectively receiving distilled water, or a calibration standard fluid having a known concentration of chiral analyte, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder,

15 vi. an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer, and

20 vii. a detector for receiving light from said analyzer and generating an electrical signal proportionate to the light striking the detector,

whereby light from said light source is polarized in said first polarizer and passes through said retarder, calibration cell, measurement cell, and analyzer and strikes said detector to produce an electrical signal proportional to the amount of light received from said analyzer, and

- (b) a fluid flow system having;
- i. an ultrafilter for receiving fluid having a concentration of chiral analytes to be measured, the output of which yields an ultrafiltrate,
  - 5 ii. a flush solution supply,
  - iii. a calibration standard supply, and
  - iv. a manifold connected to receive said ultrafiltrate, flush solution, and calibration standard to selectively connect said ultrafiltrate, flush solution, or calibration standard to the measurement
  - 10 cell of the optical platform,

whereby light from said light source is polarized and directed through said calibration cell, and through the measurement cell containing said ultrafiltrate and whereby the light passing through the ultrafiltrate is directed to said analyzer and strikes said detector to generate an electrical signal whose magnitude is a

15 representation of the degree of rotation of the polarized light resulting from the polarized light passage through said measurement cell.

4. The apparatus of Claim 3 wherein said retarder is a quarter wave plate.

5 5. The apparatus of Claim 3 wherein said calibration cell is a flow cell or fluid fill cell containing a fluid of known chiral analyte concentration.

6. The apparatus of Claim 3 wherein said calibration cell is a solid optical cell capable of imposing rotation to light passing therethrough equal to a  
10 known concentration of a chiral analyte.

7. The apparatus of Claim 3 wherein said light source comprises a light source assembly having a monochromatic light source and a thermo-electric controller for stabilizing the light source temperature.

8. In an apparatus for measuring the concentration of a chiral analyte in a sample, an optical platform comprising:

(a) a light source of monochromatic light;

5 (b) a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization;

(c) a retarder positioned to receive polarized light from said first polarizer;

(d) a calibration cell positioned to receive light from said retarder;

10 (e) a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder;

(f) an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer; and

(g) a detector for receiving light from said analyzer and generating an electrical signal proportional to the light striking the detector, whereby light from said light source is polarized in said first polarizer, passes through said retarder, calibration cell, measurement cell and analyzer and strikes said detector to produce an electrical signal proportional to the amount of light received from said analyzer.

9. The optical platform of Claim 8 wherein said retarder is a quarter wave plate.

5 10. The optical platform of Claim 8 wherein said calibration cell is a flow cell or fluid filled cell containing a fluid of known chiral analyte concentration.

11. The optical platform of Claim 8 wherein said calibration cell is a solid optical cell capable of imposing rotation to light passing therethrough equal to a  
10 known concentration of a chiral analyte.

12. The optical platform of Claim 8 wherein said light source comprises a light source assembly having a monochromatic light source and a thermo-electric controller for stabilizing and/or precision management of the light source  
15 temperature.

13. Apparatus for measuring the concentration of a chiral analyte in a sample comprising:

(a) an optical platform having;

i. a light source assembly having a monochromatic light source and a thermo-electric controller stabilizing and/or precision management of the light source temperature,

ii. a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization,

iii. a retarder positioned to receive polarized light from said first polarizer,

iv. a calibration cell positioned to receive light from said retarder,

v. a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder,

vi. an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer,

vii. a detector for receiving light from said analyzer and generating an electrical signal proportionate to the light striking the detector,

viii. a light source driver, and

ix. a feedback loop connected to said detector and to said light source driver and including a micro-processor to increase or decrease the output power of emitted light from said light source to

maintain a constant emitted power/intensity to a specified level of electrical response at said detector,

whereby light from said light source is polarized in said first polarizer and passes through said retarder, calibration cell, measurement cell, and analyzer and strikes  
5 said detector to produce an electrical signal proportional to the amount of light received from said analyzer, and

(b) a fluid flow system having:

i. an ultrafilter for receiving fluid having a concentration of chiral analytes to be measured, the output of which yields an  
10 ultrafiltrate, and

ii. means connecting said ultrafilter to said measurement cell for delivering said ultrafiltrate to said measurement cell,

whereby light from said light source is polarized and directed through said measurement cell containing said ultrafiltrate, through said analyzer to said  
15 detector to generate an electrical signal whose magnitude is a representation of the degree of rotation of polarized light resulting from the polarized light passage through said ultrafiltrate in said measurement cell.

14. Apparatus for measuring the concentration of a chiral analyte in a sample comprising:

(a) an optical platform having;

i. a light source assembly having a monochromatic light source and a thermo-electric controller for stabilizing and/or precision management of the light source temperature ,

ii. a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization,

iii. a retarder positioned to receive polarized light from said first polarizer,

iv. a calibration cell positioned to receive light from said retarder,

v. a measurement cell for selectively receiving distilled water, or a calibration standard fluid having a known concentration of chiral analyte, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder,

vi. an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer,

vii. a detector for receiving light from said analyzer and generating an electrical signal proportionate to the light striking the detector,

viii. a light source driver, and

ix. a feedback loop connected to said detector and to said light source driver and including a microprocessor to increase or

decrease the output power/intensity of emitted light from said light source to maintain a constant power mode to a specified level of electrical response at said detector,

whereby light from said light source is polarized in said first polarizer and passes through said retarder, calibration cell, measurement cell, and analyzer and strikes said detector to produce an electrical signal proportional to the amount of light received from said analyzer, and

(b) a fluid flow system having;

i. an ultrafilter for receiving fluid having a concentration of chiral analytes to be measured, the output of which yields an ultrafiltrate,

ii. a flush solution supply,

iii. a calibration standard supply, and

iv. a manifold connected to receive said ultrafiltrate, flush solution, and calibration standard to selectively connect said ultrafiltrate, flush solution, or calibration standard to the measurement cell of the optical platform,

whereby light from said light source is polarized and directed through said calibration cell, and through the measurement cell containing said ultrafiltrate and whereby the light passing through the ultrafiltrate is directed to said analyzer and strikes said detector to generate an electrical signal whose magnitude is a representation of the degree of rotation of the polarized light resulting from the polarized light passage through said measurement cell.

15. In an apparatus for measuring the concentration of a physiological chiral analyte having an optical platform including a measurement cell for receiving a fluid having a chiral analyte concentration to be measured, a fluid system comprising:

- 5           (a) an ultrafilter for receiving fluid having a concentration of chiral analytes to be measured, the output of which yields an ultrafiltrate; and
- (b) means connecting said ultrafiltrate to said measurement cell for delivering said ultrafiltrate to said measurement cell;

whereby light from said light source is polarized and directed through said measurement cell containing said ultrafiltrate, through said analyzer to said detector to generate an electrical signal whose magnitude is a representation of the degree of rotation of polarized light resulting from the polarized light's passage through said ultrafiltrate in said measurement cell.

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16. In an apparatus for measuring the concentration of a physiological chiral analyte having an optical platform including a measurement cell for receiving a fluid having a chiral analyte concentration to be measured, a fluid flow system comprising:

(a) an ultrafilter for receiving fluid having a concentration of chiral analyte to be measured, the output of which yields an ultrafiltrate;

(b) a flush solution supply;

(c) a calibration standard supply; and

(d) a manifold connected to receive said ultrafiltrate, flush solution, and calibration standard to selectively connect said ultrafiltrate flush solution or calibration standard to the measurement cell of the optical platform;

whereby light from said light source is polarized and directed through said calibration cell, and through the measurement cell containing said ultrafiltrate and

whereby light passing through the ultrafiltrate is directed to said analyzer and strikes said detector to generate an electrical signal whose magnitude is a representation of the degree of rotation of the polarized light resulting from the polarized light's passage through said measurement cell.

17. A method for measuring the concentration of a chiral analyte in a sample comprising:

(a) directing a beam of monochromatic light through a first polarizer having a direction of polarization;

5 (b) directing light emanating from said first polarizer through a retarder;

(c) directing light emanating from said retarder through a calibration cell;

10 (d) directing light emanating from said calibration cell through a measurement cell containing sample fluid having a concentration of chiral analyte to be measured;

(e) directing light from said measurement cell through an analyzer having a direction of polarization perpendicular to the direction of polarization of said first polarizer; and

15 (f) directing light emanating from said analyzer to a detector to produce an output signal corresponding to the amount of light received by the detector.

18. The method of Claim 17 including:

(a) providing a flush solution in said measurement cell having no or a known concentration of chiral analyte;

5 (b) adjusting said retarder and analyzer to obtain a minimum output signal from said detector;

(c) replacing the solution in the measurement cell with a sample fluid containing a chiral analyte to be measured; and

10 (d) repeating steps (a) - (c) and measuring the output signal from the detector corresponding to the amount of light received by the detector with the sample fluid in the measurement cell.

19. A method for measuring the concentration of a chiral analyte in a sample comprising:

- 5 (a) directing a beam of monochromatic light through a first polarizer having a direction of polarization;
- (b) directing light emanating from said first polarizer through a retarder;
- (c) directing light emanating from said retarder through a calibration cell;
- 10 (d) directing light emanating from said calibration cell through a measurement cell;
- (e) directing light emanating from said measurement cell through an analyzer having a direction of polarization perpendicular to the direction of polarization of said first polarizer;
- 15 (f) directing the beam from the analyzer to a detector to produce an output signal corresponding to the amount of light received by the detector;
- (g) placing a flush solution having no or a known concentration of chiral analyte in said measurement cell and noting the output signal from the detector;
- 20 (h) replacing the flush solution in said measurement cell with a sample fluid containing a concentration of chiral analyte to be measured; and
- (i) measuring the difference in the output signal of the detector between the signal derived with the flush solution in the calibration cell and sample fluid in the calibration cell.

20. A method for measuring the concentration of a chiral analyte in a sample comprising:

- (a) directing a beam of monochromatic light from said light source through said first polarizer having a direction of polarization;
- 5 (b) directing light emanating from said first polarizer through a retarder;
- (c) directing light from said retarder to a calibration cell chosen to produce a known output signal at a detector;
- (d) directing light emanating from said calibration cell through a  
10 measurement cell;
- (e) directing light from said measurement cell through an analyzer having a direction of polarization perpendicular to the direction of polarization of said first polarizer;
- (f) directing the beam of light from the analyzer to a detector to  
15 produce an output signal corresponding to the amount of light received by the detector;
- (g) repeating steps (a) - (f) with the measurement cell containing a flush solution having no or a known concentration of chiral analyte and, repeating steps (a) - (f) with the measurement cell filled with a sample fluid  
20 containing a concentration of chiral analyte to be measured; and
- (h) comparing the output signal corresponding to the signal received when the flush solution is in the measurement cell to the output signal when the measurement cell is filled with a sample fluid containing a concentration of chiral analyte to be measured.

21. A method for initializing apparatus for measuring the concentration of a chiral analyte, the apparatus including an optical platform having an optical path and having the following elements positioned in said optical path:

- (a) a light source of monochromatic light;
  - 5 (b) a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization;
  - (c) a retarder positioned to receive polarized light from said first polarizer;
  - (d) a calibration cell positioned to receive light from said retarder;
  - 10 (e) a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder;
  - (f) an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer; and
  - 15 (g) a detector for receiving light from said analyzer and generating an electrical signal proportional to the light striking the detector;
- the method comprising:
- 20 (h) directing a beam of monochromatic light from said light source through said first polarizer, retarder, calibration cell, measurement cell, analyzer, onto said detector;
  - (i) removing said analyzer and retarder from said optical light path;
  - 25 (j) rotationally adjusting said first polarizer to provide a maximum signal at said detector;

(k) reinstalling said analyzer;

(l) adjusting said analyzer to provide a minimum signal at said detector;

(m) reinstalling said retarder in said optical path;

5 (n) rotationally adjusting said retarder to further minimize the intensity of polarized light at said detector;

(o) repeating steps (l) and (n) until the lowest intensity or extinction is obtained at the detector; and

10 (p) adjusting the retarder to a determined baseline to provide a bias signal at said detector.

22. A method for initializing apparatus for measuring the concentration of a chiral analyte, the apparatus including an optical platform having an optical path and having the following elements positioned in said optical path:

- 5 (a) a light source producing a beam of monochromatic light having a given intensity;
- (b) a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization;
- (c) a retarder positioned to receive polarized light from said first polarizer;
- 10 (d) a calibration cell positioned to receive light from said retarder;
- (e) a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder;
- 15 (f) an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer; and
- (g) a detector for receiving light from said analyzer and generating an electrical signal proportional to the light striking the detector;
- 20 the method comprising:
  - (h) directing a beam of monochromatic light from said light source through said first polarizer, retarder, calibration cell, measurement cell, analyzer, onto said detector;
  - (i) removing said analyzer and retarder from said optical light
  - 25 path;

- (j) rotationally adjusting said first polarizer to provide a maximum signal at said detector;
- (k) reinstalling said analyzer;
- (l) adjusting said analyzer to provide a minimum signal at said  
5 detector;
- (m) reinstalling said retarder in said optical path;
- (n) rotationally adjusting said retarder to minimize the intensity of polarized light at said detector;
- (o) repeating steps (l) and (n) until the lowest intensity or  
10 extinction is obtained at the detector; and
- (p) adjusting the light source intensity to provide a baseline or bias signal level at said detector.

23. A method for initializing apparatus for measuring the concentration of a chiral analyte, the apparatus including an optical platform having an optical path and having the following elements positioned in said optical path:

- (a) a light source of monochromatic light;
  - 5 (b) a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization;
  - (c) a retarder positioned to receive polarized light from said first polarizer;
  - (d) a calibration cell positioned to receive light from said retarder;
  - 10 (e) a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder;
  - (f) an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer; and
  - 15 (g) a detector for receiving light from said analyzer and generating an electrical signal proportional to the light striking the detector;
- the method comprising:
- 20 (h) directing a beam of monochromatic light from said light source through said first polarizer, retarder, calibration cell, measurement cell, analyzer, onto said detector;
  - (i) removing said analyzer and retarder from said optical light path;
  - 25 (j) rotationally adjusting said first polarizer to provide a minimum signal at said detector;

(k) reinstalling said analyzer;

(l) adjusting said analyzer to provide a maximum signal at said detector;

(m) reinstalling said retarder in said optical path;

5 (n) rotationally adjusting said retarder to further maximize the intensity of polarized light at said detector;

(o) repeating steps (l) and (n) until the highest intensity is obtained at the detector; and

10 (p) adjusting the retarder to a determined baseline to provide a bias signal at said detector.

24. A method for initializing apparatus for measuring the concentration of a chiral analyte, the apparatus including an optical platform having an optical path and having the following elements positioned in said optical path:

- 5 (a) a light source producing a beam of monochromatic light having a given intensity;
- (b) a first polarizer positioned to receive monochromatic light from said light source and having a direction of polarization;
- (c) a retarder positioned to receive polarized light from said first polarizer;
- 10 (d) a calibration cell positioned to receive light from said retarder;
- (e) a measurement cell for selectively receiving a flush solution, distilled water, or a solution whose concentration of chiral analytes are to be measured, said measurement cell positioned to receive polarized light from said retarder;
- 15 (f) an analyzer positioned to receive light from said measurement cell and having a direction of polarization perpendicular to the polarization of said first polarizer; and
- (g) a detector for receiving light from said analyzer and generating an electrical signal proportional to the light striking the detector;
- 20 the method comprising:
  - (h) directing a beam of monochromatic light from said light source through said first polarizer, retarder, calibration cell, measurement cell, analyzer, onto said detector;
  - (i) removing said analyzer and retarder from said optical light
  - 25 path;

(j) rotationally adjusting said first polarizer to provide a minimum signal at said detector;

(k) reinstalling said analyzer;

5 (l) adjusting said analyzer to provide a maximum signal at said detector;

(m) reinstalling said retarder in said optical path;

(n) rotationally adjusting said retarder to maximize the intensity of polarized light at said detector;

10 (o) repeating steps (l) and (n) until the highest intensity is obtained at the detector; and

(p) adjusting the light source intensity to provide a baseline or bias signal level at said detector.

25. A method for measuring the concentration of a chiral analyte in a sample comprising:

- (a) directing a beam of monochromatic light through a first polarizer having a direction of polarization;
- 5 (b) directing light emanating from said first polarizer through a retarder;
- (c) directing light emanating from said retarder through a calibration cell;
- (d) directing light emanating from said calibration cell through a measurement cell containing a solution producing a known optical rotation;
- 10 (e) replace the solution in the measurement cell with a sample fluid whose chiral analyte concentration is to be determined;
- (f) repeat steps (a) through (c);
- (g) replace the solution in the measurement cell with a solution producing a known optical rotation;
- 15 (h) repeat steps (a) through (c);
- (i) average the value of the output signals from said detector corresponding to the two readings of output signals derived when the measurement cell contained the solution of known optical rotation to arrive at an average bias level; and
- 20 (j) compare said average bias level with the level of the signal when the measurement cell contains said sample fluid whose chiral analyte concentration is to be determined.

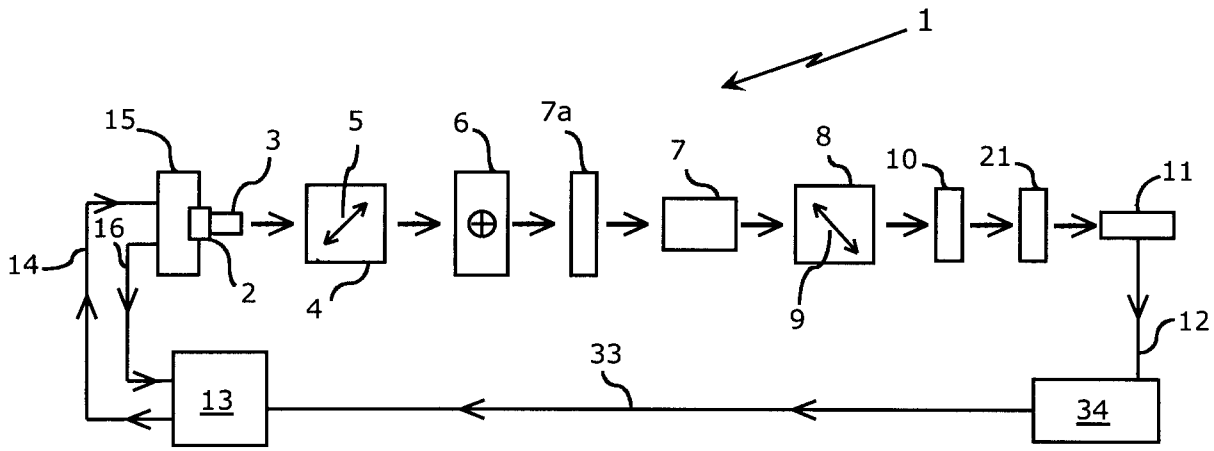


FIG. 1

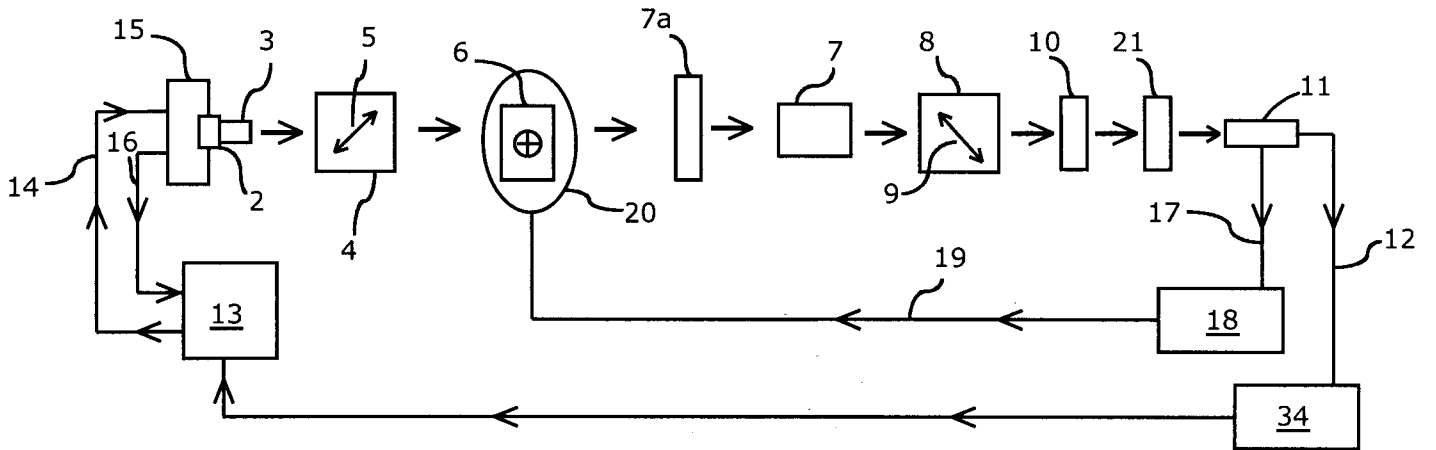


FIG. 2

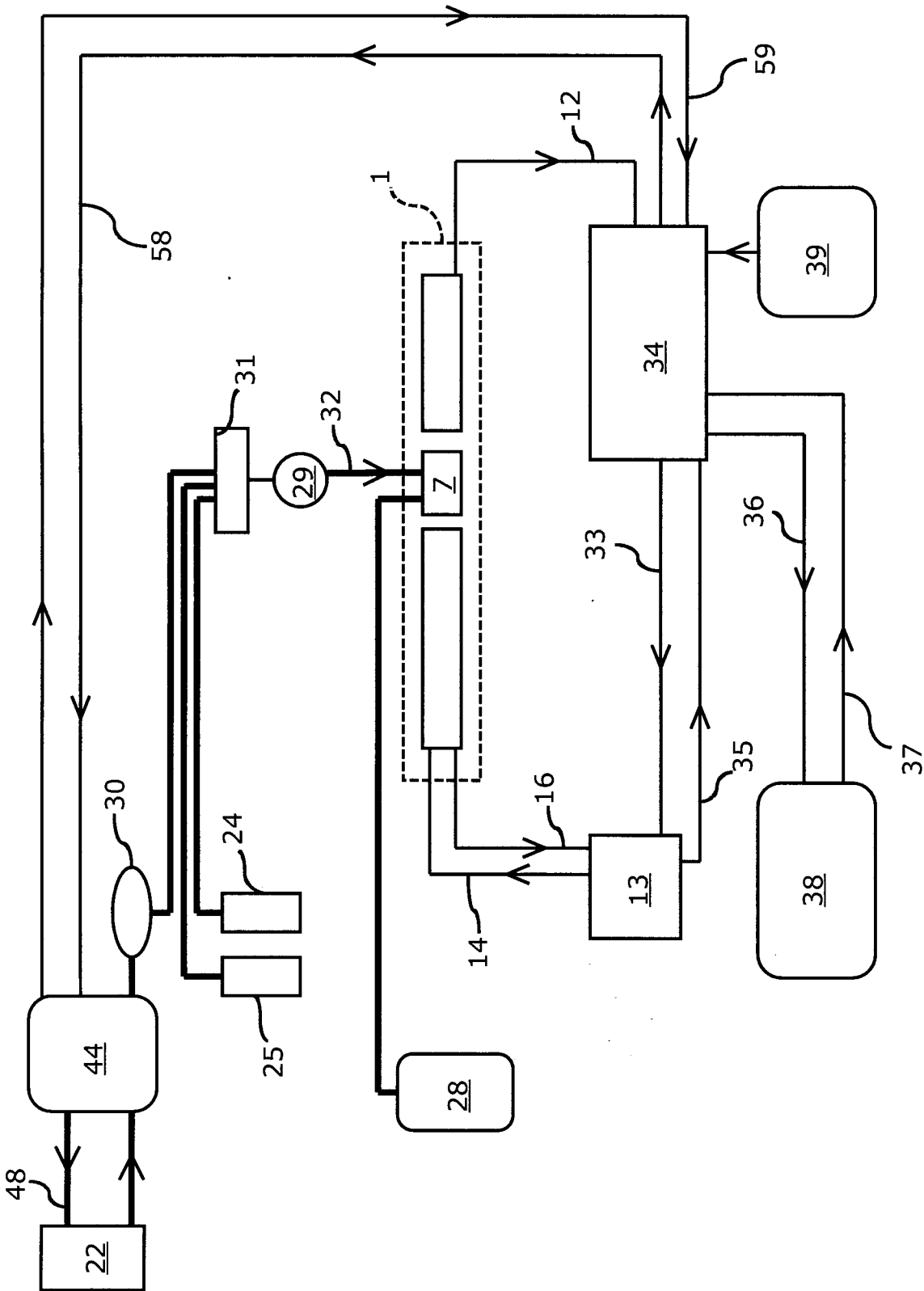


FIG. 3

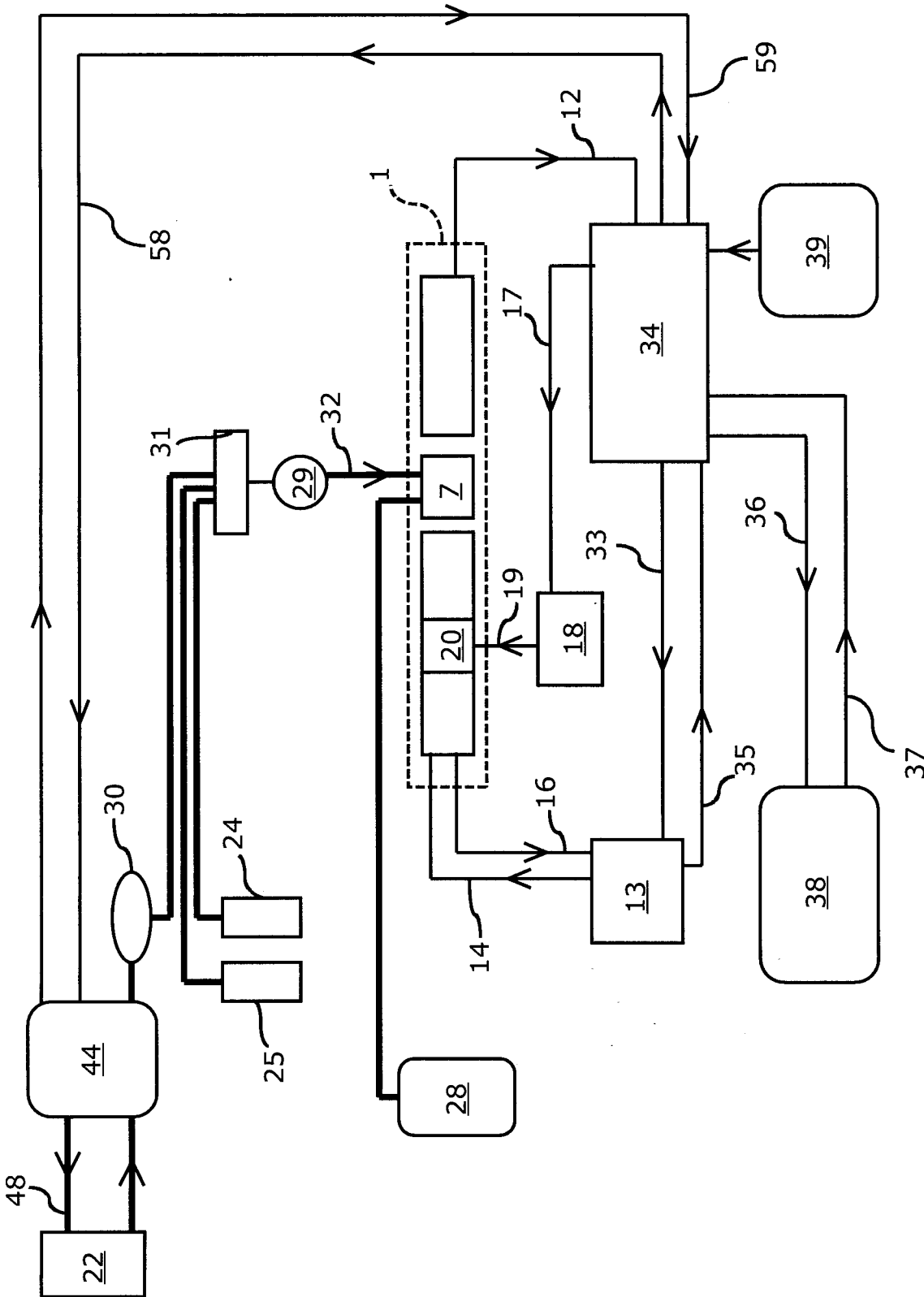


FIG. 4

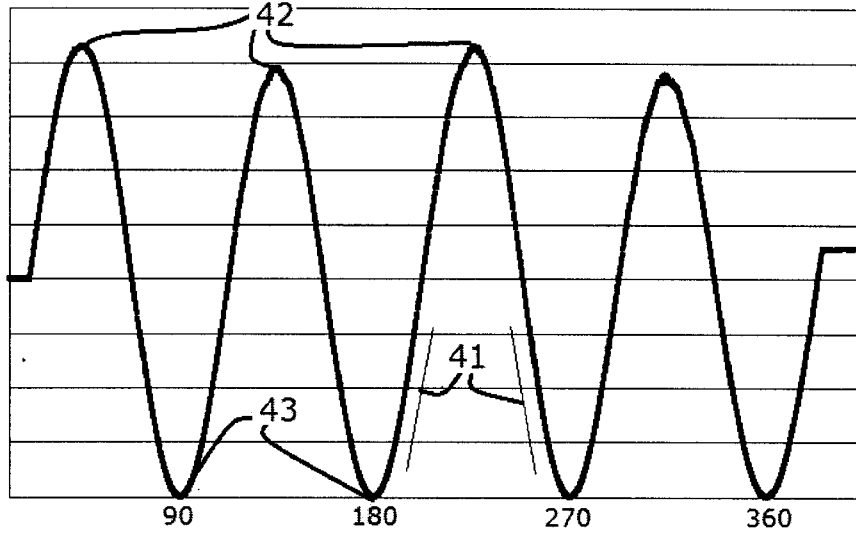


FIG. 5

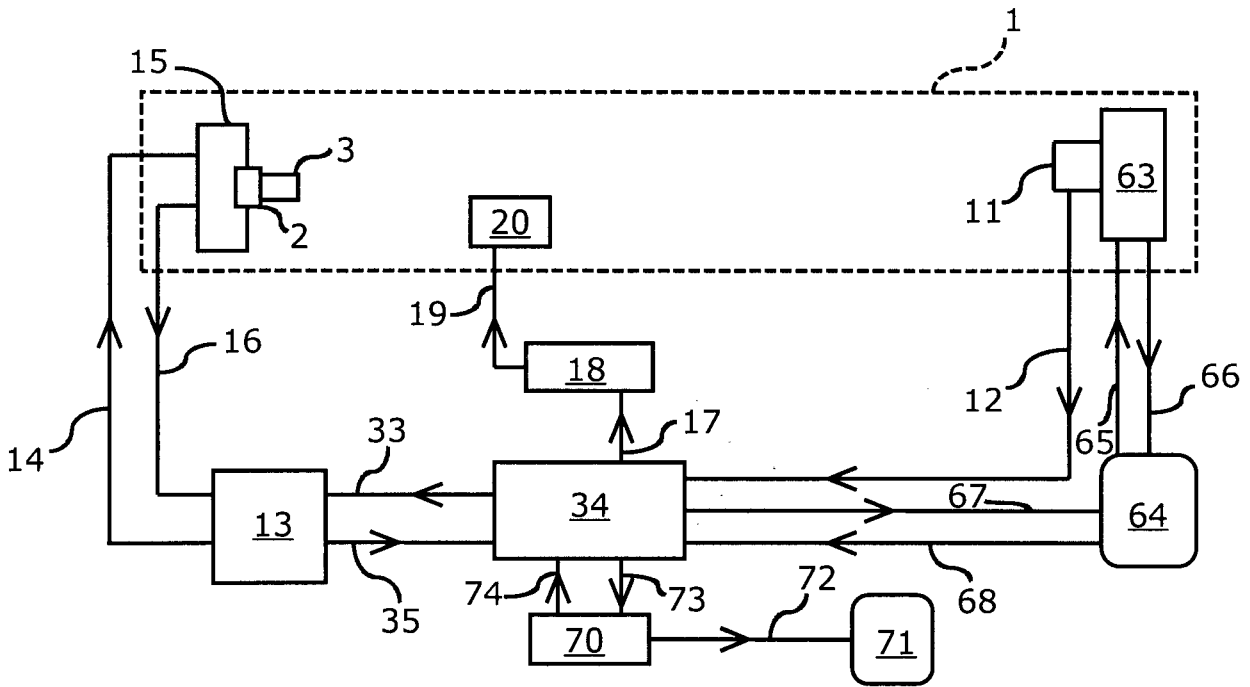


FIG. 6

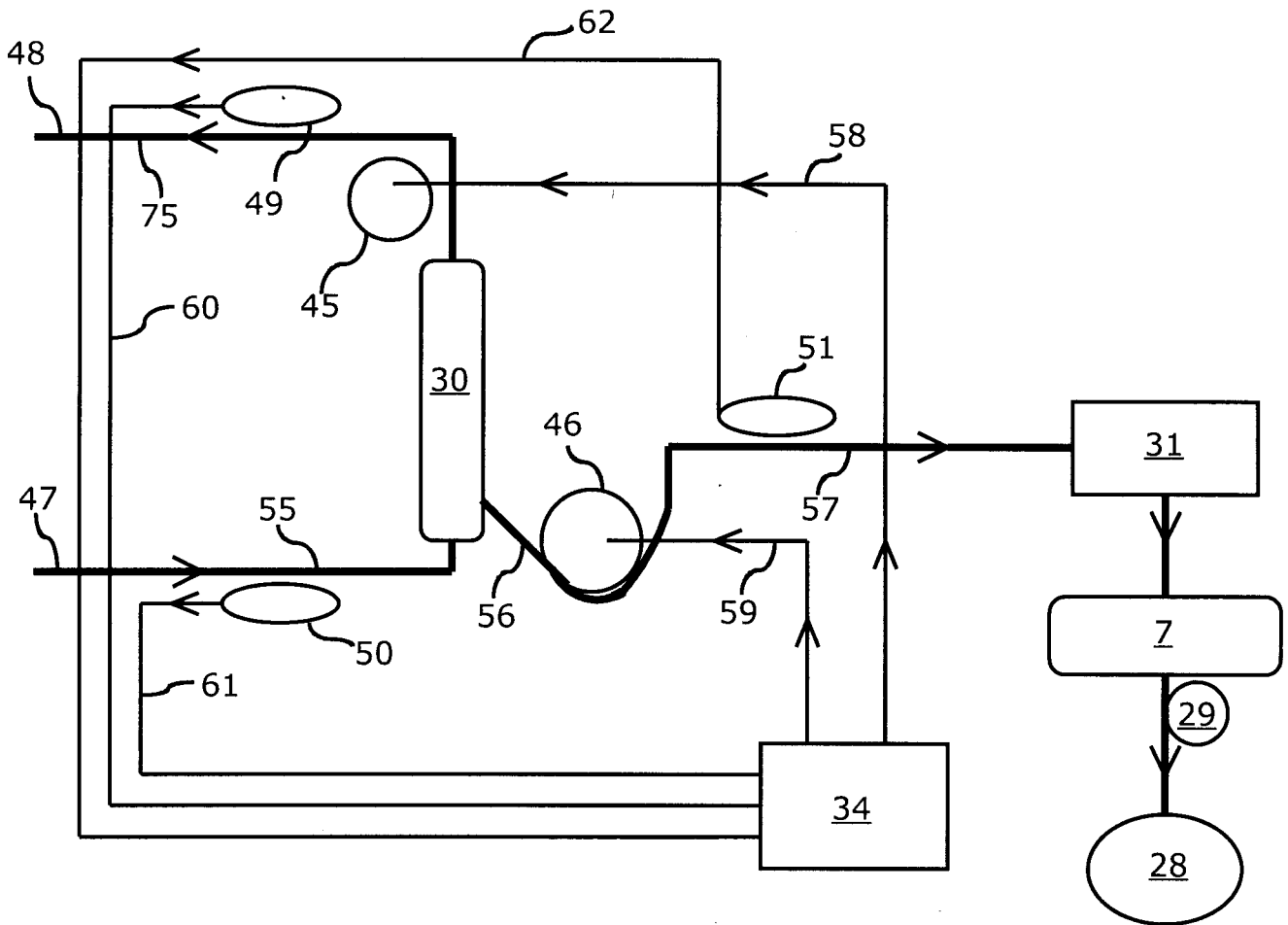


FIG. 7

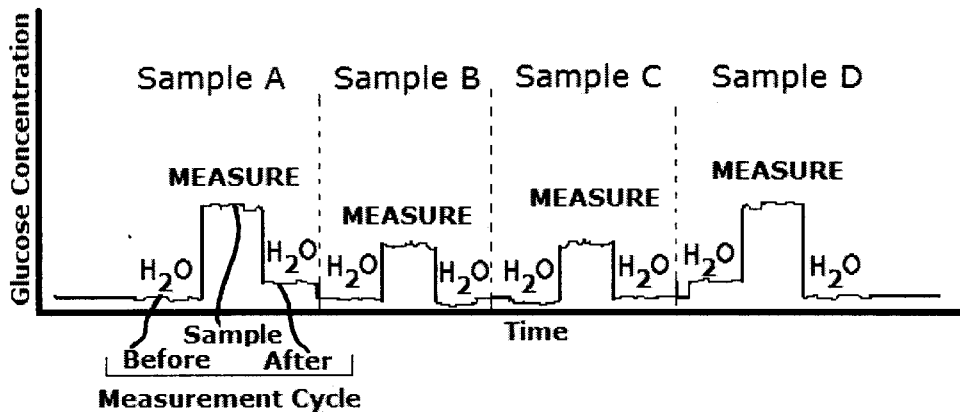


FIG. 8

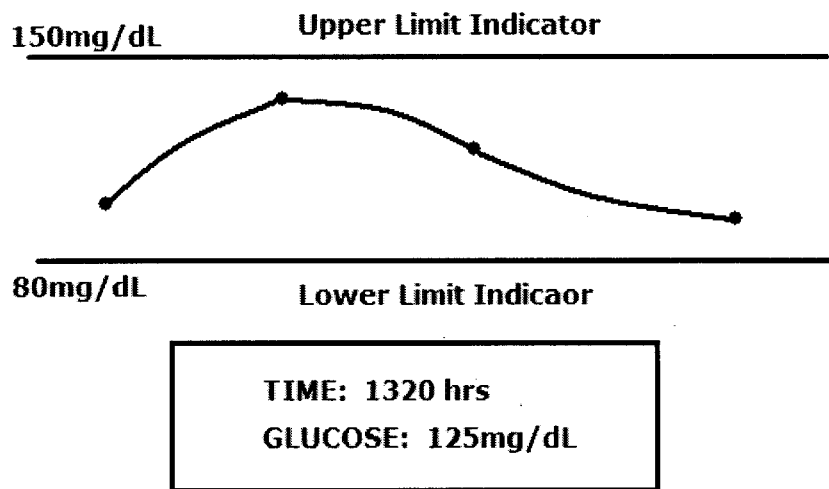


FIG. 9

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/43914

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> <b>IPC(8) - A61B 5/00, G01J 3/433, G01N 21/21 (2013.01)</b> <b>USPC - 604/67, 6.09, 6.04, 600/581, 322, 316, 310, 356/390, 368, 367, 356/367, 250/341.2, 250/339.12</b> According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) <b>IPC(8): A61B5/00, G01J3/433, G01N21/21 (2013.01)</b> <b>USPC: 604/67, 6.09, 6.04, 600/581, 322, 316, 310, 356/390, 368, 367, 356/367250/341.2, 250/339.12</b> 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 practicable, search terms used) MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); IP.com: DialogPRO; PubMed/Medline; Google/Google Scholar; Search terms used: chiral*, analyt*, sugar*, glucose*, ultrafilter* ultrafiltrat*, polar*, light source, LED, diode*, hemodialyzer*, hemoconcentrator*, analyzer*, detector*		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0009720 A1 (KUNJAN, K et al.) January 13, 2011; paragraphs [0043], [0054], [0067]-[0068], [0073], [0076]; figure 4	1-20
Y	US 2003/0233036 A1 (ANSARI, RR et al.) December 18, 2003; abstract; paragraphs [0011], [0038], [0073]	1-20
Y	US 5384028 A (ITO, N et al.) January 24, 1995; column 4, lines 17-38	3-7, 14, 16
Y	US 4759828 A (YOUNG, CC et al.) July 26, 1988; column 1, lines 10-62; claims 9, 10	5, 10, 18-20
Y	US 7356364 B1 (BULLOCK, AM et al.) April 8, 2008; column 4, lines 1-21	13-14
Y	WO 2010/036736 A2 (BARTLETT, JT et al.) April 1, 2010; paragraphs [0006]-[0009]	6, 11
Y	US 5311283 A (HEESCHEN, WA) May 10, 1994; abstract; column 1, line 65 to column 2, line 51; column 7, lines 20-41	6, 11
Y	US 2009/0270704 A1 (PEYSER, TA et al.) October 29, 2009; abstract	18, 20
Y	WO 2004/085995 A2 (ZANZUCCHI, PJ et al.) October 7, 2004; claim 73	18
A	US 7095963 B2 (KNAACK, WC et al.) August 22, 2006; column 7, line 61 to column 8, line 14	21-24
A	US 3960497 A (ACORD, WA) June 1, 1976; column 1, lines 26-40	21-24
A	US 2007/0032706 A1 (KAMATH, A et al.) February 8, 2007; paragraphs [0127], [0205], [0259]	21-24
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 30 August 2013 (30.08.2013)		Date of mailing of the international search report <b>11 SEP 2013</b>
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/43914

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/017238 A1 (KIANI, MJ et al.) February 11, 2010; paragraphs [0010], [0031]	25
A	US 7972861 B2 (DENG, Y et al) July 5, 2011; column 12, line 1-10; Table E	25

专利名称(译)	手性分析物浓度的自动测量方法		
公开(公告)号	<a href="#">EP2854624A1</a>	公开(公告)日	2015-04-08
申请号	EP2013800904	申请日	2013-06-03
[标]申请(专利权)人(译)	LESZINSKE ALAN J		
申请(专利权)人(译)	Leszinske, 艾伦, J.		
当前申请(专利权)人(译)	Leszinske, 艾伦, J.		
[标]发明人	LESZINSKE ALAN J		
发明人	LESZINSKE, ALAN, J.		
IPC分类号	A61B5/00 G01J3/433 G01N21/21		
CPC分类号	A61B5/14532 A61B5/14558 A61B5/1459 A61B5/15003 A61B5/150229 A61B5/150992 A61B5/153 A61B5/155 A61B5/6866 A61B2505/05 A61B2560/0233 G01N21/21 A61B5/1455 A61B5/1495 A61B5 /7246 G01J4/04 G01N2201/0612 G01N2201/062 G01N2201/127		
优先权	61/655806 2012-06-05 US		
其他公开文献	EP2854624A4		
外部链接	<a href="#">Espacenet</a>		

#### 摘要(译)

围手术期患者血糖浓度通过将患者流出物超滤液通过结合在自动旋光仪中的样品池施加来确定。该装置包括光学平台，流体处理子组件，控制电子设备和集成软件。已知强度和不同特定波长的稳定准直光源通过光学平台，该光学平台包括偏振器，延迟器，带通滤波器，样品流动池，分析器和检测器。记录由样品流动池中收集的患者超滤液中包含的葡萄糖产生的透射光的角度旋转，并提供葡萄糖浓度的量度。