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(54) **MOVEABLE ASSEMBLY FOR
SIMULTANEOUS DETECTION OF
ANALYTIC AND COMPENSATION SIGNALS
IN OPTICAL COMPUTING**

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(57) **ABSTRACT**

An optical computing device uses a moveable assembly to simultaneously analytic and compensation signals to determine sample characteristics in real-time. In one embodiment, the moveable assembly is a rotating carousel including at least one optical element pair positioned thereon, where one of the optical elements forms an analytic channel, and the other forms the compensation channel. Alternatively, two carousels may be utilized, where one includes the analytic channel and the other includes the compensation channel. In another embodiment, a linear array having compensation and analytic channels may be utilized. During operation, electromagnetic radiation optically interacts with the sample to form sample-interacted light, which is directed toward the optical elements on the moveable assembly. The optical elements are positioned on the moveable assemblies such that the sample-interacted light optically interacts with both simultaneously, thereby providing compensation in parallel with the sample characteristic measurement.

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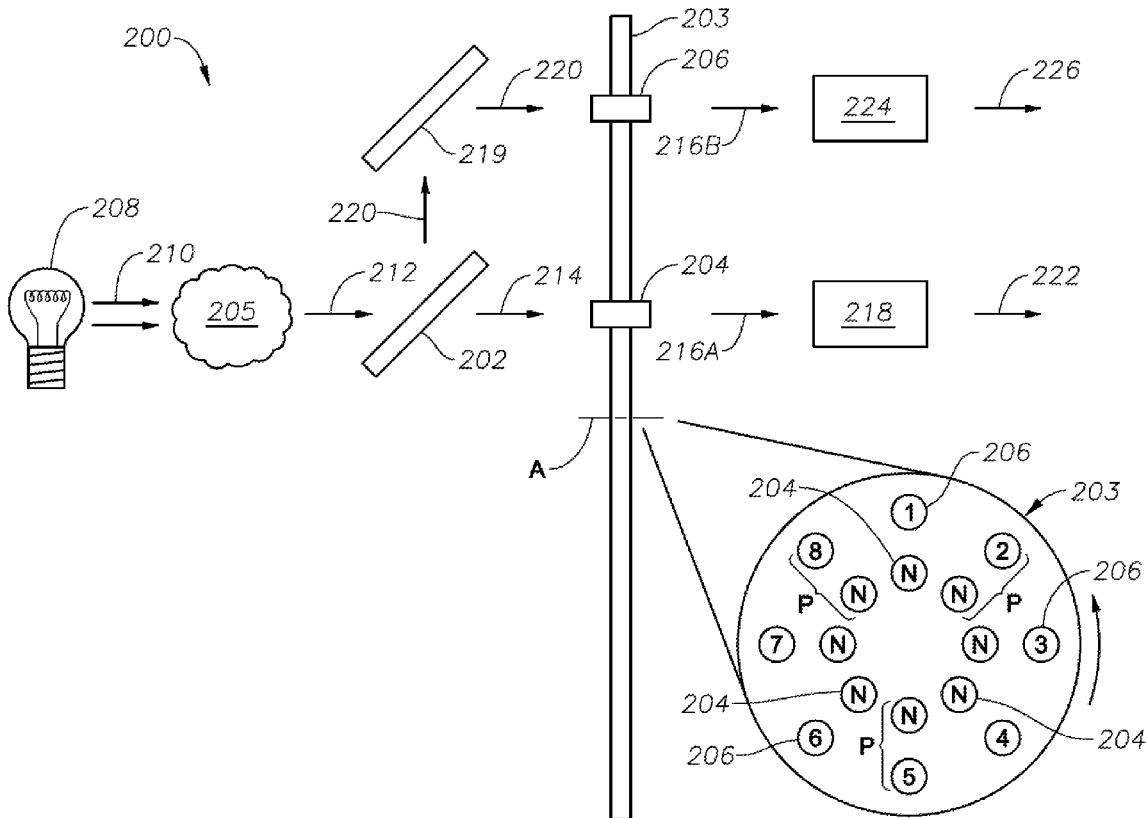
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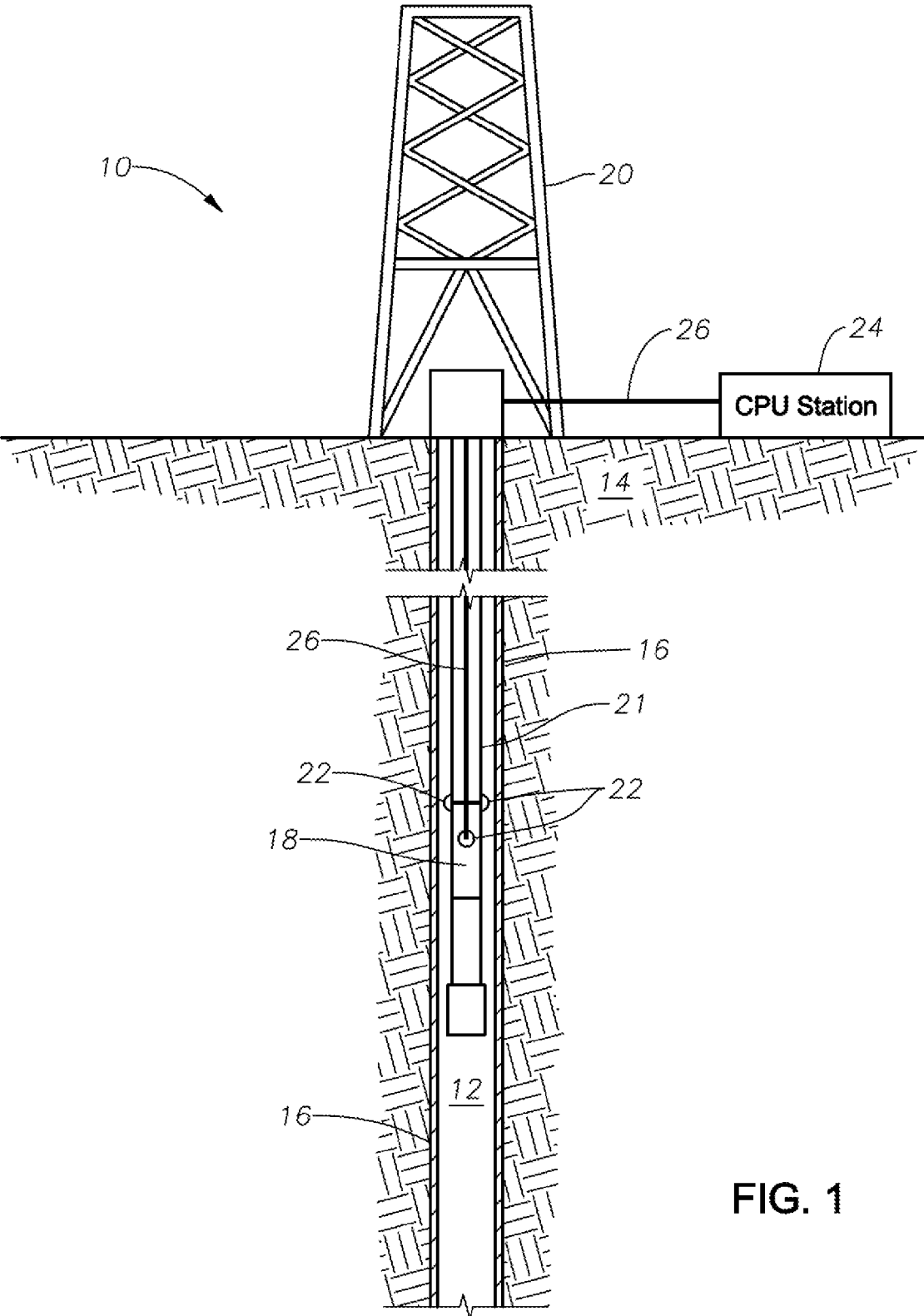


FIG. 1

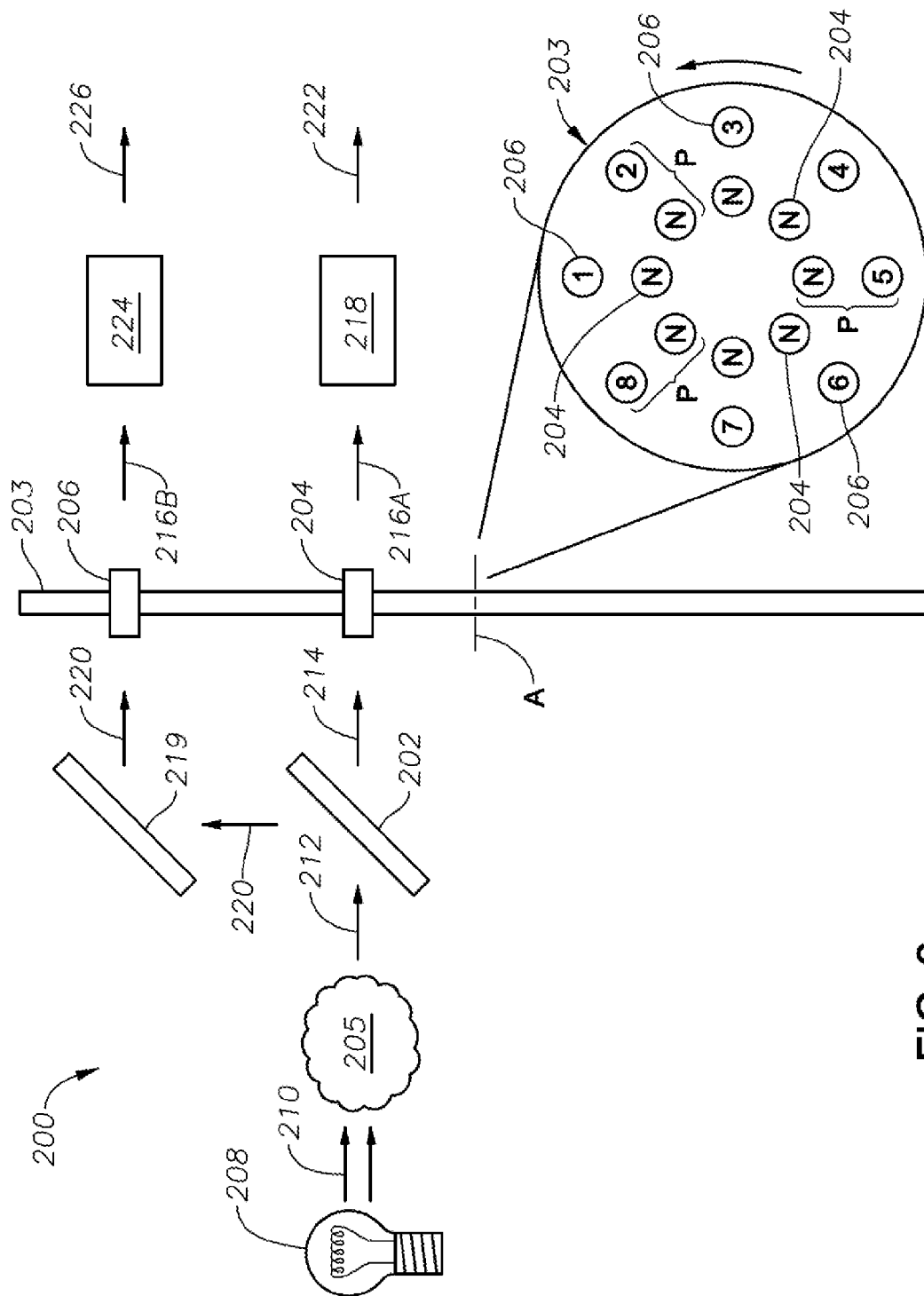


FIG. 2

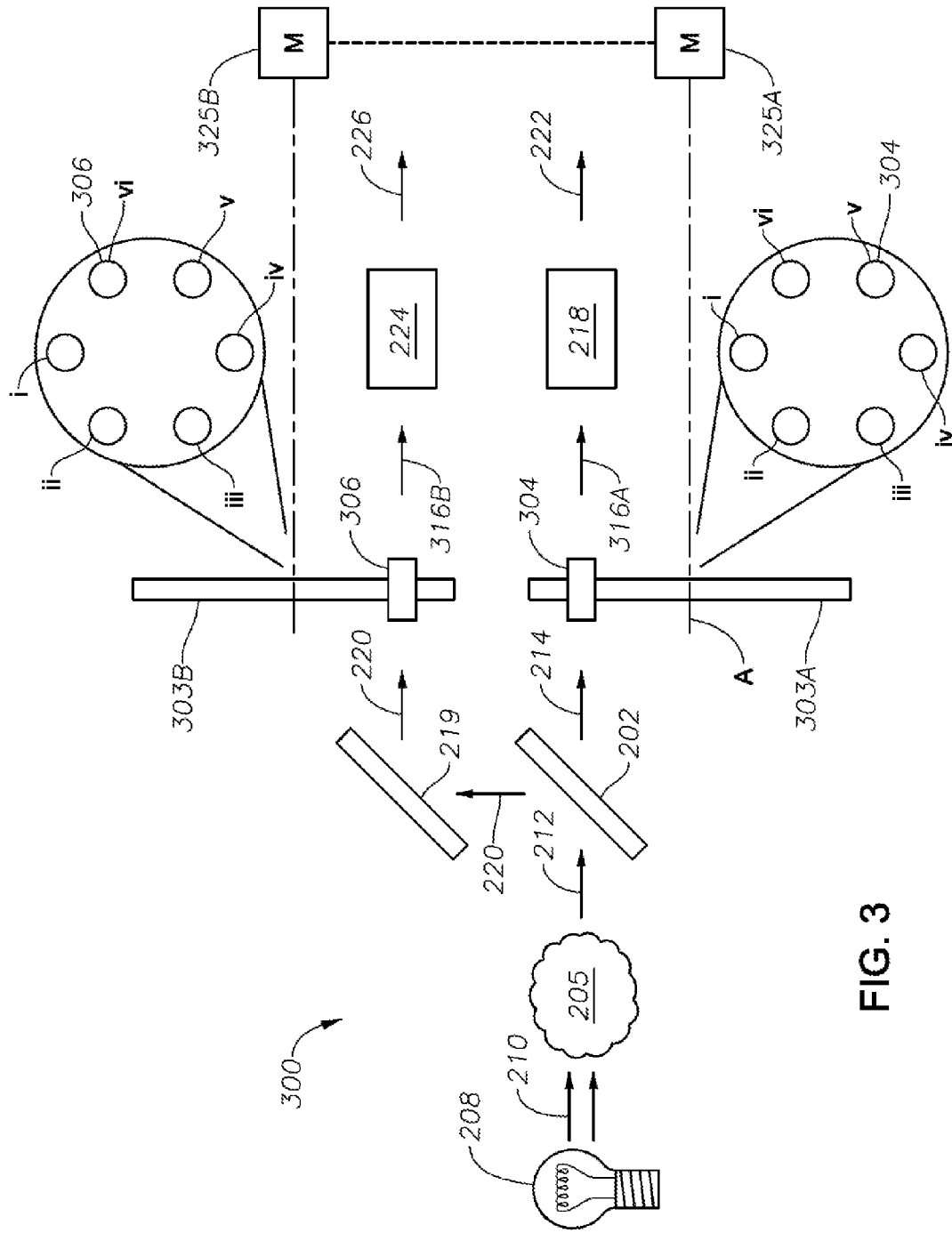


FIG. 3

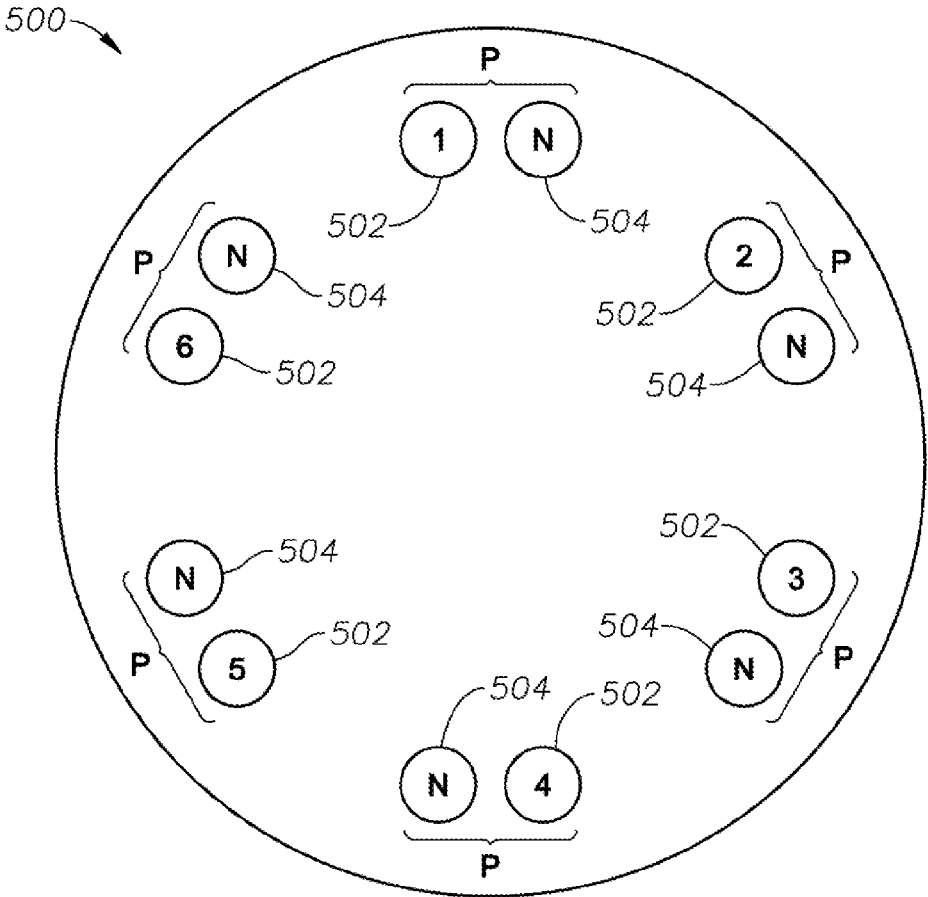


FIG. 5

**MOVEABLE ASSEMBLY FOR
SIMULTANEOUS DETECTION OF
ANALYTIC AND COMPENSATION SIGNALS
IN OPTICAL COMPUTING**

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates generally to optical sensors and, more specifically, to an Integrated Computational Element (“ICE”) core based optical device that uses moveable assemblies to simultaneously detect the analytic and compensation signals to thereby determine sample characteristics.

BACKGROUND

[0002] In recent years, optical computing techniques have been developed for applications in the oil and gas industry in the form of optical sensors in downhole or surface equipment to evaluate a variety of fluid properties. In general, an optical computing device is a device configured to receive an input of electromagnetic radiation from a sample and produce an output of electromagnetic radiation from a processing element, also referred to as an optical element, wherein the output reflects the measured intensity of the electromagnetic radiation. The optical computing device may be, for example, an ICE. One type of an ICE is an optical thin film optical interference device, also known as a multivariate optical element (“MOE”).

[0003] Fundamentally, optical computing devices utilize optical elements to perform calculations, as opposed to the hardwired circuits of conventional electronic processors. When light from a light source interacts with a substance, unique physical and chemical information about the substance is encoded in the electromagnetic radiation that is reflected from, transmitted through, or radiated from the sample. Thus, the optical computing device, through use of the ICE and one or more detectors, is capable of extracting the information of one or multiple characteristics/analytes within a substance and converting that information into a detectable output signal reflecting the overall properties of a sample. Such characteristics may include, for example, the presence of certain elements, compositions, fluid phases, etc. existing within the substance.

[0004] The characteristic or analyte of interest is directly related to the intensity of the light transmitted both through the sample and through the ICE. This light is generally referred to as the analytic “A” Channel. One challenge in optical computing or ICE computing devices is that the light intensity in the A Channel may fluctuate. Such fluctuations might occur for a variety of reasons, including weakening of the bulb over time, in response to analyte concentration variations, or other spurious effects such as dust and dirt accumulation on the optical elements and windows. These spurious effects will cause the A Channel light intensity to fluctuate and, therefore, introduce variations in the accuracy of the optical device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 illustrates a well system having optical computing devices deployed therein for sample characteristic detection according to certain illustrative embodiments of the present disclosure;

[0006] FIG. 2 is a block diagram of an optical computing device for sample characteristic detection employing a

single moveable assembly design, according to certain illustrative embodiments of the present disclosure;

[0007] FIG. 3 is a block diagram of another optical computing device employing a dual moveable assembly design, according to certain illustrative embodiments of the present disclosure;

[0008] FIG. 4 illustrates a block diagram of yet another optical computing device employing a linear array as the moveable assembly, according to certain illustrative embodiments of the present disclosure; and

[0009] FIG. 5 is a moveable assembly according to certain alternative embodiments of the present disclosure.

DESCRIPTION OF ILLUSTRATIVE
EMBODIMENTS

[0010] Illustrative embodiments and related methodologies of the present disclosure are described below as they might be employed in an optical computing device and method to simultaneously detect the analytic and compensation signals to determine sample characteristics. In the interest of clarity, not all features of an actual implementation or methodology are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers’ specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure. Further aspects and advantages of the various embodiments and related methodologies of the disclosure will become apparent from consideration of the following description and drawings.

[0011] As described herein, one or more illustrative embodiments of the present disclosure are directed to an optical computing device that simultaneously detects the analytic and compensation signals to determine sample characteristics. As previously described, one of the challenges in optical computing is that the light intensity in the A Channel may fluctuate, thereby introducing errors in the accuracy of the measurements. Therefore, illustrative embodiments of the present disclosure normalize or ratio out the spurious effects using a second compensation “B” Channel. In a first generalized embodiment, the optical computing device includes an electromagnetic radiation source and a moveable assembly, such as, for example, a rotating carousel or linear array, having at least one optical element pair positioned thereon. The optical elements may be an ICE and/or a neutral density element. The optical elements may also be band pass filters, for example, or other elements designed to pass desired portions of the electromagnetic spectrum. One of the optical elements may form an analytic channel, while the other may form a compensation channel.

[0012] During operation, electromagnetic radiation optically interacts with the sample to form sample-interacted light, which is directed toward the optical elements on the moveable assembly. The optical elements are positioned on the moveable assembly such that the sample-interacted light optically interacts with both elements simultaneously, thereby providing compensation (via the analytic channel).

[0013] In one or more generalized embodiments, the moveable assemblies may be two synchronized rotating carousels. Both carousels may include optical elements, whereby one carousel forms the analytic channel and the other forms the compensation channel. During operation, the carousels can be synchronously rotated such that the sample-interacted light simultaneously interacts with both optical elements, thereby providing compensation in parallel with the sample characteristic measurement (via the analytic channel).

[0014] Each of the above generalized embodiments may include a plurality of optical element pairs. In such embodiments, the moveable assembly may include a first and second row, whereby one of the rows forms the analytic channel, while the other row forms the compensation channel. As a result, multiple analytes may be detected in real-time while providing more accurate measurements of dynamic fluid samples.

[0015] The optical computing devices described herein may be utilized in a variety of environments. Such environments may include, for example, downhole well or completion applications. Other environments may include those as diverse as those associated with surface and undersea monitoring, satellite or drone surveillance, pipeline monitoring, or even sensors transiting a body cavity such as a digestive tract. Within those environments, the optical computing devices are utilized to detect/monitor various sample compounds or characteristics, in real time, within the environment.

[0016] Although the optical computing devices described herein may be utilized in a variety of environments, for illustrative purposes the following description will focus on downhole well applications. FIG. 1 illustrates a plurality of optical computing devices **22** positioned along a workstring **21** extending along a downhole well system **10** (also referred to herein as a downhole reservoir interrogation system) according to certain illustrative embodiments of the present disclosure. Workstring **21** may be, for example, a logging assembly, production string or drilling assembly. Well system **10** comprises a vertical wellbore **12** extending down into a hydrocarbon formation **14** (although not illustrated, wellbore **12** may also comprise one or more lateral sections). Wellbore equipment **20** is positioned atop vertical wellbore **12**, as understood in the art. Wellbore equipment may be, for example, a blow out preventer, derrick, floating platform, etc. As understood in the art, after vertical wellbore **12** is formed, tubulars **16** (casing, for example) are extended therein to complete wellbore **12**.

[0017] One or more optical computing devices **22** may be positioned along wellbore **12** at any desired location. In certain embodiments, optical computing devices **22** are positioned along the internal or external surfaces of downhole tool **18** (as shown in FIG. 1) which may be, for example, intervention equipment, surveying equipment, or completion equipment including valves, packers, screens, mandrels, gauge mandrels, in addition to casing or tubing tubulars/joints as referenced below. Alternatively, however, optical computing devices **22** may be permanently or removably attached to tubulars **16** and distributed throughout wellbore **12** in any area in which corrosion detection/monitoring or formation evaluation is desired. Optical computing devices **22** may be coupled to a remote power supply (located on the surface or a power generator positioned downhole along the wellbore, for example), while in other

embodiments each optical computing device **22** comprises an on-board battery. Moreover, optical computing devices **22** are communicably coupled to a CPU station **24** via a communications link **26**, such as, for example, a wireline, inductive coupling or other suitable communications link. Those ordinarily skilled in the art having the benefit of this disclosure will readily appreciate that the number and location of optical computing devices **22** may be manipulated as desired.

[0018] As will be described in more detail below, each optical computing device **22** comprises an ICE and neutral density (“ND”) element pair (i.e., first and second optical elements) positioned on one or more moveable assemblies which both optically interact with a sample of interest (wellbore fluid, downhole tool component, tubular, formation, for example) to determine one or more sample characteristics. In certain illustrative embodiments, optical computing devices **22** may determine the presence and quantity of specific gases, fluids, components and properties relevant to hydrocarbon exploration and production such as, for example, CO₂, H₂S, methane (C1), ethane (C2) and propane (C3), saline water, dissolved ions (Ba, Cl, Na, Fe, or Sr, for example) or various other characteristics (p.H., density and specific gravity, viscosity, total dissolved solids, sand content, etc.). Furthermore, the presence of formation characteristic data (viscosity, phase, formation chemical composition, etc.) may also be determined. In certain embodiments, a single optical computing device **22** may detect a single characteristic, while in others a single optical computing device **22** may determine multiple characteristics, as will be understood by those ordinarily skilled in the art having the benefit of this disclosure.

[0019] CPU station **24** comprises a signal processor (not shown), communications module (not shown) and other circuitry necessary to achieve the objectives of the present disclosure, as will be understood by those ordinarily skilled in the art having the benefit of this disclosure. In addition, it will also be recognized that the software instructions necessary to carry out the objectives of the present disclosure may be stored within storage located in CPU station **24** or loaded into that storage from a CD-ROM or other appropriate storage media via wired or wireless methods. Communications link **26** provides a medium of communication between CPU station **24** and optical computing devices **22**. Communications link **26** may be a wired link, such as, for example, a wireline or fiber optic cable extending down into vertical wellbore **12**. Alternatively, however, communications link **26** may be a wireless link, such as, for example, an electromagnetic device of suitable frequency, or other methods including acoustic communication and like devices.

[0020] In certain illustrative embodiments, CPU station **24**, via its signal processor, controls operation of each optical computing device **22**. In addition to sensing operations, CPU station **24** may also control activation and deactivation of optical computing devices **22**. Optical computing devices **22** each include a transmitter and receiver (transceiver, for example) (not shown) that allows bi-directional communication over communications link **26** in real-time. In certain illustrative embodiments, optical computing devices **22** will transmit all or a portion of the corrosion/formation or other sample characteristic data to CPU station **24** for further analysis. However, in other embodiments, such analysis is partially or completely handled by each

optical computing device **22** and the resulting data is then transmitted to CPU station **24** for storage or subsequent analysis. In either embodiment, the processor handling the computations analyzes the characteristic data and, through utilization of Equation of State (“EOS”) or other optical analysis techniques, derives the desired sample characteristic indicated by the transmitted data.

[0021] Still referring to the illustrative embodiment of FIG. 1, optical computing devices **22** are positioned along workstring **21** at any desired location. In this example, optical computing devices **22** are positioned along the outer diameter of downhole tool **18**. Optical computing devices **22** have a temperature and pressure resistant housing sufficient to withstand the harsh downhole environment. A variety of materials may be utilized for the housing, including, for example, stainless steels and their alloys, titanium and other high strength metals, and even carbon fiber composites and sapphire or diamond structures, as understood in the art. In certain embodiments, optical computing devices **22** are dome-shaped modules (akin to a vehicle dome light) which may be permanently or removably attached to a surface using a suitable method (welding, magnets, etc.). Module housing shapes may vary widely, provided they isolate components from the harsh down-hole environment while still allowing a unidirectional or bidirectional optical (or electromagnetic radiation) pathway from sensor to the sample of interest. Dimensions would be determined by the specific application and environmental conditions.

[0022] Alternatively, optical computing devices **22** may form part of downhole tool **18** (as shown in FIG. 1) along its inner or outer diameter. In other embodiments as will be described below, optical computing devices **22** may be coupled to downhole tool **18** using an extendable arm (adjustable stabilizer, casing scraper, downhole tractor, for example) in order to extend optical computing device **22** into close proximity with another surface (casing, tool body, formation, etc.) to thereby detect sample characteristics (e.g., formation evaluation). As previously described, optical computing devices **22** may also be permanently affixed to the inner diameter of tubular **16** by a welding or other suitable process. However, in yet another embodiment, optical computing devices **22** are removably affixed to the inner diameter of tubulars **16** using magnets or physical structures so that optical computing devices **22** may be periodically removed for service purposes or otherwise. Although illustrated in FIG. 1 as deployed along a drilling and/or logging string, embodiments of the present disclosure may also be deployed along a wireline assembly.

[0023] FIG. 2 is a block diagram of an optical computing device **200**, according to certain illustrative embodiments of the present disclosure. An electromagnetic radiation source **208** may be configured to emit or otherwise generate electromagnetic radiation **210**. As understood in the art, electromagnetic radiation source **208** may be any device capable of emitting or generating electromagnetic radiation. For example, electromagnetic radiation source **208** may be a light bulb, light emitting device, laser, blackbody, photonic crystal, or X-Ray source, etc. In other embodiments, the source of electromagnetic radiation **210** may be ambient light present in the device.

[0024] Nevertheless, in one embodiment, electromagnetic radiation **210** may be configured to optically interact with the sample **205** (wellbore fluid flowing through wellbore **12** or a portion of the formation **14**, for example) and generate

sample-interacted light **212** directed to a beam splitter **202**. Sample **205** may be any fluid (liquid or gas), solid substance or material such as, for example, downhole tool components, tubulars, rock formations, slurries, sands, muds, drill cuttings, concrete, other solid surfaces, etc. In other embodiments, however, sample **205** is a multiphase wellbore fluid (comprising oil, gas, water, solids, for example) consisting of a variety of fluid characteristics such as, for example, C1-C4 and higher hydrocarbons, groupings of such elements, and saline water.

[0025] Sample **205** may be provided to optical computing device **200** through a flow pipe or sample cell, for example, containing sample **205**, whereby it is introduced to electromagnetic radiation **210**. Alternatively, optical computing device **200** may utilize an optical configuration consisting of an internal reflectance element which analyzes the wellbore fluid as it flows thereby or which analyzes the surface of the sample (formation surface, for example). While FIG. 2 shows electromagnetic radiation **210** as passing through or incident upon the sample **205** to produce sample-interacted light **212** (i.e., transmission), it is also contemplated herein to reflect electromagnetic radiation **210** off of the sample **205** (i.e., reflectance mode), such as in the case of a sample **205** that is translucent, opaque, or solid, and equally generate the sample-interacted light **212**.

[0026] After being illuminated with electromagnetic radiation **210**, sample **205** containing an analyte of interest produces an output of electromagnetic radiation (sample-interacted light **212**, for example). As previously described, sample-interacted light **212** also contains spectral information that reflects chemical and physical variations of the sample used to determine sample characteristics. Ultimately, CPU station **24** (or a processor on-board device **200**) analyzes this spectral information to determine the sample characteristic. Although not specifically shown, one or more spectral elements may be employed in optical computing device **200** in order to restrict the optical wavelengths and/or bandwidths of the system and, thereby, eliminate unwanted electromagnetic radiation existing in wavelength regions that have no importance. Such spectral elements can be located anywhere along the optical train, but are typically employed directly after the light source which provides the initial electromagnetic radiation.

[0027] Still referring to the illustrative embodiment of FIG. 2, beam splitter **202** is employed to split sample-interacted light **212** into a transmitted electromagnetic radiation **214** (i.e., first portion) and a reflected electromagnetic radiation **220** (i.e., second portion). Reflected electromagnetic radiation **220** is then directed to optical element **219** (e.g., mirror) which directs it to moveable assembly **203** (shown here as a rotating carousel), which includes at least one optical element **204** and a paired optical element **206** associated therewith. Note that moveable assembly **203** is only one example of a moveable assembly; in other illustrative embodiments, moveable assembly **203** may be linear array or other rotating disc, such as, for example, a chopper wheel, wherein optical elements **204** and **206** are radially disposed for rotation therewith. Transmitted electromagnetic radiation **214** is also directed to the moveable assembly **203**. In this illustrative embodiment, optical element **204** is an ICE, while optical element **206** is an ND element, thereby forming an analytic and compensation channel, respectively. The ND element may be, for example, a neutral density filter which reduces or modifies the intensity of transmitted light

across all wavelengths equally. The ND filter is typically selected to have a flat spectral response in the spectral region the ICE operates within.

[0028] As shown, moveable assembly **203** includes an outer row of optical elements **206** and an inner row for optical elements **204** with respect to a center axis A. As a result, there are a number of ICE-ND pairs P which are arranged beside one another in a column-like fashion. Although illustrated as having optical ICEs **204** in the inner row and ND element **206** in the outer row, the orientations may be reversed in alternate embodiments.

[0029] The moveable assembly **203** is configured to simultaneously align optical elements **204**, **206** of each ICE-ND pair P with sample-interacted light **212** (i.e., transmitted electromagnetic radiation **214** and a reflected electromagnetic radiation **220**). In certain embodiments, each ICE-ND pair P is designed to be either associated or disassociated with the same or a different characteristic of sample **205**, thus forming a plurality of analytic and compensation channels. Although 8 optical element pairs P are shown, more or less optical element pairs may be employed along moveable assembly **203** as desired.

[0030] The moveable assembly **203** may be rotated about axis A at any desired frequency (e.g., 0.1 RPM to about 30,000 RPM). In operation, moveable assembly **203** may rotate such that the ICE and ND element of each pair P are simultaneously exposed to or otherwise optically interact with the sample-interacted light **212** for a distinct brief period of time. Thus, when an ICE used to measure an analyte of interest is aligned with its detector, the paired ND element is also aligned with its detector to provide the compensation signal. In this way, the ICE-ND element pair P are always sensing the same sample at the same time. Upon optically interacting with the transmitted electromagnetic radiation **214**, optical element **204** (the ICE) is configured to generate optically interacted light **216A** (also referred to herein as the “first optically-interacted light”) which corresponds to a sample characteristic (thus forming analytic channel A), while optical element **206** (the paired ND element) is configured to generate optically interacted light **216B** (also referred to herein as the “second optically-interacted light”) (thus forming compensation channel B) upon interacting with reflected electromagnetic radiation **220**. Detector **218** then receives optically interacted light **216A** and thereby generates a first signal **222** (i.e., analytic signal), while detector **224** simultaneously receives optically interacted light **216B** to generate second signal **226** (i.e., compensation signal). Accordingly, a signal processor (not shown) communicatively coupled to detectors **218,224** utilizes the output signals **222,226** to computationally determine the sample characteristics.

[0031] Detectors **218/224** may be any device capable of detecting electromagnetic radiation, and may be generally characterized as an optical transducer. For example, detector **218/224** may be, but is not limited to, a thermal detector such as a thermopile or photoacoustic detector, a semiconductor detector, a piezo-electric detector, charge coupled device detector, or array detector, split detector, photon detector (such as a photomultiplier tube), photodiodes, and/or combinations thereof, or the like, or other detectors known to those ordinarily skilled in the art. Detector **218/224** is further configured to produce an output signal **222** in the form of a voltage or current that corresponds to the particular characteristic of the sample **205**. In at least one

embodiment, the output signal, produced by computationally combining the output signals **222** and **226** from detector **218** and detector **224**, and the characteristic concentration of the sample **205** may be directly proportional. In other embodiments, the relationship may be a polynomial function, an exponential function, and/or a logarithmic function.

[0032] As understood in the art, optically interacted light **216B** (the compensation channel) may include a variety of electromagnetic radiation deviations such as, for example, intensity fluctuations in the electromagnetic radiation source **208**, or light scattering fluctuations from suspended particles in the sample or optical path, combinations thereof, or the like. Thus, detector **224** measures these electromagnetic radiation deviations and is used to compensate signal **222** for these deviations.

[0033] As moveable assembly **203** continues to rotate, other ICE-ND pairs P are optically interacted with sample-interacted light **212**. Here, as each ICE and ND element in pairs P simultaneously interacts with sample-interacted light **212** as previously described, time lapsed optically interacted lights (**216A₁**, **216B₁**, **216A₂**, **216B₂** . . .) are generated. Thus, in certain illustrative embodiments, detectors **218,224** may be configured to time multiplex beams (**216A₁**, **216B₁**, **216A₂**, **216B₂** . . .) between the individually-detected beams. For example, optical elements **204** and **206** may be configured to direct first beams **216A₁** and **216B₁** of a first ICE-ND pair P toward detectors **218** and **224**, respectively, at a first time **T1**, the beams **216A₂** and **216B₂** of a second ICE-ND pair P at a second time **T2**, and beams **216A₃** and **216B₃** of a third ICE-ND pair P at a third time **T3**. Consequently, detectors **218,224** receive at least three distinct beams of optically-interacted light which may be computationally combined by a signal processor (not shown) coupled to the detectors in order to provide an output in the form of a voltage that corresponds to the characteristic of the sample, as previously described.

[0034] In certain alternate embodiments, the beams (**216A₁**, **216B₁**, **216A₂**, **216B₂** . . .) may be averaged over an appropriate time domain (for example, about 1 millisecond to about 5 minutes) to more accurately determine the characteristic of sample **205**. As previously described, detectors **218,224** are positioned to detect the optically-interacted lights **216A,216B** in order to produce output signals **222**, **226**. In this embodiment, a signal processor (not shown) is communicably coupled to the detectors such that output signals **222,226** may be processed as desired to computationally determine the characteristic of sample **205**.

[0035] Although not shown in FIG. 2, in certain illustrative embodiments, detectors **218,224** may be communicably coupled to a signal processor (not shown) on-board optical computing device **200** (or remote therefrom) such that compensation signal **226** indicative of electromagnetic radiating deviations may be provided or otherwise conveyed thereto. The signal processor may then be configured to computationally combine compensation signal **226** with analytic signal **222** to provide a more accurate determination of the characteristic of sample **205**.

[0036] As previously described, optical element **204** may be an ICE, while optical element **206** may be an ND element, or vice versa. In an alternative embodiment, both optical elements **204** and **206** may be ICEs, thus forming an ICE-ICE pair whereby the ICEs form the analytic and compensation channels. In either embodiment, however, the ICE being used for the analytic channel is configured to be

associated with a particular characteristic of sample **205** or may be designed to approximate or mimic the regression vector of the characteristic in a desired manner.

[0037] FIG. 3 illustrates a block diagram of yet another optical computing device **300** employing two independent moveable assemblies (e.g., rotating carousels), according to certain illustrative embodiments of the present disclosure. Optical computing device **300** is somewhat similar to optical computing device **200** described with reference to FIG. 2 and, therefore, may be best understood with reference thereto, where like numerals indicate like elements. However, acting as the moveable assembly in this example, optical computing device **300** includes a first moveable assembly **303A** having one or more optical elements **304** (e.g., ICEs), and a second moveable assembly **303B** having one or more optical elements **306** (e.g., NDs or ICEs) paired to the optical elements **304**, as previously described. First and second moveable assemblies **303A,B** are shown in this example as rotating carousels, but may be any variety of moveable assemblies described herein. As illustrated, the moveable assemblies **303A** and **303B** may be characterized at least in one embodiment as a rotating disc, such as, for example, a chopper wheel, wherein optical elements **304** and **306** are radially disposed for rotation therewith.

[0038] Each optical element **304,306** pair may be similar in construction to those as previously described herein, and are configured to be either associated or disassociated with a particular characteristic of the sample **205**. For example, each optical element pair may be designed to determine a different sample characteristic. Although six optical element pairs are described, more or less optical pairs may be employed along moveable assemblies **303A** and **303B** as desired.

[0039] In certain illustrative embodiments, moveable assemblies **303A** and **303B** are each coupled to motors **325A** and **325B**, respectively. Although not shown, motors **325A** and **325B** may be coupled to processing circuitry, as previously described, in order to rotate assemblies **303A** and **303B** in a synchronized fashion so that corresponding pairs of optical elements **304** and **306** optically interact with sample-interacted light **212** (i.e., portions **214,220**) at the same time. Alternatively, a single motor **325** with a mechanical linkage to assemblies **303A** and **303B** may be utilized. In certain embodiments, optical element **304** is an ICE, thus forming the analytic channel, while optical element **306** is an ND element, thus forming a compensation channel for its paired ICE. In other embodiments, the analytic and compensation channels may be formed using ICEs.

[0040] Nevertheless, upon optically interacting with the portions **214** and **220** of sample-interacted light **212**, optical element pairs **304** and **306** are configured to generate optically interacted light **316A** (analytic channel) and **316B** (compensation channel), respectively.

[0041] Detector **318** then receives optically interacted light **316A** and detector **324** receives **316B** to generate a first signal **222** and second signal **226**, as previously described. Accordingly, a signal processor (not shown) communicatively coupled to detectors **218,224** utilizes the output signals to computationally determine the sample characteristics.

[0042] Furthermore, as described in relation to FIG. 2, during operation, motors **325A,B** rotate assemblies **303A** and **303B** using a synchronous frequency. As a result, the ICE-ND pairs are simultaneously interacted with sample-

interacted light **212**. As shown in FIG. 3, the optical elements **304,306** are identified by i, ii, iii, iv, v, and vi, where like numerals identify the paired ICE-ND pairs (or ICE-ICE pairs in alternate embodiments). Thus, at a first time **T1**, ICE-ND pairs i are simultaneously optically interacted with sample-interacted light **212**, then at a second time **T2**, ICE-ND pairs ii are interacted, and so on. The resulting signals may also be multiplexed or otherwise analyzed to determine sample characteristics, as previously described.

[0043] FIG. 4 illustrates a block diagram of yet another optical computing device **400** employing a linear array as the moveable assembly, according to certain illustrative embodiments of the present disclosure. Optical computing device **400** is somewhat similar to optical computing devices **200,300** described with reference to FIGS. 2 and 3, and therefore, may be best understood with reference thereto, where like numerals indicate like elements. However, optical computing device **400** includes a linear array **403** as the moveable assembly, having a first row of one or more optical elements **406** (e.g., ICEs), and a second row of corresponding optical elements **404** (e.g., NDs as illustrated, or ICEs) paired to the optical elements **406**, as previously described. Each optical element **404,406** may be similar in construction to those as previously described herein, and are configured to be either associated or disassociated with a particular characteristic of the sample **205**. Although eight optical element pairs **P** are illustrated, more or less optical pairs may be employed along linear array **403** as desired.

[0044] In certain illustrative embodiments, linear array includes a track **402** positioned thereon which mates with a gear **408** to move linear array along a single dimensional axis **A**. Although not shown, gear **408** is coupled to processing circuitry, as previously described, in order to rotate gear **408**, and thus move linear array **403**, at a desired speed to thereby sequence optical pairs **P** into interaction with sample-interacted light **212** (i.e., portions **214,220**) at the same time. As shown, the various optical pairs **P** are located beside one another in a column-like fashion. In this embodiment, optical elements **404** are ICEs, thus forming the analytic channel, while optical elements **406** are ND elements, thus forming a compensation channel for its paired ICE. In other embodiments, the desired may be flipped and/or the analytic and compensation channels may be formed using ICEs.

[0045] Nevertheless, upon optically interacting with the portions **214** and **220** of sample-interacted light **212**, optical element **406** and **404** pairs **P** are configured to generate optically interacted light **416A** (analytic channel) and **416B** (compensation channel), respectively. Detector **418** then receives optically interacted light **416A** and detector **424** receives **416B** to generate a first signal **222** and second signal **226**, as previously described. As linear array **403** continues to move along axis **A**, each optical element pair **P** is sequenced until the last pair **P** is sequenced. Thereafter, gear **408** reverses linear array **403** back along axis **A** (similar to a type-writer) where the process may begin again. Accordingly, a signal processor (not shown) communicatively coupled to detectors **418,424** utilizes the sequenced output signals to computationally determine the sample characteristics.

[0046] FIG. 5 is a diagrammatical illustration of a rotating carousel **500** that may be used as a moveable assembly as described above, according to one or more embodiments of the present disclosure. Rotating carousel **500** is similar to

moveable assembly **203** previously described with reference to FIG. 2, with some alterations. Instead of the column-like fashion of the optical pairs P, rotating carousel **500** includes a plurality of optical element **502,504** pairs P which are arranged side-by-side in an alternating row fashion. The other optical components (e.g., beam splitters, mirrors, etc.) may be arranged in any number of ways to achieve simultaneous interaction of the sample-interacted light with the analytic and compensation channels formed by the optical pairs P, as previously described. Moreover, although first optical element **502** is shown as the ICE, while second optical element **504** is shown as the ND element, the design may be reversed and/or two ICEs may be utilized, as previously described.

[0047] The aforementioned optical computing devices are illustrative in nature, and may be subject to a variety of other optical configurations. Such optical configurations not only include the reflection, absorption or transmission methods described herein, but can also involve scattering (Rayleigh & Raman, for example) as well as emission (fluorescence, X-ray excitation, etc., for example). In addition, the optical computing devices may comprise a parallel processing configuration whereby the sample-interacted light is split into multiple beams. The multiple beams may then simultaneously go through corresponding ICEs, whereby multiple characteristics and/or analytes of interest are simultaneously detected. The parallel processing configuration is particularly useful in those applications that require extremely low power or no moving parts.

[0048] Accordingly, the illustrative embodiments described herein eliminates the use of serial A and B measurements and provides more accurate measurements of dynamic fluid samples possible in systems that measure multiple ICE signals. Through the use of beam splitters and other optical elements, two optical paths (analytic and compensation channels) are created using two rows of optical elements on rotating carousels or a single row of optical elements on two synchronously rotating carousels. Each embodiment ensures that when an ICE is aligned with its detector, an ND element (or other ICE) is aligned with its detector concurrently. Such an arrangement results in the ICE and ND element always detecting the same sample at the same time.

[0049] Accordingly, the described embodiments avoid the case where, due to a time interval between the A and B channel signal detection, a different sample is interrogated by each optical channel. In cases where the sample's properties are changing rapidly relative to the time between measurements of the A and B Channels, the two channels are not observing the same sample volume at the same time, which may result in reduced performance due to compensation variations. However, by simultaneously detecting both channels, such variations are avoided.

[0050] Embodiments described herein further relate to any one or more of the following paragraphs:

[0051] 1. An optical computing device, comprising electromagnetic radiation that optically interacts with a sample to produce sample-interacted light; a moveable assembly, comprising: a first optical element that optically interacts with the sample-interacted light to produce first optically-interacted light which corresponds to a characteristic of the sample, thereby forming an analytic channel; and a second optical element that optically interacts with the sample-interacted light to produce second optically-interacted light

utilized to compensate the analytic channel, thereby forming a compensation channel, wherein the first and second optical elements are positioned along the moveable assembly to simultaneously interact with the sample-interacted light; a first detector positioned to measure the first optically-interacted light and generate a first signal; and a second detector positioned to measure the second optically-interacted light and generate a second signal, wherein the first and second signals are utilized to determine the characteristics of the sample.

[0052] 2. An optical computing device as defined in paragraph 1, further comprising: a beam splitter positioned to split the sample-interacted light into a first and second portion, the first portion being directed to the analytic channel; and an optical element positioned to direct the second portion toward the compensation channel.

[0053] 3. An optical computing device as defined in paragraphs 1 or 2, wherein the first optical element is an Integrated Computational Element ("ICE"); and the second optical element is a neutral density element.

[0054] 4. An optical computing device as defined in any of paragraphs 1-3, wherein the first and second optical elements are Integrated Computational Elements ("ICEs").

[0055] 5. An optical computing device as defined in any of paragraphs 1-4, wherein the moveable assembly comprises a plurality of analytic channels; and a plurality of compensation channels which correspond to the analytic channels.

[0056] 6. An optical computing device as defined in any of paragraphs 1-5, wherein the moveable assembly is a carousel rotatably disposed about a center axis; the analytic channels are positioned along an outer row of the carousel in relation to the center axis; the compensation channels are positioned along an inner row of the carousel in relation to the center axis; and corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair.

[0057] 7. An optical computing device as defined in any of paragraphs 1-6, wherein: the moveable assembly is a linear array; the analytic channels are positioned along a first row of the linear array; the compensation channels are positioned along a second row of the linear array; and corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair, wherein the linear array is moveable in a single dimension to sequence the optical pairs to interact with the sample-interacted light.

[0058] 8. An optical computing device as defined in any of paragraphs 1-7, wherein the moveable assembly is a carousel; and the analytic and compensation channels are positioned in an alternating row-like fashion along the carousel such that corresponding analytic and compensation channels are positioned beside each other, thus forming an optical pair.

[0059] 9. An optical computing device as defined in any of paragraphs 1-8, wherein: the moveable assembly is a carousel rotatably disposed about a center axis; the compensation channels are positioned along an outer row of the carousel in relation to the center axis; the analytic channels are positioned along an inner row of the carousel in relation to the center axis; and corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair.

[0060] 10. An optical computing device as defined in any of paragraphs 1-9, wherein the moveable assembly com-

prises: a first rotating carousel comprising the first optical element; and a second rotating carousel comprising the second optical element.

[0061] 11. An optical computing device as defined in any of paragraphs 1-9, further comprising at least one motor coupled to the first and second rotating carousels in order to synchronously rotate the first and second rotating carousels.

[0062] 12. An optical computing device as defined in any of paragraphs 1-11, further comprising a beam splitter positioned to split the sample-interacted light into a first and second portion, the first portion being directed to the analytic channel; and an optical element positioned to direct the second portion toward the compensation channel.

[0063] 13. An optical computing device as defined in any of paragraphs 1-12, wherein the first rotating carousel further comprises a plurality of analytic channels; and the second rotating carousel further comprises a plurality of compensation channels which correspond to the analytic channels.

[0064] 14. An optical computing device as defined in any one of paragraphs 1-13, further comprising an electromagnetic radiation source that generates the electromagnetic radiation.

[0065] 15. An optical computing device as defined in any one of paragraphs 1-14, further comprising a signal processor communicably coupled to the first and second detector to computationally determine the characteristics of the sample.

[0066] 16. An optical computing device as defined in any one of paragraphs 1-13, wherein the optical computing device comprises part of a downhole reservoir interrogation system.

[0067] 17. An optical computing method, comprising optically interacting electromagnetic radiation with a sample to produce sample-interacted light; actuating a moveable assembly comprising a first and second optical element; optically interacting the sample-interacted light with the first optical element to produce first optically-interacted light which corresponds to a characteristic of the sample, thereby forming an analytic channel; optically interacting the sample-interacted light with the second optical element to produce second optically-interacted light utilized to compensate the analytic channel, thereby forming a compensation channel, wherein the sample-interacted light is simultaneously optically interacted with the first and second optical elements; generating a first signal that corresponds to the analytic channel; generating a second signal that corresponds to the compensation channel; and determining the characteristics of the sample using the first and second signals.

[0068] 18. An optical computing method as defined in paragraph 17, wherein optically interacting the sample-interacted light with the first and second optical elements comprises: optically interacting the sample-interacted light with a beam splitter; splitting the sample-interacted light into a first and second portion; directing the first portion to the analytic channel; and directing the second portion toward the compensation channel.

[0069] 19. An optical computing method as defined in paragraphs 17 and 18, wherein: optically interacting the sample-interacted light with the first optical element comprises optically interacting the sample-interacted light with an Integrated Computational Element (“ICE”); and optically interacting the sample-interacted light with the second opti-

cal element comprises optically interacting the sample-interacted light with a neutral density element.

[0070] 20. An optical computing method as defined in any of paragraphs 17-19, wherein optically interacting the sample-interacted light with the first and second optical elements comprises optically interacting the sample-interacted light with Integrated Computational Elements (“ICEs”).

[0071] 21. An optical computing method as defined in any of paragraphs 17-20, wherein the moveable assembly further comprises: a plurality of analytic channels; and a plurality of compensation channels which correspond to the analytic channels, thus forming optical pairs.

[0072] 22. An optical computing method as defined in any of paragraphs 17-21, wherein: the moveable assembly is a rotating carousel; and actuating the moveable assembly comprises rotating the carousel.

[0073] 23. An optical computing method as defined in any of paragraphs 17-22, wherein: the moveable assembly is a linear array; and actuating the moveable assembly comprises moving the linear array along a single dimension, thereby sequencing the optical pairs to interact with the sample-interacted light.

[0074] 24. An optical computing method as defined in any of paragraphs 17-23, further comprising utilizing the optical computing device as part of a downhole reservoir interrogation system.

[0075] 25. An optical computing method as defined in any of paragraphs 17-24, wherein the moveable assembly comprises: a first carousel comprising a plurality of first optical elements; and a second carousel comprising a plurality of second optical elements which correspond to the first optical elements, thus forming optical pairs; and actuating the moveable assembly comprises rotating the first and second carousels.

[0076] 26. An optical computing method as defined in any of paragraphs 17-25, wherein the first and second carousels are synchronously rotated such that the optical pairs interact with the sample-interacted light in sequence.

[0077] 27. An optical computing method as defined in any of paragraphs 17-26, wherein optically interacting the sample-interacted light with the first and second optical elements comprises optically interacting the sample-interacted light with a beam splitter; splitting the sample-interacted light into a first and second portion; directing the first portion to the analytic channel; and directing the second portion toward the compensation channel.

[0078] 28. An optical computing method as defined in any of paragraphs 17-27, wherein: optically interacting the sample-interacted light with the first optical element comprises optically interacting the sample-interacted light with an Integrated Computational Element (“ICE”); and optically interacting the sample-interacted light with the second optical element comprises optically interacting the sample-interacted light with a neutral density element.

[0079] 29. An optical computing method as defined in any of paragraphs 17-28, wherein optically interacting the sample-interacted light with the first and second optical elements comprises optically interacting the sample-interacted light with Integrated Computational Elements (“ICEs”).

[0080] 30. An optical computing method as defined in any of paragraphs 17-29, further comprising utilizing the optical computing device as part of a downhole reservoir interrogation system.

[0081] Although various embodiments and methodologies have been shown and described, this disclosure is not limited to such embodiments and methodologies, and will be understood to include all modifications and variations as would be apparent to one ordinarily skilled in the art. Therefore, it should be understood that the embodiments are not intended to be limited to the particular forms disclosed. Rather, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of this disclosure as defined by the appended claims.

1. An optical computing device, comprising:
 - electromagnetic radiation that optically interacts with a sample to produce sample-interacted light;
 - a moveable assembly, comprising:
 - a first optical element that optically interacts with the sample-interacted light to produce first optically-interacted light which corresponds to a characteristic of the sample, thereby forming an analytic channel; and
 - a second optical element that optically interacts with the sample-interacted light to produce second optically-interacted light utilized to compensate the analytic channel, thereby forming a compensation channel,
 - wherein the first and second optical elements are positioned along the moveable assembly to simultaneously interact with the sample-interacted light;
 - a first detector positioned to measure the first optically-interacted light and generate a first signal; and
 - a second detector positioned to measure the second optically-interacted light and generate a second signal, wherein the first and second signals are utilized to determine the characteristics of the sample.
2. An optical computing device as defined in claim 1, further comprising:
 - a beam splitter positioned to split the sample-interacted light into a first and second portion, the first portion being directed to the analytic channel; and
 - an optical element positioned to direct the second portion toward the compensation channel.
3. An optical computing device as defined in claim 1, wherein:
 - the first optical element is an Integrated Computational Element (“ICE”) and the second optical element is a neutral density element; or
 - the first and second optical elements are ICES.
4. (canceled)
5. An optical computing device as defined in claim 1, wherein the moveable assembly comprises:
 - a plurality of analytic channels; and
 - a plurality of compensation channels which correspond to the analytic channels.
6. An optical computing device as defined in claim 5, wherein:
 - the moveable assembly is a carousel rotatably disposed about a center axis;
 - the analytic channels are positioned along an outer row of the carousel in relation to the center axis;
 - the compensation channels are positioned along an inner row of the carousel in relation to the center axis; and

corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair.

7. An optical computing device as defined in claim 5, wherein:
 - the moveable assembly is a linear array;
 - the analytic channels are positioned along a first row of the linear array;
 - the compensation channels are positioned along a second row of the linear array; and
 - corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair,
 - wherein the linear array is moveable in a single dimension to sequence the optical pairs to interact with the sample-interacted light.
8. An optical computing device as defined in claim 5, wherein:
 - the moveable assembly is a carousel; and
 - the analytic and compensation channels are positioned in an alternating row-like fashion along the carousel such that corresponding analytic and compensation channels are positioned beside each other, thus forming an optical pair.
9. An optical computing device as defined in claim 5, wherein:
 - the moveable assembly is a carousel rotatably disposed about a center axis;
 - the compensation channels are positioned along an outer row of the carousel in relation to the center axis;
 - the analytic channels are positioned along an inner row of the carousel in relation to the center axis; and
 - corresponding analytic and compensation channels are positioned beside each other in a column-fashion, thus forming an optical pair.
10. An optical computing device as defined in claim 1, wherein the moveable assembly comprises:
 - a first rotating carousel comprising the first optical element; and
 - a second rotating carousel comprising the second optical element.
11. An optical computing device as defined in claim 10, further comprising:
 - at least one motor coupled to the first and second rotating carousels in order to synchronously rotate the first and second rotating carousels; or
 - a beam splitter positioned to split the sample-interacted light into a first and second portion, the first portion being directed to the analytic channel and an optical element positioned to direct the second portion toward the compensation channel.
12. (canceled)
13. An optical computing device as defined in claim 10, wherein:
 - the first rotating carousel further comprises a plurality of analytic channels; and
 - the second rotating carousel further comprises a plurality of compensation channels which correspond to the analytic channels.
14. An optical computing device as defined in claim 1, further comprising:
 - an electromagnetic radiation source that generates the electromagnetic radiation; or

a signal processor communicably coupled to the first and second detector to computationally determine the characteristics of the sample.

15. (canceled)

16. An optical computing device as defined in claim 1, wherein the optical computing device comprises part of a downhole reservoir interrogation system.

17. An optical computing method, comprising:

optically interacting electromagnetic radiation with a sample to produce sample-interacted light;

actuating a moveable assembly comprising a first and second optical element;

optically interacting the sample-interacted light with the first optical element to produce first optically-interacted light which corresponds to a characteristic of the sample, thereby forming an analytic channel;

optically interacting the sample-interacted light with the second optical element to produce second optically-interacted light utilized to compensate the analytic channel, thereby forming a compensation channel,

wherein the sample-interacted light is simultaneously optically interacted with the first and second optical elements;

generating a first signal that corresponds to the analytic channel;

generating a second signal that corresponds to the compensation channel; and

determining the characteristics of the sample using the first and second signals.

18. An optical computing method as defined in claim 17, wherein optically interacting the sample-interacted light with the first and second optical elements comprises:

optically interacting the sample-interacted light with a beam splitter;

splitting the sample-interacted light into a first and second portion;

directing the first portion to the analytic channel; and directing the second portion toward the compensation channel.

19. An optical computing method as defined in claim 17, wherein:

optically interacting the sample-interacted light with the first optical element comprises optically interacting the sample-interacted light with an Integrated Computational Element (“ICE”); and

optically interacting the sample-interacted light with the second optical element comprises optically interacting the sample-interacted light with a neutral density element.

20. An optical computing method as defined in claim 17, wherein optically interacting the sample-interacted light with the first and second optical elements comprises optically interacting the sample-interacted light with Integrated Computational Elements (“ICEs”).

21. An optical computing method as defined in claim 17, wherein:

the moveable assembly further comprises a plurality of analytic channels and a plurality of compensation channels which correspond to the analytic channels, thus forming optical pairs;

the moveable assembly is a rotating carousel, and actuating the moveable assembly comprises rotating the carousel;

the moveable assembly is a linear array, and actuating the moveable assembly comprises moving the linear array along a single dimension, thereby sequencing the optical pairs to interact with the sample-interacted light; or

the moveable assembly comprises a first carousel having a plurality of first optical elements and a second carousel having a plurality of second optical elements which correspond to the first optical elements, thus forming optical pairs, the method further comprising actuating the moveable assembly comprises rotating the first and second carousels.

22. (canceled)

23. (canceled)

24. (canceled)

25. (canceled)

26. An optical computing method as defined in claim 21, wherein:

the first and second carousels are synchronously rotated such that the optical pairs interact with the sample-interacted light in sequence; or

optically interacting the sample-interacted light with the first and second optical elements comprises:

optically interacting the sample-interacted light with a beam splitter;

splitting the sample-interacted light into a first and second portion;

directing the first portion to the analytic channel; and directing the second portion toward the compensation channel.

27. (canceled)

28. An optical computing method as defined in claim 21, wherein:

optically interacting the sample-interacted light with the first optical element comprises optically interacting the sample-interacted light with an Integrated Computational Element (“ICE”) and optically interacting the sample-interacted light with the second optical element comprises optically interacting the sample-interacted light with a neutral density element;

optically interacting the sample-interacted light with the first and second optical elements comprises optically interacting the sample-interacted light with ICEs; or

the method further comprises utilizing the optical computing device as part of a downhole reservoir interrogation system.

29. (canceled)

30. (canceled)

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