METHODS OF ANALYZING A RESERVOIR FLUID SAMPLE DURING OR AFTER COLLECTION OF THE SAMPLE USING AN ANALYZER

Technical Field

[0001] A method of analyzing a sample using an analyzer is provided. According to an embodiment, the sample is a reservoir fluid. The sample can be analyzed during fluid flow either during or after collection of the sample. The sample can be analyzed for at least one property of the fluid. According to an embodiment, the sample is analyzed for two or more properties of the fluid.

Summary

[0002] According to an embodiment, a method of analyzing a fluid sample from a reservoir comprises: collecting the sample in a sample container, wherein the sample container includes a sample receptacle, and wherein the step of collecting comprises allowing or causing the sample to flow into the sample receptacle; determining at least one property of the sample using an analyzer, wherein the analyzer is located at one end of the sample receptacle, wherein the step of determining comprises: (A) contacting the sample with radiated energy; and (B) detecting the interaction between the radiated energy and the sample, wherein the step of determining is performed during the step of collecting, and wherein the step of determining is performed during fluid flow of the sample into the sample receptacle.

[0003] According to another embodiment, a method of analyzing a fluid sample from a reservoir comprises: collecting the sample in a sample container; transferring the sample from

the sample container to a second container, wherein the step of transferring is performed after the step of collecting; and determining at least one property of the sample using an analyzer, wherein the step of determining comprises: (A) contacting the sample with radiated energy; and (B) detecting the interaction between the radiated energy and the sample, wherein the step of determining is performed after the step of collecting, and wherein the step of determining is performed during fluid flow of the sample.

Brief Description of the Figures

[0004] The features and advantages of certain embodiments will be more readily appreciated when considered in conjunction with the accompanying figures. The figures are not to be construed as limiting any of the preferred embodiments.

[0005] **Fig. 1** is a diagram of a sample container including a sample receptacle.

[0006] **Fig. 2** is a diagram of an analyzer for analyzing one or more properties of a sample.

[0007] **Fig. 3** is a diagram of the analyzer from **Fig. 2** according to an embodiment depicting analysis of the sample during collection of the sample.

[0008] **Fig. 4** is a diagram of the analyzer from **Fig. 2** according to another embodiment depicting analysis of the sample during transference of the sample.

Detailed Description

[0009] As used herein, the words “comprise,” “have,” “include,” and all grammatical variations thereof are each

intended to have an open, non-limiting meaning that does not exclude additional elements or steps.

[0010] It should be understood that, as used herein, “first,” “second,” “third,” *etc.*, are arbitrarily assigned and are merely intended to differentiate between two or more analyzers, heating elements, *etc.*, as the case may be, and does not indicate any sequence. Furthermore, it is to be understood that the mere use of the term “first” does not require that there be any “second,” and the mere use of the term “second” does not require that there be any “third,” *etc.*

[0011] As used herein, a “fluid” is a substance having a continuous phase that tends to flow and to conform to the outline of its container when the substance is tested at a temperature of 71 °F (22 °C) and a pressure of one atmosphere "atm" (0.1 megapascals "MPa"). A fluid can be a liquid or gas. A fluid can have only one phase or more than one phase. In the oil and gas industry, a fluid having only one phase is commonly referred to as a single-phase fluid and a fluid having more than one phase is commonly referred to as a multi-phase fluid. A colloid is an example of a multi-phase fluid. A colloid can be: a slurry, which includes a continuous liquid phase and undissolved solid particles as the dispersed phase; an emulsion, which includes a continuous liquid phase and at least one dispersed phase of immiscible liquid droplets; a foam, which includes a continuous liquid phase and a gas as the dispersed phase; or a mist, which includes a continuous gas phase and liquid droplets as the dispersed phase.

[0012] Oil and gas hydrocarbons are naturally occurring in some subterranean formations. A subterranean formation containing oil or gas is sometimes referred to as a reservoir. A reservoir may be located under land or off shore. In order to

produce oil or gas, a wellbore is drilled into a reservoir or adjacent to a reservoir.

[0013] A well can include, without limitation, an oil, gas, or water production well, or an injection well. As used herein, a “well” includes at least one wellbore. A wellbore can include vertical, inclined, and horizontal portions, and it can be straight, curved, or branched. As used herein, the term “wellbore” includes any cased, and any uncased, open-hole portion of the wellbore. A near-wellbore region is the subterranean material and rock of the subterranean formation surrounding the wellbore. As used herein, a “well” also includes the near-wellbore region. As used herein, the phrase "into a well" includes into any portion of the wellbore or into the near wellbore region via the wellbore.

[0014] In the oil and gas industry it is often desirable to analyze a portion of a reservoir fluid because a reservoir fluid can contain one or more substances that might be detrimental to wellbore operations. For example, a wellbore fluid can contain a corrosive substance that might be harmful to wellbore equipment, such as pumping equipment or pipes. Examples of corrosive substances include, but are not limited to, high amounts of an acid gas, such as carbon dioxide gas (acid gas wells) and wells containing high amounts of a sour gas, such as hydrogen sulfide gas (sour gas wells).

[0015] Another potentially detrimental substance is an asphaltene. If asphaltenes are present in the reservoir fluid, then generally they are in solution due to being stabilized by resins. However, if the relative resin content decreases, then the asphaltenes may precipitate out of the fluid and deposit on pipe walls, restricting or interrupting fluid flow. It is relatively costly to remove such asphalt deposits, which may require grinding or scraping operations for removal. Other

potentially detrimental substances are aromatics and naphthanates. When combined with water, aromatics and naphthanates can cause foaming of the solution, somewhat like when water is combined with soap. The foam can also restrict or interrupt fluid flow.

[0016] Another potentially detrimental substance is a gas hydrate. Generally, a substance containing between one and six carbon atoms (C_1 to C_6) is a gas at wellbore temperatures and pressures. However, during wellbore operations, depending on the temperature at the wellhead, some or all of the gas may form gas hydrates. Gas hydrates occur naturally onshore in permafrost regions, and at certain depths in the sea where water and gas combine at low temperatures and high pressures to form the hydrate. Methane (C_1), or natural gas, is typically the dominant gas in the hydrate structure. As gas emerges from the wellhead, water molecules from the surrounding environment form a cage-like structure around high concentrations of the gas molecules and freeze into a solid gas/water structure. If a sufficient amount of gas hydrates form, the hydrates can block or clog valves and pipes leading to the surface from the cap. As such it may be desirable to test a reservoir fluid for its gas-to-oil (GOR) ratio. This ratio, along with the temperature at the wellhead, can be useful in predicting the likelihood of gas hydrate formation.

[0017] It is often desirable to take a sample of a reservoir fluid. There are a variety of instruments that can be used to collect a sample of formation fluids. One such instrument is the ARMADA® sampling system, marketed by Halliburton Energy Services, Inc. In order to collect a sample, the sampling system is placed into a wellbore at a desired location. The sampling system functions to collect multiple samples of the reservoir fluid at that location. The ARMADA®

sampling system is currently able to collect up to nine unique samples of the reservoir fluid per trip. The sampling system is then returned to the surface where the samples can be retrieved from the system.

[0018] A collected sample is generally sent to an off-site laboratory for analysis. It can be quite costly to analyze each collected sample. Furthermore, the sampling containers may not be compliant with a country's transportation regulations. In these instances, the sample is often times transferred into a shipping container that is regulation compliant. It can be expensive and time consuming to transfer multiple samples to compliant containers for laboratory analysis.

[0019] There are several devices that can be used to analyze a fluid. Some devices are designed to be used in a laboratory setting and other devices can be used in a well or at or near the well site. A spectrometer is an example of a device that can be used to analyze a fluid. Spectroscopy is the study of the interaction between matter and radiated energy. Generally, an energy source, such as light, is directed onto and possibly through a sample. A detector can then detect the light emitted from the source after the light passes through the sample. One of the central concepts in spectroscopy is a resonance and its corresponding resonant frequency. Spectroscopic data is often represented by a spectrum, a plot of the response of interest as a function of wavelength or frequency. A plot of amplitude versus excitation frequency will have a peak centered at the resonance frequency. This plot is one type of spectrum, with the peak often referred to as a spectral line, and most spectral lines have a similar appearance.

[0020] Spectroscopy can be classified based on the type of the radiative energy source, the nature of the interaction,

or the type of material of the sample. The types of radiative energy can include electromagnetic radiation, particles, acoustic, and mechanical. Techniques that employ electromagnetic radiation are typically classified by the wavelength region of the spectrum and include microwave, terahertz, far infrared, infrared, near infrared, visible, ultraviolet, x-ray and gamma spectroscopy. A wavelength is the distance over which a wave repeats itself, is inversely proportional to the frequency, and is reported in units of length (*e.g.*, micrometers, nanometers, or meters). The higher the frequency the shorter the wavelength and the lower the frequency the longer the wavelength. The frequency is the number of occurrences per unit of time, reported in units of seconds. A wavenumber is proportional to the reciprocal of the wavelength, reported in units of inverse meters (m^{-1}) or inverse centimeters (cm^{-1}). The wavelength regions for each type of electromagnetic radiation are different. For example, the near infrared region has a wavelength of approximately 800 nanometers (nm) to 2500 nm; whereas, the ultraviolet region has a wavelength of approximately 10 nm to 400 nm. Uncharged and charged particles, due to their de Broglie wavelength, can also be a source of radiative energy and electrons, protons, and neutrons are commonly used. For a particle, its kinetic energy determines its wavelength. Acoustic spectroscopy involves the use of radiated pressure waves. Mechanical methods can be employed to impart radiating energy, similar to acoustic waves, to solid materials.

[0021] Types of spectroscopy can also be distinguished by the nature of the interaction between the energy and the material. These interactions include absorption, emission, elastic scattering and reflection, impedance, inelastic scattering, and coherent interactions. Absorption occurs when

energy from the radiative source is absorbed by the material. Absorption is often determined by measuring the fraction of energy transmitted through the material, wherein absorption will decrease the transmitted portion. Emission indicates that radiative energy is released by the material. A material's blackbody spectrum is a spontaneous emission spectrum determined by its temperature. Emission can be induced by electromagnetic radiation in the case of fluorescence. Elastic scattering and reflection spectroscopy determine how incident radiation is reflected or scattered by a material. Impedance spectroscopy studies the ability of a medium to impede or slow the transmittance of energy. Inelastic scattering involves an exchange of energy between the radiation and the matter that shifts the wavelength of the scattered radiation. These include Raman and Compton scattering. Coherent or resonance spectroscopy are techniques where the radiative energy couples two quantum states of the material in a coherent interaction that is sustained by the radiating field. The coherence can be disrupted by other interactions, such as particle collisions and energy transfer, and thus, often require high intensity radiation to be sustained. Nuclear magnetic resonance (NMR) spectroscopy is a widely used resonance method and ultrafast laser methods are also now possible in the infrared and visible spectral regions.

[0022] It would be advantageous to analyze a reservoir fluid sample either during collection or after collection and prior to transportation of the sample to an off-site laboratory. By being able to analyze collected samples prior to shipment to the off-site laboratory, more informed decisions can be made at the well site, such as which, if any, samples should be sent off-site for further analysis. Being able to reduce the total number of samples sent off-site can save money and time. Thus,

there is a need for analyzing a reservoir fluid sample for at least one property during or after collection, but prior to the sample being transported off-site.

[0023] According to an embodiment, a method of analyzing a fluid sample from a reservoir comprises: collecting the sample in a sample container, wherein the sample container includes a sample receptacle, and wherein the step of collecting comprises allowing or causing the sample to flow into the sample receptacle; determining at least one property of the sample using an analyzer, wherein the analyzer is located at one end of the sample receptacle, wherein the step of determining comprises: (A) contacting the sample with radiated energy; and (B) detecting the interaction between the radiated energy and the sample, wherein the step of determining is performed during the step of collecting, and wherein the step of determining is performed during fluid flow of the sample into the sample receptacle.

[0024] According to another embodiment, a method of analyzing a fluid sample from a reservoir comprises: collecting the sample in a sample container; transferring the sample from the sample container to a second container, wherein the step of transferring is performed after the step of collecting; and determining at least one property of the sample using an analyzer, wherein the step of determining comprises: (A) contacting the sample with radiated energy; and (B) detecting the interaction between the radiated energy and the sample, wherein the step of determining is performed after the step of collecting, and wherein the step of determining is performed during fluid flow of the sample.

[0025] Any discussion of the embodiments regarding the analysis of the sample is intended to apply to all of the method embodiments. Any discussion of a particular component of an

embodiment (*e.g.*, a heating element) is meant to include the singular form of the component and also the plural form of the component, without the need to continually refer to the component in both the singular and plural form throughout. For example, if a discussion involves "the heating element **90**," it is to be understood that the discussion pertains to one heating element (singular) and two or more heating elements (plural).

[0026] Turning to the Figures. **Fig. 1** depicts a sample container **300** according to an embodiment. The methods include the step of collecting a sample in the sample container **300**. According to an embodiment, the sample container **300** is part of the ARMADA® sampling system, marketed by Halliburton Energy Services, Inc. The sample container **300** includes a sample receptacle **30**. The sample receptacle **30** can have two ends; a first end and a second end. The sample receptacle **30** can include a first opening. The sample receptacle **30** can also include a second opening. The openings can be located at the first and second ends. The sample receptacle **30** can contain the sample **34**. The sample **34** can be collected in the sample container **300** by introducing the sample **34** into the sample receptacle **30** via the first and/or second openings. The sample **34** can be a substance, such as a solid, liquid, gas, or combinations thereof. For example, the sample can be a slurry, emulsion, foam, or mist. According to an embodiment, the sample is a reservoir fluid.

[0027] The sample container **300** can further comprise a valve **35**. The valve **35** can be a one-way valve. As used herein, the term "one-way valve" means a device that allows a fluid to enter a space within an enclosed area in one direction, but does not independently allow the fluid to exit the space in a reverse direction. Of course, a one-way valve may have a release mechanism whereby a person can activate the mechanism thereby

causing at least some of the fluid within the sample retaining space to flow out of the enclosed area. However, the one-way valve should be designed such that any fluid that enters the space will not freely flow back out of that space without external intervention. As can be seen in **Fig. 1**, the valve **35** can be positioned in a first opening of the sample receptacle **30**. More than one valve **35** can be located in the sample receptacle **30**. According to an embodiment, the step of collecting comprises allowing or causing the sample **34** to flow into the sample receptacle **30**. The sample can be introduced into the sample receptacle **30** via the valve **35** positioned in the first opening of the sample receptacle **30**. In this manner, the sample can be contained inside the sample receptacle **30** until such time when it is desirable to remove the sample from the sample receptacle **30**. The sample container **300** can further include a pressurization compartment (not shown). The pressurization compartment can be used to help maintain the sample **34** in a single phase.

[0028] The sample container **300** can further comprise at least one seal **37**. The seal **37** can be positioned adjacent to the sample receptacle **30**. The seal **37** can be positioned at either end of the sample receptacle **30**. The sample container **300** can also include two or more seals. One seal **37** can be positioned at the first end of the sample receptacle **30** and the other seal (not shown) can be positioned at the second end of the sample receptacle **30**. According to an embodiment, the seal is designed such that once in place, a sample **34** located within the sample receptacle **30** is not capable of independently exiting the sample receptacle **30**. By including two or more seals, any sample **34** located within the sample receptacle **30** can be contained.

[0029] The seal **37** can be permanently or removably attached to the sample container **300**. By way of example, the seal **37** can be removably attached to the sample receptacle **30**. In this manner, once a sample has been collected and is located inside the sample receptacle **30**, the sample can be contained within the sample receptacle **30** by attaching the seal **37** to an end of the sample receptacle **30**. Moreover, in the event it is desirable to remove the sample **34** from the sample receptacle **30**, then the seal **37** can be removed. The seal **37** can include an opening.

[0030] The methods include the step of collecting the sample **34** in the sample container **300**. The step of collecting can include placing the sample container **300** into a well. The step of collecting can comprise allowing or causing the sample **34** to flow into the sample receptacle **30**. The methods can further include the step of removing the sample container **300** from the well, wherein the step of removing can be performed after the step of collecting. By way of example, once the sample **34** is collected, the sample container **300** can be returned to the surface. The methods can further include the step of retrieving the sample receptacle **30** from the sample container **300**, wherein the step of retrieving is performed after the step of collecting and/or after the step of removing. The methods can further include the step of attaching one or more seals **37** to the ends of the sample receptacle **30**, wherein the step of attaching is performed after the step of retrieving. In this manner, the sample **34** can be contained within the sample receptacle **30**. The sample **34** can then be stored, analyzed, transferred, or transported to an off-site location.

[0031] The methods include the step of determining at least one property of the sample **34** using an analyzer. The at least one property can be selected from the group consisting of:

asphaltenes; saturates; resins; aromatics; solid particulate content; hydrocarbon composition and content; gas composition C_1 - C_{13} and content; carbon dioxide gas; hydrogen sulfide gas; and correlated pressure, volume, or temperature properties including fluid compressibility, gas-to-oil ratio, bubble point, density, a petroleum formation factor, viscosity, a gas component of a gas phase of a petroleum, total stream percentage of water, gas, oil, solid particles, solid types, oil finger printing, reservoir continuity, and oil type; water elements including ion composition and content, anions, cations, salinity, organics, pH, mixing ratios, tracer components, contamination; or other hydrocarbon, gas, solids, or water properties that can be related to spectral characteristics, including the use of regression methods.

[0032] Turning to **Fig. 2**, the at least one property is determined using an analyzer **20**. The analyzer **20** may be an optical analyzer, such as a spectrometer. According to an embodiment, the analyzer **20** includes a source of radiated energy **22** and a detector **24**. The source of radiated energy **22** can be a light source. The source of radiated energy **22** and the detector **24** may be selected from all available spectroscopy technologies.

[0033] Any available spectroscopy method can be used in the determination of the at least one property of the sample **34** or two or more properties of the sample. The spectroscopy can be selected from the group consisting of absorption spectroscopy, fluorescence spectroscopy, X-ray spectroscopy, plasma emission spectroscopy, spark or arc (emission) spectroscopy, visible absorption spectroscopy, ultraviolet (UV) spectroscopy, infrared (IR) spectroscopy (including near-infrared (NIR) spectroscopy, mid-infrared (MIR) spectroscopy, and far-infrared (FIR) spectroscopy), Raman spectroscopy, coherent anti-Stokes Raman spectroscopy (CARS), nuclear magnetic

resonance, photo emission, Mossbauer spectroscopy, acoustic spectroscopy, laser spectroscopy, Fourier transform spectroscopy, and Fourier transform infrared spectroscopy (FTIR) and combinations thereof. The exact spectroscopy method utilized may vary depending on the desired property to be determined. According to an embodiment, the spectroscopy method utilized is selected such that the desired property of the sample **34** is capable of being detected, and preferably quantified.

[0034] The step of determining includes contacting the sample **34** with radiated energy. The analyzer **20** can include the source of radiated energy **22**. The source of radiated energy **22** can be ionizing radiation or non-ionizing radiation. The source of radiated energy **22** can be selected from the group consisting of a tunable source, a broadband source (BBS), a fiber amplified stimulated emission (ASE) source, black body radiation, enhanced black body radiation, a laser, infrared, supercontinuum radiation, frequency combined radiation, fluorescence, phosphorescence, and terahertz radiation. A broadband light source is a source containing the full spectrum of wavelengths, generally ranging from about 720 nm to about 1,620 nm. In an embodiment, the source of radiated energy **22** includes any type of infrared source.

[0035] The source of radiated energy **22** (*e.g.*, light) can be emitted in a desired wavelength or range of wavelengths. The desired wavelength or range can be determined based on the desired property of the sample to be determined. According to an embodiment, the desired wavelength or range of wavelengths is selected such that the at least one property of the sample can be determined. For example, if the desired property to be determined is carbon dioxide (CO_2), then the desired wavelength can be selected to be 4,300 nanometers (nm) as CO_2 has an

absorption peak at that wavelength. The light emitted can also be in a range that encompasses the desired wavelength. For example, to detect CO_2, the light emitted can be in the mid-infrared range of approximately 2,500 to 25,000 nm. By way of another example, hydrogen sulfide gas (H_2S) can present absorption peaks at 1,900, 2,300, 2,600, 3,800 and 4,100 nm. According to this example the light emitted can include the entire IR spectrum or the NIR and MIR ranges of 800 to 2,500 nm and 2,500 to 25,000 nm, respectively. By way of another example, CH_4 and Gas-to-Oil ratio (GOR) can present absorption peaks at approximately 1,700 and 2,300 nm; whereas aromatics can present an absorption peak at approximately 2,450 nm. Accordingly, the light emitted can be in the near IR range.

[0036] According to an embodiment, the methods include the step of determining two or more properties of the sample **34**. A separate analyzer **20**, depicted as **20'** in the Figures, can be used for each property to be determined. Of course each analyzer **20** can also be designed such that each analyzer is capable of determining two or more properties of the sample **34**. According to this embodiment, the wavelength or wavelength range can be selected such that the two or more properties of the sample **34** can be determined. By way of example, in order to determine if both CO_2 and H_2S are present in the sample, the wavelength range can be selected to be the MIR range of approximately 2,500 to 25,000 nm. In this manner, should CO_2 and H_2S both be present in the sample, then absorption peaks would indicate such presence. By way of another example, in order to determine if both CH_4 and aromatics are present in the sample, the wavelength range can be selected to be the NIR range of approximately 800 to 2,500 nm. In an embodiment the source of radiated energy **22** is directed to the sample **34** in order to determine the two or more properties. The source of radiated

energy **22** can transmit light rays in a range of from 4,000 to 5,000 nm, which is a range for absorbance of carbon dioxide. Using Beer's Law and assuming a fixed path length, the amount of carbon dioxide in the sample **34** is proportional to the absorption of light in this range. The source of radiated energy **22** can also transmit light rays in a range of from 1,900 to 4,200 nm, which is a range for absorbance of hydrogen sulfide. Data collected from these two wavelength ranges may provide information for determining the presence and possibly the amount of carbon dioxide and hydrogen sulfide in the sample **34**.

[0037] The source of radiated energy **22** can be a light source. The light source can be in the IR range. According to an embodiment, the IR light source is a MIR range light source. In an embodiment the MIR range light source is a tunable light source. The tunable light source may be selected from the group of an optical parametric oscillator (OPO) pumped by a pulsed laser, a tunable laser diode, and a broadband source (BBS) with a tunable filter. In an embodiment, the tunable MIR light source is adapted to cause pulses of light to be emitted at or near the absorption peak of the at least one property of the sample **34**.

[0038] The water content of the sample can be determined in any manner and can be determined by optical or non-optical means. According to an embodiment, the water content in the sample and the compensation, if any, of the optical response shifts for the determination of at least one property of the sample can be determined.

[0039] If the tunable light source is a broadband source, then detection of the at least one property of the sample **34** may be improved by applying frequency modulation to the broadband source signal by modulating the drive current or

by chopping so that unwanted signals can be avoided in the detector of the spectrometer by using phase sensitive detection. The broadband source may be pulsed with or without frequency modulation.

[0040] In an embodiment the source of radiated energy **22** can include a laser diode array. In a laser diode array light source system, desired wavelengths are generated by individual laser diodes. The output from the laser diode sources may be controlled in order to provide signals that are arranged together or in a multiplexed fashion. By utilizing a laser diode array light source, time and/or frequency division multiplexing may be accomplished at the spectrometer. A one-shot measurement or an equivalent measurement may be accomplished with the laser diode array. A probe-type or sample-type optical cell system may also be utilized.

[0041] The step of determining also comprises detecting the interaction between the radiated energy and the sample **34**. The detection of the interaction can occur via the use of at least one detector **24**. According to an embodiment, the analyzer **20** can include at least one detector **24**. According to an embodiment, the detector **24** is capable of detecting the interaction between the radiated energy and the sample **34**. The radiated energy can be partially or fully absorbed by the sample **34**, wherein some or none of the radiated energy is then transmitted through the sample. According to an embodiment, the detector **24** is capable of detecting the amount of radiated energy that is absorbed and/or transmitted by the sample **34**. The effectiveness of the detector **24** may be dependent upon temperature conditions. Generally, as temperatures increase, the detector **24** becomes less sensitive. The detector **24** can include a mechanism whereby thermal noise is reduced and sensitivity to emitted radiated energy is increased. The

detector **24** can be selected from the group consisting of thermal piles, photo acoustic detectors, thermoelectric detectors, quantum dot detectors, momentum gate detectors, frequency combined detectors, high temperature solid gate detectors, and detectors enhanced by meta materials such as infinite index of refraction, and combinations thereof.

[0042] The source of radiated energy **22** can also include a splitter. For example, a light that is emitted can be split into two separate beams in which one beam passes through the sample **34** and the other beam passes through a reference sample. Both beams are subsequently directed to a splitter before passing to the detector **24**. The splitter quickly alternates which of the two beams enters the detector. The two signals are then compared in order to determine the property of the sample **34**.

[0043] The spectroscopy can be performed by a diffraction grating or optical filter, which allows selection of different narrow-band wavelengths from a white light or broadband source. A broadband source can be used in conjunction with Fiber Bragg Grating (FBG). FBG includes a narrow band reflection mirror whose wavelength can be controlled by the FBG fabrication process. The broadband light source can be utilized in a fiber optic system. The fiber optic system can contain a fiber having a plurality of FBGs. Accordingly, the broadband source is effectively converted into a plurality of discrete sources having desired wavelengths.

[0044] The spectroscopy can also be Fourier spectroscopy. Fourier spectroscopy, or Fourier transform spectroscopy, is a method of measurement for collecting spectra. In Fourier transform spectroscopy, rather than allowing only one wavelength at a time to pass through the sample to the detector, this technique lets through a beam containing many different

wavelengths of light at once, and measures the total beam intensity. Next, the beam is modified to contain a different combination of wavelengths, giving a second data point. This process is repeated many times. Afterwards, a computer takes all this data and works backwards to infer how much light there is at each wavelength. The analyzer **20** can include one or more mirrors used to select the desired wavelengths to pass through the sample **34** to the detector **24**. There can be a certain configuration of mirrors that allows some wavelengths to pass through but blocks others (due to wave interference). The beam can be modified for each new data point by moving one of the mirrors; this changes the set of wavelengths that can pass through. The analyzer **20** can internally generate a fixed and variable length path for the optical beam and then recombine these beams, thereby generating optical interference. The resulting signal includes summed interference pattern for all wavelengths not absorbed by the sample. As a result, the measurement system is not a one-shot type system, and hence the sampler-type probe is preferred for use with this type of spectrometer.

[0045] The Fourier spectroscopy can utilize an IR light source, also referred to as Fourier transform infrared (FTIR) spectroscopy. In an embodiment, IR light is guided through an interferometer, the IR light then passes through the sample **34**, and a measured signal is then obtained, called the interferogram. In an embodiment Fourier transform is performed on this signal data, which results in a spectrum identical to that from conventional infrared spectroscopy. The benefits of FTIR include a faster measurement of a single spectrum. The measurement is faster for the FTIR because the information at all wavelengths is detected simultaneously.

[0046] As can be seen in **Fig. 2**, the step of determining at least one property of the sample can further comprise transmitting data from the detector **24** to a computer **12**. The computer **12** can be used to analyze the data from the detector **24** such that the presence of one or more properties of the sample **34** can be determined. The computer **12** can also be used to quantify the amount of the one or more properties in the sample **34**. Either the raw detector data outputs may be sent to the computer **12**, or the signals may be subtracted with an analog circuit and magnified with an operational amplifier converted to voltage and sent to the computer **12** as a proportional signal, for example. In this manner, one can quickly determine which samples, if any, might need to be stored or sent off-site to a laboratory for further testing. By being able to determine the one or more properties of collected samples, allows workers to effectively determine whether more sampling needs to be performed and also decrease costs and time in sending every sample collected off-site for testing.

[0047] As can be seen in **Figs. 2 and 3**, the sample **34** may be located between the source of radiated energy **22** and the detector **24**. As can be seen in **Fig. 3**, the analyzer can include a housing **26**. The housing **26** can contain the source of radiated energy **22** and the detector **24**. The housing **26** can be magnetized metal or stainless steel and may have appropriate protective coatings. The housing **26** can be circular, cylindrical, or rectangular. The housing **26** is preferably constructed so that it is readily attachable and detachable from a tube **72**. The tube **72** preferably includes a circular or rectangular opening forming a window that is transparent to the radiated energy. In this manner, the radiated energy can penetrate through the opening and come in contact with the sample **34** flowing through the tube **72**. The interaction between the radiated energy and

the sample **34** can then be detected via the detector **24** and another opening in the tube **72** adjacent to the detector.

[0048] According to an embodiment, the step of determining is performed during the step of collecting the sample **34** and is performed during fluid flow of the sample **34** into the sample receptacle **30**. The following is one example of use according to this embodiment. The sample container **300** can be introduced into a well. As can be seen in **Fig. 1**, the analyzer **20** can be located at one end of the sample receptacle **30**. One or more samples **34** can flow or be caused to flow through the tube **72**, in fluid flow direction **54** and into one or more sample receptacles **30**. As the one or more samples **34** flow into each sample receptacle **30**, the analyzer **20** can be used to determine one or more properties of the fluid. The analyzer **20** determines the presence and also possibly the amount of the property in real time and reports that information instantaneously as it occurs in the sample **34**. Each sample container **300** can contain a plurality of sample receptacles **30**. Moreover, there can be more than one sample container **300** and there can also be more than one analyzer **20**. If there is more than one sample container **300**, then a first analyzer **20** can be positioned adjacent to a first sample container **300** and a second analyzer **20'** can be positioned adjacent to a second sample container **300**, *etc*. One analyzer **20** can be designed to determine a first property of the sample **34**, while another analyzer **20'** can be designed to determine a second property of the sample **34**.

[0049] It is often desirable to transfer a collected sample into a storage container. The sample can be stored and/or transported off-site to another location for further analysis. According to an embodiment, and as can be seen in **Fig. 4**, the methods include the step of transferring the sample

34 from the sample container **300** to a second container **80**, wherein the step of transferring is performed after the step of collecting. The second container **80** can be a storage or transportation container. This may be desirable, for example, if the sample container **300** does not meet transportation regulations and the sample needs to be transported off-site. The sample **34** can be transferred via a tube **72**. The tube **72** can be connected to the sample container **300** in a variety of ways, for example, in a manner such that the sample **34** is capable of being removed from the sample receptacle **30** and placed into the second container **80**. By way of example, the sample container **300** can contain a female end **31** that is capable of connecting to a male end **71** of the tube **72**. The ends can be threaded together, for example, via threads **33** on the female end **31**. The female end **31** can also include a seal **37**. The seal **37** can be removed prior to attaching the tube **72** to the sample container **300**. The sample **34** can be transferred via a variety of means, for example, via a piston **50**. This way, the sample **34** can flow from the sample receptacle **30**, through the tube **72**, and into the second container **80**. The sample **34** can also be heated via one or more heating elements **90 and 90'**.

[0050] According to an embodiment, the step of determining the at least one property of the sample is performed after the step of collecting and is performed during fluid flow of the sample. The step of determining the at least one property of the sample **34** can be performed during the step of transferring the sample **34** from the sample container **300** to the second container **80**. One or more analyzers **20 and 20'** can be positioned adjacent to the tube **72**. In this manner, as the sample **34** is being transferred from the sample receptacle **30** into the second container **80**, the analyzer **20** can determine the at least one property of the sample **34**. As discussed above, a

first analyzer **20** can be designed to determine a first property of the sample **34** and a second analyzer **20'** can be designed to determine a second property of the sample. Moreover, one analyzer **20** can also be designed to determine two or more properties of the sample. There can also be more than two analyzers **20** located adjacent to the tube **72.**

[0051] The methods can further include the step of transporting one or more of the samples off-site, wherein the step of transporting can be performed after the step of determining. The results from the analyzer **20** can be useful in deciding which, if any, of the samples might need to be transported off-site. By being able to determine at least one property of the sample, workers are able to more accurately determine which samples may require further analysis at an off-site location. The information obtained by using the analyzer **20** on samples, particularly at a well site, can enable workers to obtain useful and oftentimes, essential information about the properties of a sample and the subterranean formation environment.

[0052] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is, therefore, evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. While compositions and methods are described in terms of “comprising,”

"containing," or "including" various components or steps, the compositions and methods also can "consist essentially of" or "consist of" the various components and steps. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b,") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an", as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent(s) or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

WHAT IS CLAIMED IS:

1. A method of analyzing a fluid sample from a reservoir comprising:

collecting the sample in a sample container,

wherein the sample container includes a sample receptacle, and

wherein the step of collecting comprises allowing or causing the sample to flow into the sample receptacle;

determining at least one property of the sample using an analyzer, wherein the analyzer is located at one end of the sample receptacle,

wherein the step of determining comprises:

(A) contacting the sample with radiated energy; and

(B) detecting the interaction between the radiated energy and the sample,

wherein the step of determining is performed during the step of collecting, and

wherein the step of determining is performed during fluid flow of the sample into the sample receptacle.

2. The method according to Claim 1, wherein the step of collecting comprises placing the sample container into a well.

3. The method according to Claim 1, wherein the at least one property is selected from the group consisting of: asphaltenes; saturates; resins; aromatics; solid particulate content; hydrocarbon composition and content; gas composition C_1 – C_{13} and content; carbon dioxide gas; hydrogen sulfide gas; and correlated pressure, volume, or temperature properties including fluid compressibility, gas-to-oil ratio, bubble point, density,

a petroleum formation factor, viscosity, a gas component of a gas phase of a petroleum, total stream percentage of water, gas, oil, solid particles, solid types, oil finger printing, reservoir continuity, and oil type; water elements including ion composition and content, anions, cations, salinity, organics, pH, mixing ratios, tracer components, contamination; or other hydrocarbon, gas, solids, or water properties that can be related to spectral characteristics, including the use of regression methods.

4. The method according to Claim 1, wherein the analyzer is an optical analyzer.

5. The method according to Claim 1, wherein the determination of the at least one property of the sample is performed using spectroscopy.

6. The method according to Claim 5, wherein the spectroscopy is selected from the group consisting of absorption spectroscopy, fluorescence spectroscopy, X-ray spectroscopy, plasma emission spectroscopy, spark or arc (emission) spectroscopy, visible absorption spectroscopy, ultraviolet (UV) spectroscopy, infrared (IR) spectroscopy (including near-infrared (NIR) spectroscopy, mid-infrared (MIR) spectroscopy, and far-infrared (FIR) spectroscopy), Raman spectroscopy, coherent anti-Stokes Raman spectroscopy (CARS), nuclear magnetic resonance, photo emission, Mossbauer spectroscopy, acoustic spectroscopy, laser spectroscopy, Fourier transform spectroscopy, and Fourier transform infrared spectroscopy (FTIR) and combinations thereof.

7. The method according to Claim 1, wherein the analyzer comprises a source of the radiated energy and a detector.

8. The method according to Claim 7, wherein the detector is capable of detecting the interaction between the radiated energy and the sample.

9. The method according to Claim 8, wherein the step of determining the at least one property of the sample further comprises transmitting data from the detector to a computer.

10. The method according to Claim 7, wherein the source of the radiated energy is emitted in a desired wavelength or range of wavelengths.

11. The method according to Claim 10, wherein the desired wavelength or range of wavelengths is selected such that the at least one property of the sample can be determined.

12. The method according to Claim 1, further comprising the step of determining two or more properties of the sample.

13. A method of analyzing a fluid sample from a reservoir comprising:

collecting the sample in a sample container;

transferring the sample from the sample container to a second container,

wherein the step of transferring is performed after the step of collecting; and

determining at least one property of the sample using an analyzer,

wherein the step of determining comprises:

(A) contacting the sample with radiated energy; and

(B) detecting the interaction between the radiated energy and the sample,

wherein the step of determining is performed after the step of collecting, and

wherein the step of determining is performed during fluid flow of the sample.

14. The method according to Claim 13, wherein the step of determining the at least one property of the sample is performed during the step of transferring the sample.

15. The method according to Claim 13, wherein the second container is a storage or transportation container.

16. The method according to Claim 13, wherein the sample is transferred to the second container via a tube.

17. The method according to Claim 16, wherein the analyzer is positioned adjacent to the tube.

18. The method according to Claim 13, further comprising the step of transporting the sample off-site, wherein the step of transporting is performed after the step of determining.

19. The method according to Claim 13, wherein the at least one property is selected from the group consisting of: asphaltenes; saturates; resins; aromatics; solid particulate content; hydrocarbon composition and content; gas composition C_1 – C_{13} and content; carbon dioxide gas; hydrogen sulfide gas; and correlated pressure, volume, or temperature properties including fluid compressibility, gas-to-oil ratio, bubble point, density, a petroleum formation factor, viscosity, a gas component of a gas phase of a petroleum, total stream percentage of water, gas, oil, solid particles, solid types, oil finger printing, reservoir continuity, and oil type; water elements including ion composition and content, anions, cations, salinity, organics, pH, mixing ratios, tracer components, contamination; or other hydrocarbon, gas, solids, or water properties that can be related to spectral characteristics, including the use of regression methods.

20. The method according to Claim 13, wherein the analyzer is an optical analyzer.

21. The method according to Claim 13, wherein the determination of the at least one property of the sample is performed using spectroscopy.

22. The method according to Claim 21, wherein the spectroscopy is selected from the group consisting of absorption spectroscopy, fluorescence spectroscopy, X-ray spectroscopy, plasma emission spectroscopy, spark or arc (emission)

spectroscopy, visible absorption spectroscopy, ultraviolet (UV) spectroscopy, infrared (IR) spectroscopy (including near-infrared (NIR) spectroscopy, mid-infrared (MIR) spectroscopy, and far-infrared (FIR) spectroscopy), Raman spectroscopy, coherent anti-Stokes Raman spectroscopy (CARS), nuclear magnetic resonance, photo emission, Mossbauer spectroscopy, acoustic spectroscopy, laser spectroscopy, Fourier transform spectroscopy, and Fourier transform infrared spectroscopy (FTIR) and combinations thereof.

23. The method according to Claim 13, wherein the analyzer comprises a source of the radiated energy and a detector.

24. The method according to Claim 23, wherein the detector is capable of detecting the interaction between the radiated energy and the sample.

25. The method according to Claim 24, wherein the step of determining the at least one property of the sample further comprises transmitting data from the detector to a computer.

26. The method according to Claim 23, wherein the source of the radiated energy is emitted in a desired wavelength or range of wavelengths.

27. The method according to Claim 26, wherein the desired wavelength or range of wavelengths is selected such that the at least one property of the sample can be determined.

28. The method according to Claim 13, further comprising the step of determining two or more properties of the sample.