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CLINICAL SPECTROPHOTOMETER FOR GENERAL CHEMISTRY, IMMUNO-ASSAY AND NUCLEIC ACID DETECTION

Abstract

The single-use disposable spectrophotometer described herein can measure one or more blood chemistry analytes from a drop of whole blood. A passive filtration system takes whole blood and delivers plasma along with a dissolved reporter molecule to one or more spectrophotometers which can operate with narrow band optical spectrum centered on an optical detection frequency. The spectrophotometer detects the changes in absorption of the plasma as a result of a chemistry reaction to determine the concentration or activity of one or more analytes.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 17/929,291, filed September 1, 2022, which is a continuation of International Application No. PCT/US2021/023741, filed Mar. 23, 2021, which claims the benefit of U.S. Provisional Application Nos. 62/994,131, filed Mar. 4, 2020; and 63/009,190, filed Apr. 13, 2020, all of which are incorporated by reference herein.

TECHNICAL FIELD

[0002] The present disclosure relates to single-use, disposable, digital biosensors and integrated circuit-based biosensors with whole blood sample preparation.

BACKGROUND

[0003] A chemistry test can be used to measure the concentration or activity of one or more analytes, i.e., endogenous compounds, circulating in blood. These analytes are often small molecules such as ions, blood gases and enzymes. Examples of analytes include albumin, blood urea nitrogen, uric acid, calcium, carbon dioxide (bicarbonate), chloride, creatinine, glucose, potassium, sodium, magnesium, phosphorus, lactate, amylase, lactate dehydrogenase, direct bilirubin, total cholesterol, high-density lipoprotein cholesterol, triglycerides, total bilirubin, total protein, creatine kinase, alanine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST) and gamma glutamyltransferase. These chemistry tests are also commonly referred to as blood chemistries, general chemistries, basic or complete metabolic panels, chemistry panels or specific organ panels. The results from a chemistry test can provide insight into the function of the kidneys, liver, heart, pancreas, bones and lungs among other biological systems.

[0004] The results from a chemistry test can be critically time sensitive, yet the instruments capable of performing such measurements are often relegated to emergency departments and central laboratories and require burdensome calibration and maintenance.

[0005] Spectrophotometry was developed by Arnold Beckman in **1940**. While the testing modality for a variety of blood tests has evolved, spectrophotometry continues to be the bedrock of modern laboratory testing.

SUMMARY

[0006] The spectrophotometer can be miniaturized and integrated into a single-use disposable device. Users can place samples of blood from a finger-stick or venipuncture on the inlet of the device. The sample can be wicked into a membrane filtration sample preparation system, which can passively provide plasma to a disposable spectrophotometer for quantification of one or more analytes in the sample.

[0007] The spectrophotometer can have a variety of features: 1) the detection can be performed on undiluted samples, 2) the path length can be shorter than in conventional spectrophotometers, 3) the illumination can be from an LED emitting light with a narrow band optical spectrum, 4) the reflector can be made from injection molded plastic, 5) the reagents can be stored in a dry state in device and 6) there can be at least one photodiode per well, 7) the spectrophotometer can be integrated into a single-use, disposable device.

[0008] The device can be a single-use clinical spectrophotometer for measuring the concentration or activity of one or more analytes in a sample. The device can have: [0009] a filter module that can be mounted on surface, wherein filter module can comprise a filter, a prefilter and one or a plurality of lamination surfaces and wherein filter and prefilter and one or a plurality of lamination surfaces can be laminated together; [0010] wherein filter can be a plasma separation membrane, and wherein filter or prefilter can be impregnated with a reporter molecule; [0011] a surface that can fluidically connect filter with spectrophotometer, wherein plasma from filter can flow directly from surface into spectrophotometer; [0012] a chemical reaction that can be a homogenous reaction limited by the concentration or activity of analyte in plasma in well, and wherein reporter molecule can be a product or reactant to chemical reaction; [0013] a spectrophotometer that can contain an optical cavity, wherein optical cavity can be a fluid stop gap; [0014] wherein spectrophotometer can contain plasma with dissolved reporter molecule in suspension, wherein spectrophotometer can measure the rate of change or absolute change of the concentration of the reporter molecule in plasma in a well, and [0015] calculate a corresponding concentration or activity of an analyte in plasma in the well.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1A presents a cross-sectional side view of a device comprising a filter, a surface and a spectrophotometer.

[0017] FIG. 1B is a cross-sectional top view of IC and an LED mounted on a PCB.

[0018] FIG. 1C presents a cross-sectional top view of tape with channels mounted on PCB.

[0019] FIG. 1D shows a cross-sectional top view of filter, filter and AOW mounted on tape.

[0020] FIG. 1E is the top view of the device with a reflector.

[0021] FIG. 2 presents a cross-sectional side view of the device with IC9 IC 9 and filter 2 mounted above AOW 4.

[0022] FIG. 3 is a cross-sectional side view of the device wherein a cover is used to retain plasma in the well.

[0023] FIG. 4A shows a cross-sectional side view of an implementation of the device where a filter is mounted on AOW and AOW is mounted on PCB.

[0024] FIG. 4B presents a cross-sectional side view of an implementation of the device with two LEDs, and where a first and second LED are emitting light into the same well.

[0025] FIG. 5 shows the cross-sectional side view of a reflectance spectrophotometer implementation of the device.

[0026] FIG. 6 is a cross-sectional side view of the device wherein filter is in capillary.

[0027] FIG. 7 presents the cross-sectional side view of device inserted into port of reader.

[0028] FIG. 8 presents the top view of the device wherein light traverses the well laterally or a horizontally through well.

[0029] FIG. 9 shows the cross-sectional side view of device fitted with a vial.

[0030] FIG. 10 presents a cross-sectional side view of a filter module mounted on surface.

[0031] FIG. 11 presents the cross-sectional top view of tape with channel and enlargement on surface.

[0032] FIG. 12 presents the cross-sectional top view of filter module integrated with AOW.

[0033] FIG. 13 shows the cross-sectional side view of the reflector with cavity mounted on AOW with optic tape.

[0034] FIG. 14 presents the cross-sectional side view of top housing fitted into bottom housing 92 and applying pressure to crush filter module. 2

DETAILED DESCRIPTION

[0035] Spectrophotometer **15** can be an absorption spectrophotometer, wherein light **21** traverses through plasma **17** and wherein reporter molecule **56** can absorb part or all of light **21** traversing through plasma **17**. Spectrophotometer **15** can be a reflectance spectrophotometer, wherein light **21** reflects off plasma **17** and wherein reporter molecule **56** can absorb part or all of light **21** reflecting off plasma **17**. Spectrophotometer **15** can be a single frequency spectrophotometer.

Spectrophotometer **15** can operate using a narrow band optical spectrum, centered at optical detection frequency **60**. Spectrophotometer **15** can be configured to measure concentration or activity of analyte **36** in plasma **17**. Spectrophotometer **15** can be configured to measure the absolute or rate of change of the absorption of plasma **17** in well **19** at the optical detection frequency **60**.

[0036] Spectrophotometer **15** can be configured to measure the rate of or absolute change in the absorption of reporter molecule **56** in plasma **17** in well **19** at the optical frequency **60**.

Spectrophotometer **15** can comprise a surface capillary **22** that can fluidically connect filter **2** or surface **11** with well **19**. Spectrophotometer **15** can comprise a light emitting diode (LED) **5** capable of emitting light **21** with a peak frequency at optical detection frequency **60**. LED **5** can be capable of emitting light **21** with a narrow band optical spectrum. Spectrophotometer **15** can comprise a reflector **6** capable of redirecting light **21** at a detection frequency **60** through plasma **17** in well **19** and onto photodetector **8**. Reflector **6** can be capable of redirecting light **21** at a detection frequency **60** through plasma **17** normal to the detection plane of photodetector **8**.

Spectrophotometer **15** can comprise a photodetector **8** that can be sensitive to light **21** at a detection frequency **60**. Photodetector **8** can be capable of measuring the change over time of the transmittance of plasma **17** in well **19** at detection frequency **60**, resulting from the change over time of the concentration of reporter molecule **56** in plasma **17** in well **19**, corresponding to the concentration or activity of analyte **36** in plasma **17** in well **19**. Photodetector **8** can be capable of measuring the change over time of the transmittance of plasma **17** in well **19** at detection frequency **60**, resulting from the change over time of interferences. Photodetector **8** can be capable of measuring the change over time in the transmittance of reporter molecule **56** in plasma **17** in well **19** at detection frequency **60**.

[0037] Device **1** can analyze a variety of sample types such as whole blood, plasma, serum, plasma products, calibrators, purified solutions, tears, saliva and urine. Device **1** and spectrophotometer **15** can analyze aqueous samples in well **19**. Device **1** can be used to measure the plasma concentration of albumin, blood urea nitrogen, uric acid, calcium, carbon dioxide (bicarbonate), chloride, creatinine, glucose, potassium, sodium, magnesium, phosphorus, lactate, amylase, lactate dehydrogenase, direct bilirubin, total cholesterol, high-density lipoprotein cholesterol, triglycerides, total bilirubin, total protein, creatine kinase, alanine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST) and gamma-glutamyl transferase, and other analytes. An analyte can also be referred to as an endogenous compound.

Multiplexing

[0038] The optical detection frequency **60** can be 340 nm, 405 nm, 467 nm, 550 nm, 600 nm, 850 nm or other frequencies. Spectrophotometer **15** can comprise a plurality of wells, through which light **21** can travel to a plurality of photodetectors. Spectrophotometer **15** can contain a single reflector **6** and a single LED **5**, wherein reflector **6** has the necessary optical elements to split light **21** from a single LED **5** and redirect the split light through a plurality of wells onto a plurality of photodetectors. Each well can be above, below, adjacent, abutted or in proximity to a dedicated photodetector. Spectrophotometer **15** can have a plurality of wells, wherein each well can be each adjacent to a single photodetector. Device **1** can comprise a single filter **2** and a plurality of wells, such that plasma **17** from whole blood **16** can flow passively from filter **2**, across one or more surfaces into a plurality of wells. A plurality of spectrophotometers can share a single filter, such that plasma **17** from whole blood **16** can flow passively from filter **2** into a plurality of wells in a plurality of spectrophotometers. Device **1** can comprise one or more surfaces that can fluidically

connect one or more filters to one or more wells in one or more spectrophotometers. Device **1** can comprise a plurality of spectrophotometers, wherein the plurality of spectrophotometers can operate at different frequencies of detection. A plurality of spectrophotometers can share a single IC **9** or AOW **4**.

Reaction

[0039] Chemical reaction **35** can be composed of multiple reactions. Chemical reaction **35** can be homogeneous and label-free. Chemical reaction **35** can be limited by the concentration or activity of analyte **36** in plasma **17** in well **19**. For chemical reaction **35** to be limited by the concentration or activity of analyte **36**, the concentration or activity of analytes **36** can be rate limiting reagents in chemical reaction **35** or the concentration or activity of analytes **36** can be the endpoint limiting reagents in chemical reaction **35**. Reporter molecule **56** can be a product or reactant to chemical reaction **35**. Reporter molecule **56** can be in excess in chemical reaction **35** wherein reporter molecule **56** may not be the rate limiting reagent. Dissolved reagents **33** can be in excess in plasma **17** such that chemical reaction **35** can be limited by the concentration or activity of analyte **36**. Reporter molecule **56** or reporter reagent can be a molecule that can absorb light with a linear extinction coefficient, whereby changes in the concentration of reporter molecule **56** can be calculated using Beer-Lambert's law. Reporter molecule **56** can absorb light at the optical detection frequency **60**. Reporter molecule **56** can have an absorption peak at the optical detection frequency **60**.

[0040] Chemical reactions **35** can be a zero-order, pseudo-zero order, a first order or a higher order chemical reaction. In a rate measurement, the rate of reporter molecule **56** consumed or produced can be measured. This rate can be proportional to concentration or activity of one or more analytes in plasma **17**. In an endpoint measurement, the total amount of reporter molecule **56** consumed or produced can be measured. This amount can be proportional to a physiological concentration or activity of one or more analytes.

[0041] Chemical reaction **35** can alter the absorption of plasma **17** in well **19** at the optical detection frequency **60**. Chemical reaction **35** can alter the concentration of reporter molecule **56** in plasma **17** in well **19**. The change in concentration of reporter molecule **56** in plasma **17** in well **19** can change the absorption of plasma **17** in well **19** at the optical frequency of detection **60**. By measuring light absorption of plasma **17** in well **19** from the LED **5** at two different time points, and accounting for the time elapsed, a rate or endpoint measurement of reactions **35** can be calculated.

[0042] Surface **11** can be coated with surface reagents **30**. Surface **11** adjacent to gap **12** **28** can be coated with a hydrophilic reagent **31**, such as surface reagents **30**. Filter **2** can be coated or impregnated with filter reagents **32**. Well **19** can be coated on the inside with well reagents **34**. The bottom surface of AOW **4** can be coated with surface reagents **30** or well reagents **34**. Additional reagents **37** can be dried in the form of a dried sphere **38**. The dried sphere **38** can be placed at the top of well **19**, at the bottom of well **19**, inside well **19**, below the filter **2**, above the filter **2**, next to filter **2**, or in gap **12**. The dried sphere **38** can be manufactured through lyophilization. The diameter of the dried sphere **38** can be less than 2 mm, 1.5 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm, 0.2 mm, or 0.1 mm. The dried sphere **38** can dissolve when contacted with fluid, such as the plasma **17**. All the reagents can be stored dry in device until re-hydrated by plasma **17**.

[0043] A drop of whole blood **16** from a fingerstick or venous whole blood draw can be applied on filter **2**. The whole blood **16** can mix with filter reagents **32**. Filter **2** can trap the blood cells in whole blood **16** and let pass through plasma **17**. Plasma **17** can mix with filter reagents **32**. Plasma **17** can flow from filter **2** onto surface **11**. Plasma **17** can wick or sheet on surface **11**, across gap **12**, within slot **25**. Hydrophilic reagent **31** can promote plasma **17** sheeting or wicking across gap **12** into surface capillary **22**. Surface capillary **22** can be formed between the AOW **4** and surface **11**, or between the IC **9** and surface **11**. Plasma **17** can mix with surface reagent **30**. Surface capillary **22** can connect to well **19** such that Plasma **17** can flow from surface capillary **22** and into well **19**.

Plasma **17** can flow up or down well **19** due to capillary action and can cease to flow once it reaches the opposite side of well **19**. Plasma can contact lens **51** or protrusion **50** and excess plasma can vent through vent **52**. A vent **52** can be an air channel that lets air pass through.

[0044] Reporter molecule **56** can be included in surface reagents **30**, hydrophilic reagents **31**, filter reagents **32**, well reagents **34**, or additional reagents **37**. Plasma **17** can mix with or dissolve dried reporter molecule **56** surface reagents **30**, hydrophilic reagents **31**, filter reagents **32**, prefilter reagents, well reagents **34** and additional reagents **37**. Reporter molecule **56**, surface reagents **30**, hydrophilic reagents **31**, filter reagents **32**, well reagents **34**, or additional reagents **37** can combine or dissolve into dissolved reagents **33** in plasma **17**. Reporter molecule **56**, surface reagents **30**, hydrophilic reagents **31**, filter reagents **32**, well reagents **34**, or additional reagents **37** can dissolve upon contact with plasma **17**.

[0045] The dissolved reagents **33** in plasma **17** can participate in or initiate chemical reaction **35** in plasma **17** in well **19** that can alter the plasma absorption of plasma **17** in well **19** at an optical detection frequency **60**.

[0046] Device **1** can be configured to perform two multiplexed chemistry tests. A chemistry test that can have medical relevance is alanine aminotransferase (ALT) and aspartate aminotransferase (AST). The design in FIG. **1** can be configured so that ALT and AST measurements are performed separately and concurrently in well **19** and well **7**, respectively. ALT can be performed using Filter **2**, on surface **11** inside channel **25** and in well **19**. AST can be performed using filter **55**, on surface **11** inside channel **23** and in well **7**. The chemical reactions for measuring ALT and AST are two examples of chemical reaction **35**.

[0047] The chemical reaction for measuring ALT can comprise 1) ALT in plasma catalyzing the transfer of an amino group from L-alanine to alpha-ketoglutarate to form L-glutamate and pyruvate, and 2) lactate dehydrogenase (LDH) catalyzing the conversion of pyruvate to lactate and the oxidation of Nicotinamide adenine dinucleotide (NADH) to NAD⁺. The chemical reaction for measuring AST can comprise 1) AST catalyzing the conversion of L-aspartate and alpha-ketoglutarate into oxaloacetate and L-glutamate, and 2) Malate dehydrogenase (MDH) catalyzing the conversion of oxaloacetate into malate and the oxidation of NADH to NAD⁺. The reagent substrates for measuring AST and ALT can be introduced in abundance so the rate of the chemical reactions can be limited by the rate of endogenous AST and ALT in the plasma **17**, respectively. The reporter molecule **56** for both ALT and AST reactions can be NADH. NADH has a narrow band absorptions spectrum centered on 340 nm, so the amount or rate of NADH consumed in the chemical reactions can be measured by illuminating the wells **19** and **7** with light from an LED **5** emitting light **21** with a narrow band optical spectrum with an optical detection frequency of 340 nm. Reflector **6** can redirect light **21** from LED **5** into both wells **7** and **19**. In a rate measurement, the rate of change of the absorption at 340 nm can be due to the conversion of NADH to NAD⁺ and can be proportional to the amount of ALT or AST present in the plasma **17**. Photodetector **8** can measure the change in the amount of light transmitted through the plasma **17** in well **19** over time, and can determine from calibration values stored on the IC **9** the corresponding concentration of endogenous ALT and AST.

[0048] Filter reagents for filter **2** for ALT can comprise dried 1-alanine, NADH, alpha-ketoglutarate, LDH and excipients. The surface reagents for ALT can comprise 1-alanine, NADH, alpha-ketoglutarate, LDH and excipients. The well reagents for ALT can comprise hydrophilic reagents to maximize the capillary force, 1-alanine, NADH, alpha-ketoglutarate, LDH and excipients. The additional reagents for ALT can comprise 1-alanine, NADH, alpha-ketoglutarate, LDH and excipients. **28**

[0049] Filter reagents for filter **55** for AST can comprise dried 1-aspartate, NADH, alpha-ketoglutarate, MDH and excipients. The surface reagents for AST can comprise 1-aspartate, NADH, alpha-ketoglutarate, MDH and excipients. The well reagents for AST can comprise hydrophilic reagents to maximize the capillary force, 1-aspartate, NADH, alpha-ketoglutarate,

MDH and excipients. The additional reagents for AST can comprise 1-aspartate, NADH, alpha-ketoglutarate, MDH and excipients.

[0050] The ALT chemical reaction can be confined to well **19** by applying the ALT reagents exclusively to filter **2**, on surface **11** inside channel **25** or in well **19**. The AST chemical reaction can be confined to well **7** by applying the AST reagents exclusively to filter **55**, on surface **11** inside channel **23** or in well **7**.

[0051] Whole blood **16** can be applied to both filter **2** and filter **55** simultaneously. The chemical reactions in wells **19** and **7** can be measured concurrently or at different times.

[0052] ALT and AST are both examples of chemical reaction **35** where a rate measurement can be proportional to the activity of ALT and AST in whole blood **16**. Chemical reaction **35** can be a rate reaction wherein the measurement can be performed in a single well **19**.

[0053] Chemical reaction **35** can be an endpoint reaction, wherein the measurement can be performed in two wells, namely well **19** and well **7**. Well **19** can be used to measure the concentration of reporter molecule **56** produced or consumed, while well **7** can be used to measure the concentration of reporter molecule **56** prior to any consumption or production. The dissolved reagents in well **7** can omit a key reagent necessary for chemical reaction **35**, wherein the reporter molecule **56** in well **7** can be neither consumed nor produced.

[0054] The dominant source of noise in an ALT assay can be the natural oxidation of NADH into NAD⁺ by endogenous reactions other than chemical reaction **35**. Well **7** can be used as a blank well to measure the natural oxidation of NADH, or other blank measurement. The blank measurement can be subtracted from the chemical reaction **35** in well **19**, or from other chemistry reaction measurements, to eliminate the contribution of the natural oxidation of NADH or other sources of noise. L-alanine can be omitted from the dissolved reagents, such that chemical reaction **35** cannot run in well **7** and only the blank measurement can be made in well **7**. In the case of ALT, NADH can be dried in Filter **2** that can be shared between the measurement wells **7** and **19**. Blank wells can be used to measure interfering substances that can change the absorption of the plasma during run time of the assay.

[0055] Device **1** can contain a blank filter **55** which can produce plasma **17** without reporter molecule **56**. Device **1** can contain a blank well **7** which can accumulate plasma **17** produced by blank filter **55**, to measure the absorption of plasma **17** without reporter molecule **56**, or blank measurement. The blank measurement can be used to determine the concentration of reporter molecule **56** dissolved in plasma **17**, or the intrinsic absorption of plasma **17** or both. The blank measurement can be subtracted from the absorption measurements in other wells. The blank measurement or NADH-blank measurement can be combined to measure endpoint reactions by providing the concentration of the reporter reagent **56** before and after reaction **35** occurs.

[0056] The optical detection frequency **60** of the emission of the LEDs **5** can be selected to correspond to the spectral absorptivity of analyte **36** that yields the highest signal to noise ratio.

[0057] A plurality of wells can contain plasma with a plurality of dissolved reagents, wherein the dissolved reagents in one well can be different from the next well. A plurality of wells can be illuminated with light with a plurality of optical detection frequencies, wherein the optical detection frequencies in one well is different from the optical detection frequency of the next. A plurality of wells can receive plasma from a shared filter. Some wells can be used as blanks, wherein chemical reaction **35** may not proceed. The results from blank wells can be combined with the results from analyte measurement wells, wherein the concentration or activity of an analyte is measured.

Analyte Measurement

[0058] Spectrophotometer **15** can comprise an integrated circuit (IC) **9** that can integrate or embed one or more photodetectors, namely photodetector **8**. IC **9** can integrate a calculation circuit that can calculate an absorption measurement from a transmittance measurement. The calculation circuit can calculate the rate of or absolute change of the absorption of reporter molecule **56** in plasma **17** in well **19** from the rate of or absolute change in the transmittance of reporter molecule

56 in plasma **17** in well **19**. The calculation circuit can calculate the rate of or absolute change of the absorption of plasma in well **19** from the rate of or absolute change in the transmittance of plasma **17** in well **19**. The calculation circuits can calculate the ratio of serial measurements of transmittance. The calculation circuits can perform the logarithmic function in a base, such as 2, e, 8, 10, 16 or any other. The calculation circuits can perform the inverse logarithmic function, i.e. the exponential function in a base such as 2, e, 8, 10, 16 or any other. The calculation circuits can calculate the concentration or activity of analyte **36** in plasma **17** in well **19** using Beer-Lambert's law and serial measurements of the absorption or serial measurements of transmittances of plasma **17**, the nominal path length in well **19**, the elapsed time between serial measurements and the extinction coefficient of reporter molecule **56**. The calculation circuits can calculate the concentration of analyte **36** in plasma **17** in well **19** from serial transmittance or absorption measurements from a control well. Calculation circuits can be arithmetic a logic unit (ALU), a digital signal processor (DSP) or a look-up table, or a combination thereof. Stored information stored or encoded in device **1** can be stored or encoded in volatile or non-volatile memory integrated in IC **9** or in a separate memory chip IC electrically connected to IC **9**. Stored information can store or encode the nominal path length of well **19** and the extinction coefficient of reporter molecule **56**.

Path Length Control

[0059] Path length **39** can be the distance traveled by light **21** from LED **5** through plasma **17** in well **19**. Different rays of light **21** can travel a plurality of paths through plasma **17** in well **19**. Path length **39** can be the mean of the distribution of the distances the different rays of light **21** traveled through plasma **17** in well **19**. Path length **39** can be less than 5 mm, 4 mm, 3 mm, 2 mm, 1.5 mm, 1.25 mm, 1 mm, 0.75 mm, 0.6 mm, 0.5 mm, 0.4 mm, 0.3 mm, 0.25 mm. The coefficient of variance of the distribution of the distances the different rays of light **21** traveled through plasma **17** in well **19**, can be less than 50%, 25%, 15%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2% or 1%. For a device **1** with a plurality of wells, the path lengths for each well can differ.

[0060] A nominal path length is a length that can be calculated from design specifications and measurements to estimate the actual path length **39**. The path length **39** in device **1** is generally much shorter than traditional quantitative spectrophotometers. So small manufacturing tolerances can greatly affect path length **39**. The nominal path length of well **19** can be different from the actual path length **39** as a result of manufacturing tolerances. This difference between the actual path length **39** and the nominal path length can impact the performance of spectrophotometer **15**. The nominal path lengths for each well or aspects of the nominal path length for each well can be measured individually or in combination during manufacturing and can be stored in the stored information. Aspects of the nominal path length that can be measured individually or in combination during manufacturing can include the depth of well **9**, the thickness of tape **10**, the profile of reflector **6**, the profile of protrusion **50**, the profile of lens **51**, the co-planarity of IC **9** and surface **11**, the position of LED **5** on PCB, the relative position of LED **5** with respect to reflector **6**, the relative position of LED **5** with respect to well **19**, and the relative position of reflector **6** with respect to well **19** or incident angle of light **21** on the detection plane of photodetector **8**. Multiple aspects of the nominal path length can be combined mathematically or measured at once. The nominal path length can be a combination of one or more aspects of the nominal path length. The nominal path length can vary from the actual path length **39** by a path length error less than 20%, 15%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2% or 1%.

[0061] Light scattering off the walls of well **19** can widen the distribution of the distances traveled by the rays of light **21** and therefore affect the path length error. The construction of well **19** and photodetector **8** can be configured to avoid or reduce detection of light **21** scattering off the walls of well **19**. Photodetector **8** can be inset to the aperture of well **19** in proximity to photodiode **8** to reduce or eliminate the detection of light **21** scattering off the walls of well **19**. The construction of well **19** and photodetector **8** can be configured to avoid or reduce light **21** scattering off the walls of

well **19**. The sidewalls of well **19** can have a draft angle of 1°, 2.5°, 5°, 10°, 12.5°, or 15°, wherein well **19** widens in the direction of photodetector **8**. The draft angle can reduce or eliminate the scattering off the walls of well **19** of rays of light **21** that radiate out from reflector **6** and are not normal, i.e. not perpendicular, to the plane of photodetector **8**. **17**

[0062] Light **21** from LED **5** can be redirected by reflector **6** such that light **21** is incident normal or oblique to the plane of photodetector **8**. For superior path length **39** control, light can be incident normal to the plane of photodetector **8** so that stray rays at oblique angles can accrue minimal additional path length error by the combination of symmetry and trigonometry of small angles.

[0063] Another large source of path length error is the air-plasma interface at the top of well **19**.

The plasma meniscus at the top of well **19** can expand, contract or change shape at run time depending on the volume of plasma **17** extracted by filter **2**. Protrusion **50** can contact the plasma **17** at the top of well **19** such that light **21** can travel directly from reflector **6** into plasma. Light **21** can avoid traversing the air-plasma interface. cl Narrow Band Optical Spectrum

[0064] Optical detection frequency **60** can be the peak frequency of a narrow band optical spectrum. A narrow band optical spectrum can be an optical spectrum with frequency peak and Full Width Half Maximum (FWHM) of less than 200 nm, 100 nm, 50 nm, 25 nm, 20 nm, 15 nm, 10 nm, 5 nm, 4 nm, 3 nm, 2 nm or 1 nm.

Optical Filter

[0065] Light **21** emitted from LED **5** can have a broad spectrum with no or small peak frequency. Light **21** can be white light. To achieve operation with a narrow band optical spectrum at a single frequency, spectrophotometer **15** can contain an optical filter **80**. An optical filter **80** can have an optical passband at the optical detection frequency **60**. The passband bandwidth of optical filter **80** can be less than 200 nm, 100 nm, 50 nm, 25 nm, 20 nm, 15 nm, 10 nm, 5 nm, 4 nm, 3 nm, 2 nm or 1 nm. Optical filter **80** can be placed on or near photodetector **8**, IC **9**, inlet of reflector **6**, lens **58** of reflector **6**, lens **51**, protrusion **50**, reflector **6**, LED **5**, lens **57**. Optical filter **80** can be placed in the path traveled by light **21** between LED **5** and photodetector **8**. Optical filter **80** can be coated on photodetector **8**, IC **9**, inlet of reflector **6**, lens **58** of reflector **6**, lens **51**, protrusion **50**, reflector **6**, LED **5**, lens **57**. Device **1** can contain a plurality of spectrophotometers with optical filters having the same or different optical passbands.

Integrated Circuit

[0066] IC **9** can be a Complementary Metal Oxide Semiconductor (CMOS) IC. IC **9** can comprise a photodetector **8** electrically connected to a charge integrator such as a capacitor. Photodetector **8** can produce a photocurrent that is proportional to the light incident on the surface of photodetector **8**. The photocurrent can charge or discharge the charge integrator. The charge integrator can be connected to an amplifier or a comparator embedded on IC **9**. The IC **9** can generate a first reference voltage that can be used as a comparison trigger for the comparator. IC **9** can drive a current through LED **5**. IC **9** can pre-charge the charge integrator to a second reference voltage. IC **9** can drive current through LED **5** and measure the integration time until the charge integrator voltage reaches the first reference voltage and triggers the comparator. The integration time can be the time elapsed from when the charge integrator is no longer pre-charged until the comparator is triggered and switches state. The charge integrator voltage or input of the comparator can be chopped to minimize 1/f noise. The input of the comparator can be inverted. The average integration time can be the average between the two integration times with the comparator inputs in the inverted and non-inverted states. The average integration time can correspond to the radiant flux of light from LED **5** incident on photodetector **8**, and by extension corresponds to the concentration or activity of analytes **36** being measured. IC **9** can make one or more time resolved plasma absorption measurements of the absorption of plasma **17** in well **19** before, during or after reactions **35**.

[0067] IC **9** can integrate a microcontroller or microprocessor to control the state of device **1**, memory to store calibration data and results, a power management unit to drive the LEDs and sink

power from the battery **40**. IC **9** can integrate a boost converter or a power converter to increase the supply voltage above what the batteries **40** can supply. By integrating a boost converter, the supply voltage for IC **9**, LED **5** and display **41** can be boosted up and device **1** can run off a single battery **40**. Device **1** can sink less than 20 mA, or less than 10 mA or less than 5 mA or less than 2 mA or less than 1 mA or less than 0.5 mA from battery **40**.

Temperature Control

[0068] Temperature is an important factor that can alter the optical power emitted by LED **5**, the sensitivity of photodetector **8** or the activity of enzymes or other reagents in reactions **35**. IC **9** can integrate one or more temperature sensors to measure the temperature of IC **9**, surface **11**, plasma **17**, LED **5** or the ambient temperature inside device **1**. Temperature sensors can be any electronic device with deterministic temperature coefficients, such as bipolar junction transistors (BJT), diodes, bandgap or resistors. The one or more temperature sensors can be calibrated during manufacturing using a single point manufacturing temperature calibration or a multi-point temperature calibration. The temperature sensors can be soaked and calibrated at manufacturing temperature during manufacturing. The Manufacturing temperature can be equal to the run time heater temperature, such as 25 C, 30 C, 35 C, 36 C, 37 C, 38 C, 39 C or 40 C. Run time can be defined as the time when device **1** is activated. The one or more temperature sensor calibration values and algorithms to combine them with run time temperature measurements can be stored in memory on IC **9**. Temperature sensor calibration values can be combined with run time temperature measurements from temperature sensors to provide accurate temperature measurements. Calibrated run time temperature measurements can be accurate to within 2 C, 1 C, 0.5 C, 0.25 C or 0.1 C of actual temperatures. LED **5**, BJTs integrated in IC **9**, and resistors integrated in IC **9** can be temperature sensors. The calibration measurements from temperature sensors can be used to mathematically compensate the plasma absorption measurements for temperature changes at run time or differences between run time temperature and manufacturing temperature.

[0069] IC **9** can integrate a bandgap or other circuits to generate currents with or without temperature compensation. The current through LED **5** can be temperature compensated to control the output power of LED **5**. The temperature coefficient and electronic characteristics of LED **5** at manufacturing temperature can be measured and stored in the memory of IC **9**. The temperature coefficient of LED **5** can be used to compensate for temperature changes at run time or differences between run time temperature and manufacturing temperature. LED **5** can be used to measure the junction temperature of LED **5** at run time using the temperature coefficient and electronic characteristics of LED **5**. Electronics to measure the junction temperature of LED **5** at run time can be integrated in IC **9**. The first or second reference voltage for the comparator can be compensated so the integration time of the photocurrent is constant or nearly constant with respect to changes in run temperature or difference between run time temperature and manufacturing temperature.

[0070] Reactions **35** can provide higher signal to noise ratio at higher reaction temperatures, namely physiological temperature between 30 C and 40 C, such as 30 C, 35 C, 36 C, 37 C, 38 C, 39 C or 40 C. IC **9** can integrate circuits to raise the reaction temperature of reactions **35** or maintain reaction temperature to within 2 C, 1 C, 0.5 C, 0.25 C, 0.125 C of a desired reaction temperature. IC **9** can integrate one or more heaters circuits to raise the reaction temperature of reactions **35** or maintain reactions **35** at to within 2 C, 1 C, 0.5 C, 0.25 C, 0.125 C of a desired reaction temperature. The heaters can be heater resistors integrated in IC **9**. Heater resistors can be integrated into the silicon substrate of IC **9**. Heater resistors integrated into the silicon substrate of IC **9** can be n-well, p-well or doped well resistors. Heater resistors can be integrated into the inter-layer dielectric (ILD) of IC **9**. Heater resistors integrated into the ILD can include resistors fabricated out of poly-silicon or metal. The heater can be heated to a run time heater temperature. The run time heater temperature can be measured by a temperature sensor. The reaction temperature can be measured by a temperature sensor.

[0071] A temperature sensor can be placed in proximity to the heater. A temperature sensor can be

placed to within 1 mm, 500 μm , 250 μm , 125 μm , 100 μm , 50 μm , 25 μm , 20 μm , 10 μm or 5 μm of the heater for superior temperature control. The heater can be a temperature sensors. A temperature sensor can be placed in the ILD near or at the surface of the IC to measure the reaction temperature or the temperature of the plasma **17** in well **19** above the IC. The reaction temperature can be the temperature of the plasma **17** in well **19**. Metal pads or vias can be used to thermally couple plasma **17** in well **19** above IC **9** to a sensor embedded in IC **9**.

[0072] The power through the heater can be modulated. Examples of heater modulation schemes include pulse width modulation, amplitude modulation and frequency modulation. The run time heater temperature can be different than the reaction temperature by a heat loss offset. IC can compensate for the heat loss offset by increasing the run time heater temperature. The heat loss offset can be estimated using the steady state power consumption of the heater. The heater can be a well resistor embedded in the silicon substrate of IC **9**. The heater can be circular and circumscribe around the outer perimeter of photodetector **8**. The heater can be constructed from a number of separate resistor in parallel and series. The heater can be powered using digital pulse width modulation techniques. The volume of plasma in well **19** can be less than 1 μl and the distance from photodiode **8** to the opposite end of well **19** can be less than 1 mm to ensure rapid and even Photodetector

[0073] All the photodetectors on IC **9** can be equidistant from one-another and arranged in a line. Deviations from this linear equidistant photodetector placement can be less than 1 mm, 0.5 mm, or 0.25 mm. The photodetectors on IC **9** can be approximately equidistant from one-another and approximately arranged in a line. The photodetectors on IC **9** can be less than 3 mm, 2.5 mm, 2 mm, 1.75 mm, 1.5 mm, 1.25 mm, 1 mm, or 0.5 mm apart. Photodetector **8** can be any photoelectric device sensitive to the intensity of light. Photodetector **8** can be an active pixel sensor or charge coupled sensor. Photodetector **8** can be any photosensitive CMOS device. Photodetector **8** can be a photodiode. Photodetector **8** can be a polysilicon photodiode or a photodiode embedded in the substrate. Photodetector **8** can be n-doped or a p-doped well diode. Photodetector **8** can be implemented in an isolation well or in a stacked configuration to eliminate cross-talk from other photodetectors integrated in IC **9** or other noisy electronics integrated on IC **9**. The passivation and dielectric layers above photodetector **8** can be thinned or etched to minimize attenuation of light through the ILD before reaching the embedded photodetector **8**. Silicon dioxide from the ILD of IC **9** can have similar refractive index as plasma **17**. Silicon dioxide from the ILD can be exposed above photodetector **8** to eliminate reflections. Standard passivation layers like polyimide and silicon nitride with different refractive indexes to plasma **17** be etched, removed or eliminated above photodetector **8**. The optical detection frequency can be ultra-violet (UV), namely at 340 nm and 405 nm wavelengths. Light **21** at 340 nm and 405 nm wavelengths may not penetrate deep into the silicon substrate. To improve the quantum efficiency of photodetector **8** for 340 nm or 405 nm wavelengths, photodetector **8** can comprise a shallow junction photodiode integrated in the silicon substrate. The depth of the junction of photodetector **8** can be less than 5 μm , 4 μm , 3 μm , 2 μm , 1 μm , 0.5 μm or 0.25 μm . The profile of the junction can be exponentially decreasing or a buried Gaussian. An epi-layer, or a buried implant layer or a buried reverse implant layer can be embedded in the silicon substrate below the junction of the photodiode **8** to tailor the junction thickness and increase sensitivity at UV optical frequencies.

[0074] Photodetector **8** can be larger on a side than 10 μm , 50 μm , 100 μm , 200 μm , 300 μm , 400 μm , 500 μm , or 1 mm. The area of photodetector can be larger than 100 μm^2 , 1000 μm^2 , or 1 mm^2 . The area of photodetector **8** can be larger than or equal to the cross-sectional area of the aperture of well **19** in proximity to photodetector **8** to capture all the light **21** that enters well **19**.

[0075] Multiple photodetector can be placed below each well **19**. The photodetectors can be manufactured using different material or have one or more optical color filters patterned or placed on them to discriminate different frequencies of light **21**. The surface of the IC **9** can be coated with an anti-reflective coating (ARC) to minimize the amount of light that reflects off the surface of the

IC **9** before reaching the photodetector **8**.

[0076] Photodetector **8** can be placed below, above or laterally to well **19** such that photodetector **8** can detect or measure the intensity of the light that traveled through well **19** along path length **39**. Photodetector **8** can detect or measure the plasma absorption of plasma **17** in well **19** along path length **39**. The photodetector **8** can be integrated into IC **9**. IC **9** can be embedded inside, above, on or below PCB **3**. IC **9** can be mounted parallel to or flush with PCB **3**.

Plasma Filter

[0077] Filter **2** can comprise one or more plasma separation membranes, one or more structures to elute filter reagents **32**, one or more structures to promote mixing of plasma **17** with filter reagents **32** or one or more structures to slow or control the flow of plasma **17**. Filter **2** can comprise multiple stacked, abutted, offset or laminated filters. Filter **2** can be square, circular or any other arbitrary shape. Filter **2** can be manufactured from polyethersulfone/polyvinylpyrrolidone (PES/PVP) and have graduated porosity to trap red blood cells. Filter **2** can be coated with glycine or other reagents to minimize cell leakage and lysis. The area of filter **2** can be less than 10 mm.sup.2 or 30 mm.sup.2 or 100 mm.sup.2 or 300 mm.sup.2 and can accept less than 50 ul, 25 ul, 15 uL, 10 ul, 5 ul of whole blood. Filter **2** can be mounted in proximity, above, below, on or laterally to surface **11** or AOW **4**. Filter **2** can accept whole blood **16** and block red blood cells from flowing to well **19**. Platelets and white blood cells are interferers in spectrophotometer implementations due to light scattering. Historically, the solution to eliminating white blood cells has been to spin down the whole blood for an extended period of time and remove the buffy layer. Filter **2** can be configured to rapidly block white blood cells and platelets. Filter **2** can have a constriction layer with pore size smaller than 2.5 um, 2 um, 1.5 um, 1 um, 0.75 um, or 0.5 um.

[0078] Filter **2** can be mounted above, below, laterally or in proximity to surface **11** or AOW **4**. The distance from filter **2** to surface **11** can be less than 0.5 mm, 200 um, 100 um, 50 um, 25 um, 10 um, 1 um. Filter **2** can be snap-fit, friction fit, heat staked, glued or adhered to surface **11** or AOW **4**. Filter **2** can be adhered to surface **11** or AOW with double-sided tape **10**. Filter **2** can contact surface **11** or AOW **4**. Plasma can flow through filter **2** onto surface **11**. Filter **2** can be impregnated with dried filter reagents **32** that become dissolved into plasma **17**.

Plasma Flow

[0079] Filter **2** can be in proximity to and fluidically connected to spectrophotometer **15** such that plasma **17** from whole blood **16** can flow directly or indirectly from filter **2** into spectrophotometer **15**. Plasma **17** from whole blood **16** can flow passively from filter **2** into spectrophotometer **15** without assistance from the user or pneumatic forces. Plasma **17** from whole blood **16** can flow from filter **2** into spectrophotometer **15** as a result of surface tension effects, such as capillary or low contact angle on surface **11**. Filter **2** can be in proximity to or fluidically connected to well **19** such that plasma **17** from whole blood **16** can flow directly or indirectly from filter **2** into well **19**. Plasma **17** from whole blood **16** can flow passively from filter **2** into well **19** without assistance from the user or pneumatic pressure differentials. Plasma **17** from whole blood **16** can flow from filter **2** into well **19** as a result of surface tension effects, such as capillary effects in well **19** and low contact angle on surface **11**. Filter **2** can be fluidically connected to spectrophotometer **15** by surface **11**. Filter **2** can be fluidically connected to well **19** of spectrophotometer **15** by capillary **22**. Surface **11** can be the surface of a printed circuit board (PCB) **3** or the surface of the Array of Wells (AOW) **4** or the surface of an integrated circuit (IC) **9**. Surface **11** can be co-planar with IC **9**, wherein surface **11** can be the surface of photodetector **8**. Light **21** can transmit in a single direction through surface **11** before illuminating photodetector **8**. The path of light **21** can include surface **11**. Surface **11** can be in the path of light **21** traveling from LED **5** to detector **8**. The surface of photodetector **8** can be incorporated in surface **11**. The surface of IC **9** can be incorporated in surface **11** using a method described in Murali, P. Izyumin, I. Prabhu, S. Cohen, D. Boser, B. (2014). A MAGNETIC FLOW CYTOMETER WITH INTEGRATED MICROFLUIDICS. 159-162. 10.31438/trf.hh2014.44. The surface of the IC can be the surface of photodetector **8**.

[0080] Surface **11** can be hydrophilic or coated with a hydrophilic reagent **31**. Plasma **17** from whole blood **16** can flow on surface **11** into well **19** or into capillary **22**. Plasma **17** can flow between surface **11** and filter **2** into well **19** or capillary **22**. Plasma **17** can flow through filter **2** and through the edge **20** of filter **2** into capillary **22** and well **19**. Plasma **17** on surface **11** can flow into capillary **22** of spectrophotometer **15** due to the low contact angle of plasma **17** on surface **11**. Plasma on surface **11** can flow through capillary **22** and into well **19**. Capillary **22** can be formed by the proximity of AOW **4** or IC **9** and surface **11**. Capillary **22** can be formed between AOW **4** or IC **9** and surface **11**. Plasma in surface capillary **22** can flow into well **19** by capillary action. Well **19** and capillary **22** can be fluidically connected such that plasma in capillary **22** can flow into well **19**. Plasma **17** can fill well **19**. Filter **2** can be fluidically connected to well **19** through surface **11** and surface capillary **22**. Capillary **22** can be parallel to surface **11**.

[0081] The edge **20** of filter **2** can be in proximity or in contact with AOW **4** or IC **9**. Filter can have a barrier **13** that can prevent red blood cells in whole blood **16** from passing through edge **20** onto surface **11** and capillary **22**. Filter **2** can have a barrier **13** that can allow plasma **17** in whole blood **16** to pass through edge **20** onto surface **11** and capillary **22**. The edge **20** of filter **2** can be in proximity or in contact with photodetector **15**. The edge **20** of filter **2** can be in proximity or in contact with capillary **22**. Filter **2** or edge **20** of filter **2** can be partially or completely inside capillary **22**. Filter **2** can contain a barrier **13** and wherein barrier **13** can be inside capillary **22**.

[0082] Barrier **13** can be a notch, depression, indent, hydrophobic barrier or any feature in filter **2** that can reduce or eliminate the passage of whole blood cells through or around edge **20** or around filter **2** into plasma **17**. Barrier **13** can be a notch, depression, indent, hydrophobic barrier or any feature along edge **20** of filter **2**. Barrier **13** can be manufactured by crushing filter **2** wherein blood cells are blocked from traveling through, over or under the crush region. The crush region can be less than 5 mm, 2 mm, 1 mm, or 0.5 mm or 0.25 mm from the edge of filter **2**. Barrier **13** can be manufactured by crushing filter **2** along edge **20**. The presence of whole blood cells in well **19** can interfere with the chemistry measurements. Barrier **13** can be a material blocking the movement of whole blood cells on, along or through edge **20** or filter **2**. Barrier **13** can be a physical dam or barrier on edge **20**. Barrier **13** can slow, reduce or prevent whole blood cells from mixing with plasma **17** in gap **12**, under filter **2** or in capillary **22**. Barrier **13** can be on top of filter **2** and can prevent whole blood cells from passing through edge **20** or over the top of filter **2**. Barrier **13** can be on filter **2** in proximity to edge **20**.

[0083] Gap **12** can be the space between AOW **4** or IC **9** and filter **2**. Gap **12** can be the space between AOW **4** or IC **9** and edge **20** of filter **2**. Barrier **13** can reduce or eliminate blood cells from wicking through or over edge **20** into gap **12** or surface **11** or capillary **22** and ultimately into well **19**. The length of gap **12** can be less than 5 mm, 2 mm, 1 mm, 0.5 mm, 0.2 mm, 0.1 mm, 0.05 mm, or 0.025 mm. The length of gap **12** can be defined as the distance between filter **2** and AOW **4** or IC **9**. The gap **12** or barrier **13** can be used to control or slow down the flow of plasma into well **19** and promote mixing. Surface **11** adjacent to gap **12** can be hydrophilic such that plasma under filter **2** can sheet or flow across surface **11** adjacent to gap and into capillary **22** or well **19**. There may be no material such as a filter or AOW or IC directly atop surface **11** over gap **12**.

[0084] The length of gap **12** can determine time necessary for plasma under filter **2** to sheet or flow across surface **11** adjacent to gap **12**. Surface **11** adjacent to gap **12** can be exposed. The length of gap **12** can be long enough to ensure proper mixing of dissolved reagents in plasma **17**.

Light Emitting Diode

[0085] LED **5** can be mounted on surface **11**, PCB **3** or PCB **62** using epoxy, tape, an electrical socket, wirebonds, bump bond or reflowed or soldered electrical connections. LED **5** can emit light **21** with narrow band optical spectrum centered on a peak frequency, namely the optical detection frequency **60**. LED **5** can emit light **21** with a narrow band optical spectrum with a FWHM of less than 200 nm, 100 nm, 50 nm, 25 nm, 20 nm, 15 nm, 10 nm, 5 nm, 4 nm, 3 nm, 2 nm or 1 nm.

Spectrophotometer **15** can be a single frequency spectrophotometer, wherein spectrophotometer **15**

can produce or measure the intensity of light **21** at only one optical frequency, namely the optical detection frequency **60**. Device **1** can contain a plurality of single frequency spectrophotometers. Each of the plurality of single frequency spectrophotometer can produce or measure the intensity of light at a different optical detection frequency. The plurality of single frequency spectrophotometers can contain plasma from the filter **2** of different filters. The plurality of single frequency spectrophotometers can be fluidically connected to filter **2** or different filters. The plurality of single frequency spectrophotometers can be fluidically connects the surface **11** or different surfaces. Device **1** can have multiple LEDs emitting at different optical detection frequencies. A plurality of LEDs can be mounted on the same surface **11**, PCB **3** or PCB **62**. A plurality of LEDs can be mounted on different flex PCBs.

[0086] LED **5** can emit light **21** with a wide angle emission profile. LED **5** can be packaged with a lens **57** to direct or concentrate light **21** towards for example an input lens **58** of reflector **6**.

[0087] LED **5** can be packaged using plastic or quartz or be a package-free bare die. LED **5** can be flipped chip bonded onto a PCB and the illumination can emit from the backside of LED **5**, opposite the bonding pads. LED **5** can be chip-on-board mounted on a PCB. Plastic packages can degrade in UV light, but since device **1** is a single-use disposable, long term degradation of the LED package is not a concern. LED **5** can be a laser diode emitting a laser or coherent light.

[0088] LED **5** can be constructed of Aluminum Gallium Nitride (AlGa_N) or Gallium Nitride (Ga_N) or both. LED can be constructed from typical LED materials known in the art. The substrate for LED **5** can be sapphire or silicon carbide or other more typical LED substrates known in the art. LED **5** constructed from AlGa_N or Ga_N can emit with peak frequencies at 340 nm and 405 nm.

LED **5** constructed from AlGa_N or Ga_N can be low power and can be powered by a single battery.

[0089] The LED **5** can be flip chip bonded onto a PCB **3**. PCB **3** can feature registration and the flip-chip bonding process can result in LED **5** positional errors. To overcome these errors, LED **5** can be placed on PCB **3** first and IC **9**, AOW **4** and reflector **6** can be placed on PCB subsequently to LED **5** and registered to LED **5**. In some cases, components will be mounted on the other side of the PCB. LED **5** can be registered to a through-feature like one or more vias or one or more edges of PCB **3**, and IC **9**, AOW **4** and reflector **6** can be registered to the same through-features.

[0090] Spectrophotometer **15** can be encased in an optical shield **82** that blocks light from the exterior from entering well **19**. Optical shield **82** can be on device **1** in housing **44**.

Array of Wells

[0091] The AOW **4** can comprise an array of **1** to **100** wells, in which the transmittance of plasma **17** with reporter molecule **56** can be measured. One or more AOW **4** can be mounted in proximity, above, below, on or laterally to surface **11**, PCB **3** or IC **9**. AOW **4** can be positioned in proximity, below, above, on, laterally to, adjacent to or in contact to filter **2** or edge **20** of filter **2**, or barrier **13** of filter **2**. AOW **4** can contain well **19**. AOW **4** can be opaque to the optical detection frequency **60** to avoid signal cross talk among the wells. A single AOW **4** can be shared among multiple spectrophotometers. Reflector **6** can be over-molded onto AOW **4**. AOW **4** can be constructed from standard injection molded plastics. AOW **4** can contain a pocket for the wirebonds of IC **9**. AOW **4** can contain a pocket that crushes filter **2** and creates barrier **13**. Capillary **22** can be formed in between AOW **4** or IC **9** and surface **11**. AOW **4** can contain capillary **22**.

[0092] Well **19** can be a capillary with parallel surfaces. The parallel surface of well **19** in the configuration of a capillary can be perpendicular to light **21**, wherein light **21** enters through one parallel surface and exits through the parallel surface on the opposite side of the capillary. Light **21** can pass through capillary **22**, wherein AOW **4** is constructed with material transparent to light **21**.

[0093] Well **19** can have a maximum depth of 5 mm, 3 mm, 2 mm, or 1.5 mm, or 1 mm, or 0.75 mm, or 0.6 mm, or 0.5 mm, or 0.4 mm. Well **19** can have a maximum diameter of 2 mm, 1.5 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm or 0.25 mm. Well **19** can be cylindrical with drafted sidewalls.

[0094] The AOW **4** can be snap-fit, friction fit, heat staked, glued or adhered to surface **11**. AOW **4**

can be adhered to surface **11** with double-sided tape **10**. AOW **4** can be machined or injection molded. AOW **4** can be manufactured from an injection moldable plastic such as Polymethylmethacrylate (PMMA), Acrylonitrile butadiene styrene (ABS) or hydrophilic polymers. AOW **4** can be transparent, translucent or opaque. AOW **4** can have mounting points or through holes for reflector **6**. Surface **11** can have mounting points or through holes for AOW **4** and reflector **6**. AOW **4** can have capillary draw texture on the inside of the wells.

[0095] The inner volume of well **19** can be less than 2 μL , or 1 μL , 0.5 μL , or 0.25 μL , or 0.1 μL of plasma **17**. Well **19** can be vertical or positioned at an angle vis-a-vis surface **11**. Well **19** can have tapered sidewall to promote capillary action.

Tape Design

[0096] Double sided tape **10** can be mounted on surface **11**. The AOW **4** can be mounted above, below, on or laterally to tape **10**. Filter **2** and filter **55** can be mounted above or below, on or laterally to tape **10**. Filter **2** and AOW **4** can abut or be separated by a gap **12**, wherein the surface **11** adjacent or nearest to gap **12** can be exposed or uncovered.

[0097] Tape **10** can contain between **1** and **100** slots or channels that can fluidically connect one or more filters with one or more wells in one or more AOWs, such that plasma **17** from the one or more filters can flow unassisted into one or more wells. Channel **25** in tape **10** can direct the plasma **17** from filter **2**, across gap **12**, into capillary **22** and into well **19**. Capillary **22** can be formed by surface **11**, AOW **4** and channel **24**. Capillary **22** can be formed by surface **11**, IC **9** and channel **25**. Channel **25** can fluidically connect filter **2** to well **19**. Slot **25** in tape **10** can direct the plasma **17** from filter **2** into well **19**.

[0098] Channels **23** and **25** can be fluidically isolated from one another on surface **11** such that plasma in one channel cannot flow into another channel or plasma in one channel cannot mix with plasma from another channel. Plasma in channels **23** and **25** can have different dissolved reagents. Channel **23** can delineate a separate reaction chamber, where a distinct chemical reaction **35** can be performed. A channel can contact a plurality of wells to a single filter.

[0099] Double-sided tape **10** can be hydrophobic or hydrophilic. Tape **10** can be hydrophobic to avoid delamination after prolonged exposure to plasma **17**. Also, the use of hydrophobic tape **10** can facilitate spotting of different surface reagents spotted in different slots by eliminating unwanted mixing. Tape **10** can be thin to minimize the dead volume of plasma **17** and therefore to reduce the amount of whole blood **16** needed to run device **1**. The thickness of Tape **10** can be less than 1 mm, 0.1 mm, 0.05 mm, 0.025 mm or 0.01 mm. Multiple slots can connect to multiple fluidically isolated filters but channel multiple plasmas to the same AOW or to same well in AOW. Multiple slots can connect to a single filter **2**.

Reflector

[0100] Reflector **6** can be composed of multiple optical elements. Optical elements can be optical splitters, optical combiners, mirrors, lenses, optical diffusers, passive optical amplifiers, apertures, fully or partially reflective surfaces, total internal reflective surfaces, waveguides and other features to control or direct light **21**. The reflector **6** can be injection molded from an injection moldable plastic transparent to light **21**. However, for directing shorter wavelength lights like 340 nm and 405 nm light, the material from which the light-pipe or waveguide is manufactured can be transparent or translucent to ultra-violet light, such as cyclic olefin copolymers or PMMA. The refractive index of reflector **6** can be higher, lower or within 10%, 20%, 30%, 50%, 100% of the refractive index of plasma **17**.

[0101] A first optical element **28** can redirect light **21** approximately 90° from LED **5** to a second optical element **29**. The second optical element **29** can redirect light **21** approximately 90° from the first optical element **28** into plasma **17** in well **19**. The first or second optical elements can also split light **21**, focus light **21** or change the radiation pattern of light **21**. Reflector **6** can direct light **21** from one diode to a plurality of wells. Reflector **6** can direct the light from a plurality of diodes into a well **19**.

[0102] Reflector **6** can have a protrusion **50**. Protrusion **50** can act as a waveguide. Protrusion can contact plasma **17** in well **19**. Protrusion **50** can penetrate well **19** or be mounted in well **19**, on the opposite side of photodetector **8**. Protrusion **50** can contain a lens **51** that focuses the light from LEDs **5** or **26** onto the bottom of well **19**. Protrusion **50** in reflector **6** can channel or direct the light from second optical element **29**, through lens **51** and into the plasma **17** in well **19**. Lens **51** can also be flat or concave. Lens **51** can be convex to avoid bubbles being trapped underneath it when well **19** fills by capillary action from the bottom up. The center of lens **51** can be the first point on reflector **6** that touches plasma **17** as well **19** fills. Photodetector **8** can be exposed to light **21** from LED **5** that traverses from protrusion **50** or lens **51** directly into plasma **17** in well **19**. Light **21** can exit protrusion **50** through lens **51**. Lens **51** can form the tip of protrusion **50**. Lens **51** can focus light **21** onto photodetector **8**. Protrusion **50** and lens **51** can be mounted above well **19** or inside well **19**. Protrusion **50** and lens **51** can be centered with respect to well **19**. Protrusion **50** or lens **51** can contact plasma **17** at one end of well **19**, opposite photodetector **8**. Protrusion **50** or lens **51** can contact the sidewalls of well **19** opposite photodetector **8**. A vent **52** can be formed between the protrusion **50** or lens **51** and the sidewall of well **19**. Vent **52** can allow air inside well **19** to exit out of well **19** to maintain capillary action in well **19**. Protrusion **50** and lens **51** can be in proximity to well **19** without contacting well **19**. The minimal distance between protrusion **50** or lens **51** and the sidewall of well **19** can be less than 1 mm, 0.5 mm, 0.25 mm, 0.1 mm, 0.05 mm, 0.025 mm, 0.01 mm, 0.005 mm, or 0.001 mm. The vent **52** can be an annulus around the top rim of well **19**.

[0103] Lens **51** or protrusion **50** can be above plasma **17** or well **19** and avoid contacting them. Lens **51** can focus light onto the aperture of well **19** opposite photodetector **8**. The aperture of well **19** opposite the photodetector **8** can be reduced to minimize the optical interference of the meniscus of the plasma **17** on the illumination of photodetector **8**. The diameter of the top aperture of well **19** can be less than 2 mm, 1.5 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm, 0.2 mm, or 0.1 mm. The sidewalls of well **19** can be drafter to improve capillary flow, eliminate light reflecting off the sidewalls and to reduce the diameter of the top aperture of well **19**. The diameter of the aperture of well **19** opposite photodetector **8** can be smaller than the diameter of the aperture of well **19** closest to photodetector **8**.

[0104] Protrusion **50** and lens **51** can be used for underfill and overfill control. The assay measurement can begin when plasma **17** contacts lens **51** or protrusion **50**. The amount of light that reaches photodetector **8** can increase, decrease or change abruptly when plasma **17** contacts lens **51** or protrusion **50**. The change in the amount of light on photodetector **8** when plasma **17** contacts lens **51** or protrusion **50** can be detected and used to begin the assay measurement in well **19**. The assay measurements in different wells can begin at different times. The change or lack of change in the amount of light that reaches photodetector **8** when plasma **17** contacts lens **51** or protrusion **50** can be used to indicate under-fill situations where not enough sample was applied to filter **2**.

[0105] Reflector **6** can have a third optical element **53** to collect, focus or split light directly from LED **5**, wherein LED **5** can be unpackaged and emit light across a wide angular pattern.

Housing

[0106] Device **1** can also include a desiccant **43**, a display **41** and one or more batteries **40** to provide power to LED **5**, IC **9** and display **41**. Display **41** and battery **40** can be electrically connected to IC **9**. Display **41** and battery **40** can be electrically connected to PCB **3**. The device **1** can include a plastic housing **44** to encase device **1** and all the sub-components. The housing **44** can have branding and test identifiers and a QR code printed or molded on its exterior. Device **1** can have a button **45** or a pull tab **61** to activate device **1**. Display **41** of device **1** can prompt a user to apply a drop of whole blood **16** on filter **2**. Display **41** can display the results of a chemistry test. Display **41** can display to the use such are over-sampling or under-sampling situations, the time remaining until the assay is complete, error codes or other information.

[0107] Device **1** can also have a sample capillary **14** that collects whole blood **16** from a finger, pipette or syringe and wicks it to multiple filters, such as filter **2** and filter **55**. Device **1** can be

configured to accept less than 15 uL of whole blood, or less than 10 uL of whole blood or less than 5 uL of whole blood. The results from the measurement from device **1** can be displayed on display **41** or wirelessly transmitted to a nearby wireless device. Device **1** can have a near-field communication (NFC) wireless module. In the cases where the change in amount of the optical density of the light transmitted through the plasma **17** changes quickly, device **1** can report results as soon as they are available. Results can be reported in less than 15 minutes, or less than 10 minutes, or less than 5 minutes, or less than 3 minutes, or less than 1 minute. Digital display **41** can be a liquid crystal display (LCD), a dot matrix display, an organic LED (OLED) display, an e-ink display or other displays. Display **40** can display the concentration of one or more analytes **36**. Battery **40** can power spectrophotometer **15** and display **41**. Spectrophotometer **15** can comprise an integrated circuit (IC) **9**. Device **1** can have a single PCB **3**. PCB **3** can be a 2-layer PCB. [0108] Device **1** can be integrated into a blood collection system that is fitted onto a patient and take whole blood from the patient. Device **1** can be integrated into the blood collection system and can take whole blood from the blood collections system for analysis. The blood collection may or may not have an LCD to display the assay results. The assay results can be transmitted wirelessly to a nearby mobile device. Battery **40** can be a coin cell battery. Battery **40** can be a single coin cell battery.

Other Sensors

[0109] Device **1** can have additional detection ICs. The additional detection ICs can be integrated on PCB **3**, or on AOW**4**. An additional detection IC can be an electrochemical IC containing electrochemical sensors that can function either in plasma or whole blood. Platinum electrodes and permselective films can be patterned on a separate electrochemical IC to enable electrochemical sensing on device **1**. Ion selective electrodes (ISE) can be integrated in the electrochemical IC. ISE can be used to quantify electrolytes such as sodium, potassium and chloride. An additional detection IC can be an immuno-assay IC. An immuno-assay IC can be a magnetic sensing IC **83** that performs magnetic particle labeled immuno-assays, wherein magnetic particles conjugated to antibodies can capture soluble target proteins in plasma **17**. The magnetic particles can sediment via gravity to the antibody coated surface of the magnetic sensing IC to which they can bind strongly in the presence of the target proteins. Magnetic sensing IC **83** can integrate current carrying conductors adjacent to magnetic particle sensors. The current carrying conductors can remove magnetic particles weakly bound to the surface of the magnetic sensing IC **83** from atop the magnetic particle sensors, while the magnetic particles sensors can detect magnetic particles that remain strongly bound to surface of the magnetic sensing IC above magnetic particle sensors. Magnetic particles can loaded and stored in a dry state in a well. Plasma can rehydrate and release the dried magnetic particles which incubate with plasma **17**, capture the target proteins and sediment to the surface of the magnetic sensing IC. The magnetic particles can be dried in a filter or in a capillary. The magnetic particles can be dried on the bottom of a filter. The magnetic particle sensors can be implemented as photodetectors **8** or as magnetic sensors embedded in the magnetic sensing IC **83**. Device **1** can contain multiple IC **9**, additional detection ICs to perform chemistry tests and to perform immuno-assays. Device **1** can contain one or more IC **9**, one or more electrochemical ICs and one or more magnetic sensing ICs. Electrochemical IC and magnetic sensing IC **83** can be integrated on or parallel or flush with PCB **3**. IC **9**, electrochemical IC and magnetic sensing IC can have digital interfaces for communication like I^{sup}.2C or SPI. One IC in device **1** can be the master IC. IC **9** can be the master IC. The master IC can contain the processor, the memory, the power management. The master IC can communicate and coordinate with all other IC in device **1**.

Sample

[0110] Sample **18** can be applied on filter **2**. Filtrate **24** can be sample **18** filtered through filter **2**. Filtrate **24** can contain dissolved reagents **33**. Filtrate **24** can flow through filter **2** and onto surface **11**. Filtrate **24** can flow on surface **11** as a result of hydrophilic reagents **31** or as a result of the

hydrophilicity of surface **11**. Filtrate **24** can flow or sheet or wick across surface **11**. Filtrate **24** can flow or sheet or wick across gap **12** into capillary **22**. Filtrate **24** can flow through surface capillary **22**. Filtrate **24** can fill well **19**. Protrusion **50** or output lens **51** can contact filtrate **24**. Cover **64** can contact filtrate **24**. Spectrophotometer **15** can measure the absorbance of filtrate **24** in well **19**. Plasma **17** is one example of filtrate **24**, wherein sample **18** is whole blood **16**. Spectrophotometer **15** can measure the absorbance of fluid in well **19**. Filtrate **24** can be defined as any fluid in well **19**.

[0111] Sample **18** can be whole blood, serum, plasma, saliva, mucus, pulmonary fluid, feces, cerebral fluids, oral swab collections, nasal swab collections, pulmonary lavages, nasopharyngeal swab collections, gum scrapings or other fluids or secretions, dilutions, elutions, or dissolutions thereof.

[0112] Device **1** can be used for detecting or measuring multiple types of analytes **36**. Analyte **36** can be one or more Ribonucleic acid (RNA) or Deoxyribonucleic acid (DNA) oligonucleotides **110**, one or more antibodies **111** or proteins **112**, general chemistry biomarkers or electrochemistry biomarkers. The presence of oligonucleotides **110** can be indicative of the presence of an active infection of one or a plurality viruses. The titers or the presence of one or a plurality of antibodies **111** can be indicative of one or more past infections of one or more viruses. Device **1** can detect the presence of one or more oligonucleotides **110** in sample **18**. Device **1** can detect the presence or measure the titer of one or more antibodies **111** or proteins in sample **18**.

Reader Implementation

[0113] One or more devices **1** can be inserted into or used with a reader **100**. Reader **100** can contain a port **101**, a battery **104**, a digital display **105**, an NFC module **106**, a LED **109** and a photodetector **113**. Reader **100** can have a plurality of ports, LEDs and photodetectors. Reader **100** can contain a plurality of ports **101** for inserting one or more device **1**. Battery **104** can be electrically connected to display **105**, NFC Module **106** and LED **109**. LED **109** can emit light **21** with a narrow band spectrum centered on the optical detection frequency **60**. Light **21** from LED **109** can traverse well **19** on device **1**. Light **21** can be incident on photodetector **113**. Reader **100** can measure the absorbance of the filtrate **24** in well **19** in device **1**. Display **105** can display the absorbance, concentration or activity measurements from device **1** or reader **100**. NFC Module **106** can communicate with NFC module **42**. Reader **100** or port **101** can accept one or a plurality of devices **1**, simultaneously or in series.

[0114] Reader **100** can be disposable or reusable. Reader **100** can contain a heater **102** and a temperature sensor **108** for maintaining a constant reaction temperature in well **19**, for isothermal amplification or general chemistry reactions. Reader **100** can have a plurality of heaters for heating a plurality of devices to different temperatures. Heater **102** and temperature sensor **108** can be electrically connected to battery **104** or the power management system. Heater **102** can be part of a thermocycler for running a polymerase chain reaction (PCR). The reader **100** can contain a fan, for convective heating or cooling. The reader **100** can have a heat sink or a heater **102** with high surface area to increase heat transfer to air or coolant. The fan and the heat sink can decrease the time necessary to heat or cool the filtrate in well **19** in device **1** to a desired reaction temperature.

[0115] Reader **100** can retrieve absorbance, concentration or activity measurements from device **1** inserted in port **101**. Reader **100** can retrieve absorbance, concentration or activity measurements from device **1** in proximity to reader **100**. Reader **100** can measure the absorbance of the sample **18** or filtrate **24** or plasma **17** in well **19** in device **1**. Reader **100** can measure the transmittance of the sample **18** or filtrate **24** or plasma **17** in well **19** in device **1**. Reader **100** can measure the reflectance of the sample **18** or filtrate **24** or plasma **17** in well **19** in device **1**. Reader **100** can measure the reflectance of the sample **18** or filtrate **24** or plasma **17** in contact with reflectance surface **81**.

[0116] Reader **100** or port **101** can contain a digital connector to connect and communicate with device **1**. Reader **100** or port **101** can contain an RFID transceiver or NFC module that can connect

or communicate with the NFC module in device **1**. Reader **100** or port **101** can contain a camera, image sensor or photodetector that can read display **41** or the output of device **1**. Reader **100** or port **101** can be configured to allow light **21** from an LED **109** integrated on reader **100** to pass through well **19** on device **1**. Reader **100** or port **101** can be configured to allow light **21** from an LED **109** integrated on reader **100** to reflect off reflectance surface **81** and be incident on photodetector **113**. Reader **100** or port **101** can be configured to allow light **21** to pass through well **19** on device **1** and to be incident on photodetector **113** integrated on reader **100**. Reader **100** or port **101** can contain one or a plurality of windows, openings or apertures **116** that can allow all or a fraction of light **21** to pass from LED **109** through well **19** and into photodetector **113**. Aperture **116** can be a hole in material opaque to light **21**. The hole or aperture **116** can be smaller than 2 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm or 0.25 mm in diameter. Aperture **116** can be any shape.

[0117] Reader **100** or port **101** can operate at one or two or three or more optical detection frequencies **60**. Different ports in reader **100** can operate at different optical detection frequencies **60**. Reader **100** can be configured such that devices operating at one optical detection frequency **60** may not be inserted into a second port that operates at another optical detection frequency. Reader **100** can have a reflector **114** that can redirect light **21** from LED **109** through a plurality of wells **19** and onto one or a plurality of photodetectors **113**. Reflector **114** can redirect light **21** from LED **109** through a plurality of wells **19** in a plurality of devices **1** and onto one or a plurality of photodetectors **113**. Reader **100** can have a plurality of identical LEDs **109** wherein light from one LED **109** traverses one or more wells on device **1**. Reader **100** can have a plurality of LEDs **109** emitting light **21** with different optical detection frequencies **60**. Reader **100** can have a plurality of photodetectors **113** wherein each photodetector **113** can detect light **21** passing through one or more wells **19** in one or more devices **1**. Reader **100** can have an optical diffuser **115** to provide uniform illumination into one or more wells on device **1**, or through one or more wells on a plurality of devices **1**. Aperture **116** can be above, below or lateral to device **1** and well **19**. A plurality of apertures **116** can be in proximity to device and well **19**. Two apertures can be on either side of well **19**. Photodetector **113** can be bigger or smaller than aperture **116**. Diffuser **115** can be bigger or smaller than aperture **116**. Aperture **116** can be bigger or smaller than the diameter or aperture of well **19**. The difference between the amount of power of light **21** transmitted through well **19** and well **7** can be less than 20%, 15%, 10%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or 1%. The difference between the amount of power of light **21** transmitted through well **19** containing a control sample from a first device **1** and the amount of power of light **21** transmitted through well **19** containing a control sample from a second device **1** can be less than 20%, 15%, 10%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or 1%. Reader **100** can perform rate or endpoint absorption measurements of chemical reaction **35** in well **19**. **28**

[0118] Reader **100** can have blinds **121** positioned between each well **19** to optically isolate the wells from one another. Reader **100** can have blinds **121** positioned between each LED **109** to optically isolate the LEDs from one another. Reader **100** can have blinds **121** positioned between different paths of light **21** to optically isolate the different light paths from one another. The blinds **121** can contact device **1** or well **19**. The blinds **121** can be in proximity to device **1** or well **19**. Cross illumination can occur wherein light **21** intended to pass through one well passes through an adjacent well. Cross illumination can occur wherein light intended to be incident on one photodetector is incident on an adjacent photodetector. Reader **100** can correct for cross illumination numerically. Reader **100** can contain one LED per well, wherein the pitch of the LEDs is approximately equal to the pitch of the wells. Reader **100** can employ one photodetector per well, wherein the pitch of the photodetectors is approximately equal to the pitch of the wells.

[0119] Reader **100** or port **101** can have blinds between wells, wherein the pitch of the blinds is approximately equal to the pitch of the wells. Reader **100** or port **101** can contain one aperture per well, wherein the pitch of the apertures is approximately equal to the pitch of the wells. Reader **100** or port **101** can contain two apertures per well, on either side of the well, wherein the pitch of the

apertures is approximately equal to the pitch of the wells. Reader **100** can power a plurality of LEDs **109** at one time, or reader **100** can power a plurality of LEDs **109** in sequence.

[0120] Reader **100** can communicate to clinic or hospital information system. Reader **100** can be connected physically or wirelessly to the clinic or hospital information system. Devices **1** can communicate with each other or to reader **100** via I2C, SPI, RFID or other digital interfaces. Devices can communicate with each other via the reader. The reader can connect to other readers. Multiple readers connected together can share a single power source or power supply. The power source could be battery **104** or a power outlet connection. Multiple readers connected together can share a single connection to the clinic or hospital information network. Reader **100** can have a case that can contain slots to connect to other readers. The case can contain electrical leads for supplying power and information. Reader **100** can be a mobile device such as a laptop, tablet or phone.

[0121] Reader **100** or port **101** can have physical registrations points or features to hold device **1** at a preset position with respect to reader **100** or port **101**. Device **1** can have physical registrations points or features to align device **1** at a preset position with respect to reader **100** or port **101**. Reader **100** can have features so device **1** can be securely inserted into or removed from port **101**. Reader **100** or port **101** can have a mechanical slide or mechanical guide to insert and remove device **1** from port **101**. The mechanical guide can assist inserting device **1** in port **101** or reader **100**. The shape of port **101** can be complementary to the shape of device **1**. Port **101** can have a swinging or sliding door through which device **1** can be inserted. The door on port **101** can block light from entering inside port **101**. The position of device **1** inserted into port **101** can vary less than 250 μm , 100 μm , 50 μm , 25 μm , 10 μm , 5 μm from a nominal position.

[0122] The reader **100** can detect if device **1** is inserted in port **101**. The reader **100** can contain detection apparatus wherein the detection apparatus can detect when device **1** is inserted in port **101**. The reader can use LED **109** and the photodetector **113** to detect the presence of device **1** at or near a nominal position in port **101**. The amount of light **21** from the LED **109** incident onto the photodetector **113** can indicate whether device **1** is inserted in port **101** at or near a nominal position.

Cartridge Implementation

[0123] Surface **11** can be transparent. Surface **11** of device **1** can be constructed from a plastic transparent to light **21**. Surface **11** can be glass or plastic and can be coated with a protein adhesion layer. Surface **11** can be perpendicular to the path of light **21** from LED **109** or LED **5** to photodetector **8** or photodetector **113**. Light **21** can be incident on surface **11**. Surface **11** can transmit light **21**.

[0124] Well **19** can have two opposing flat inner surfaces that transmit light **21**. Light **21** can travel perpendicularly through two surfaces that form inner surface of well **19**. Surface **11** can be an inner surface of well **19**. Cover **64** can be an inner surface of well **19**. The two opposing inner surfaces can have different shapes. One inner surface can be the output lens **51**. Another inner surface can be surface **11**. Light **21** from LED **109** can be redirected by reflector **114** or reflector **6**, incident on one or more inner surfaces of well **19** and incident on photodetector **113**. The AOW **4** can be transparent or opaque. The cross-sectional top view of well **19** can be circular, rectangular or any other shape. The cross-sectional side view of well **19** can be circular, rectangular or any other shape.

[0125] Light **21** can traverse well **19** in device **1** laterally to avoid bubbles generated by heating or by imperfect capillary flow. Bubbles in well **19** can percolate to the top of well **19**. Light **21** can traverse laterally through well **19** below the bubbles. Wells on the same device **1** or well on different devices can be in different orientations. The path of light taken by light **21** through the filtrate **24** in well **19** can be vertical. The path of light taken by light **21** through the filtrate **24** in well **19** can be horizontal or lateral. Control wells can be used to determine the background signals for device **1**. Control wells can be used to determine the background signals for device **1** for filtrate

24 or plasma **17**. Control wells can be used as one point in an endpoint measurement. The results from reader **100** or device **1** can be qualitative, indicating the presence or absence of one or more analytes.

[0126] A vial **103** can be mounted to AOW **4**, surface **11**, filter **2**, tape **10** or other feature on device **1**. The vial **103** can be twisted, popped, pushed, friction fit onto AOW **4**, surface **11**, filter **2**, tape **10** or other feature on device **1**. Vial **103** can have a seal on the bottom configured to open and release the contents of vial **103** when vial **103** is mounted, twisted, popped, pushed or friction fit. A user can add a sample **18** into vial **103**. Sample **18** in vial **103** can be mixed and diluted. A user can mount vial **103** on device **1**. Vial **103** can contain a buffer or diluent necessary for running reaction **35**. The vial **103** can contain dried reagents. The vial **103** can have a lid that a user need to remove to add sample **18** or a swab of a sample **18**. Vial **103** can contain a buffer solution or diluent for diluting one or more samples **18** or whole blood **16**. Filter **2** below vial **103** can be a porous material impregnated with filter reagents **32**.

Immunoassay detection

[0127] Reader **100** can read a lateral flow strip. The results from the lateral flow strip can be interpreted visually by reader **100**. Reader **100** can contain one or a plurality of optical detectors, photodetectors, imaging system or cameras to detect and measure the test and control lines of a lateral flow strip. A lateral flow strip can be inserted into port **101**. Device **1** can contain a magnetic sensing IC **83** and can use magnetic particles to bind to antibodies to one or more viruses. Magnetic sensing IC **83** can be integrated into IC **9**. Device **1** or magnetic sensing IC **83** can contain a surface **11** onto which magnetic beads can bind specifically. Reader **100** can contain one or more magnets **117** that can be configured to generate the magnetic forces to remove the non-specifically bound magnetic particles from surface **11**. Magnet **117** can be a permanent magnet or an electromagnet. Reader **100** can have a linear motion system to move magnet **117** in proximity to well **19**. Reader **100** can have a swing arm to move magnet **117** in proximity to well **19**. Magnet **117** can be stationary in reader **100** and device **1** can be mobile.

[0128] Device **1** can be moved in proximity to magnet **117**. Magnet **117** can be above, below or to the side of device **1** and well **19**. Magnet **117** can be in proximity to well **117**. Magnet **117** can be above well **19** and pull non-specifically bound magnetic particles up off surface **11**. Magnet **117** can be positioned laterally to well **19** and pull non-specifically bound magnetic particles up laterally across surface **11**. Reader **100** can contain an imaging system **118** to detect, count, estimate or measure the number of magnetic particles are specifically bound to surface **11**. The imaging system **118** can use direct illumination, backlit illumination or total internal reflection to detect the magnetic particles that can be specifically bound on surface **11**. The imaging system **118** can use near-field or far-field optical detection of the magnetic particles on surface **11**. Imaging system **118** can have pixels to detect magnetic particles. Surface **11** can adhere to antibodies or antigen or be coated with an adhesion layer that can adhere to antibodies or antigen. Antibodies and antigens can be bound to the adhesion layer. The adhesion layer can be a thin layer of gold coated or deposited on surface **11** of the magnetic sensing IC **83**. The surface of magnetic sensing IC **83** can be surface **11**. The wells in device **1** can be placed vertically or effectively vertically such that magnetic particles can settle to surface **11** due to gravity.

[0129] Magnetic particles can be pulled towards surface **11** by a permanent magnet or electromagnet.

[0130] The magnetic sensing IC **83** can be manufactured on a wafer. A thin layer of gold acting as the protein adhesion layer can be deposited directly onto the magnetic sensing IC wafer through vacuum, electron beam or sputtering deposition. The pads can be protected with a shadow mask. A protective layer can be applied to the gold layer prior to wafer dicing, and can be removed prior to coating with antibodies and antigen. Alternatively, antibodies and antigen can be coated directly onto the protein adhesion layer on magnetic sensing IC wafer. The pads of the magnetic sensing IC **83** can be protected with photoresist during the protein adhesion layer deposition or the antibody or

antigen coating processes. The proteins can be protected using photoresist during the wafer dicing process.

[0131] The surface or the adhesion layer or surface **11** can be coated with one or more viral antigens or with antibodies against a virus. Device **1** can perform a sandwich capture immunoassay or a competitive immunoassay. Magnetic particles can be dried in filter **2** or prefilter **59** or on surface **11** or the surface of lens **51**. The surface **11** or adhesion layer can be coated with angiotensin converting enzyme 2 (ACE2) proteins. More than one surfaces or regions of the same surface **11** of device **1** can be coated with different epitopes of the ACE2 protein. The surface or adhesion layer can be coated one or more spike proteins (S proteins). A plurality of surfaces or regions on one surface can be coated with different S proteins that bind to different regions of ACE2. Device **1** can detect or measure the presence of virus proteins in a sample, or device **1** can detect or measure the presence of antibodies to the virus in the sample.

[0132] Device **1** can detect multiple different isotypes from a sample, for example, Immunoglobulin G (IgG) and Immunoglobulin M (IgM) specific to a strain of a virus. Device **1** can detect multiple strains of a virus in a simplex format, wherein the presence of any of the strains yields a positive. Device **1** can detect multiple strains of a virus independently in a multiplexed format. Device **1** can detect different isotypes in a simplex format wherein the presence of any of the isotypes yields a positive. Device **1** can detect different isotypes individually in a multiplexed format. Chemical reaction **35** can be an antibody antigen binding reaction.

[0133] The magnetic particles can be dried on the surface of protrusion **50**, lens **51** or cover **64**. Magnetic particles coated with a plurality of proteins can be loaded on a plurality of filters, wells, surface or lenses. Each filter or well can have magnetic particles coated with one type or set of proteins, wherein multiplexed assays can be performed in a plurality of wells. Magnetic particles coated with a plurality of proteins can be loaded on a plurality of locations on surface **11**. Each location on surface **11** can have magnetic particles coated with one type or set of proteins, wherein multiplexed assays can be performed in a plurality of wells. Magnetic particles coated with a plurality of proteins can be loaded on a plurality of wells or output lenses. Each well can have magnetic particles coated with one type or set of proteins, wherein multiplexed assays can be performed in a plurality of wells.

Oligonucleotide Detection

[0134] Chemical reaction **35** can be an amplification chemical reaction. Device **1** can perform an amplification chemical reaction. An amplification chemical reaction can amplify RNA or DNA, through reverse transcriptase loop mediated isothermal amplification (RT LAMP), loop mediated isothermal amplification (LAMP), or other forms of isothermal amplification, Polymerase Chain Reaction (PCR) or Real Time (RT) PCR. The product or reactant of the amplification chemical reaction can contain a reporter molecule **56** that can be detected and their concentration measured spectroscopically by spectrometer **15** or by reader **100**. Device **1** can contain amplification reagents **120** in a wet or dry state. The amplifications reagents **120** can comprise primers, polymerase enzymes, detergents and drying excipients. The amplification reagents can be in the vial, prefilter reagents **54**, filter reagents **32**, surface reagents **30**, additional reagents **37** or diluent reagents **119**. The amplification reagents **120** can be dried. The diluent in vial **103** can have diluent reagents **119** necessary to perform an isothermal amplification chemical reaction. The diluent in vial **103** can have diluent reagents **119** necessary to perform a chemical reaction **35**.

[0135] The sample **18** can be mixed with the diluent and diluent reagents **119** and introduced onto the filter **2** or prefilter **59**. The filtrate **24** can enter well **19**. The IC **9** can heat well **19** to the needed isothermal amplification temperature, like 65, 70, 75, 80 degrees Celsius or other temperatures. A separate heater on device **1** can heat well **19** to the needed isothermal amplification temperature, like 65, 70, 75, 80 degrees Celsius or other temperatures. The reader **100** can have a heater **102**. Reader **100** or heater **102** can heat well **19** to the needed isothermal amplification temperature, like 65, 70, 75, 80 degrees Celsius or other temperature. The amplification temperature can be

thermocycled to perform PCR.

[0136] For well inner volumes exceeding 1 μ L, a plurality of ICs with a single well **19** can be integrated into and co-planar with PCB **3**.

Communication

[0137] Device **1** can have a near field communication (NFC) module **42** to communicate with reader **100**, a mobile device or a laboratory information interface. The NFC module **42** can comprise an antenna and a transceiver IC. The antenna and transceiver IC can be mounted on PCB **3** or can connect to PCB **3**. The antenna can be formed by traces on PCB **3**. The antenna can be printed on or adhered to the bottom side of top housing **91**. The antenna can be printed on or adhered to the top side of the bottom housing **92**. The antenna can be electronically connected to NFC module **42**. IC **9** can be electrically connected to NFC module **42**. IC **9** can integrate the transceiver IC. Device **1** can transmit or receive assay information via the NFC module **42**. Stored information can comprise assay information. Assay information can be the serial number of device **1**, the time needed for device **1** to analyze sample **18**, the time and date, the species of animal providing the sample, the age of the patient or animal. Assay information can be the measurements results or error codes resulting from device **1** analyzing sample **18** or whole blood **16**. NFC module **42** can contain non-volatile memory. The non-volatile memory on NFC module **42** can store assay information or stored information. The non-volatile memory on NFC module **42** can store the program to control device **1**. The program to control device **1** can be transferred from NFC module **42** to IC **9**. IC **9** can process assay information stored in the non-volatile memory on NFC module **42**. IC **9** can communicate with NFC module **42** via I2C, SPI, RFID or other serial or parallel digital interfaces.

[0138] Device **1** can be in a powered off state until the NFC module **42** is activated. The NFC module **42** can activate or turn on the power to device **1**. NFC module **42** can activate or turn on the power to IC **9**. NFC module **42** can activate or turn on the power to the power management or the power control system for device **1**. The NFC module can be in a power down state. The NFC module can be activated or turned on by the proximity of another NFC module. Device **1** can be activated or turned on by bringing another NFC module in proximity. Device **1** can be activated or turned on by the proximity of another NFC module. Device **1** can be activated or turned on by a radio frequency signal. Device **1** can have an electronic latch that changes state in proximity to another NFC transceiver. Device **1** can have an electronic power switch that changes state in proximity to another NFC transceiver. NFC module **42** can change the state of an electronic power switch. NFC module **42** can be integrated on IC **9**. The electronic latch and power switch and the power management or power control system can be integrated on IC **9**.

[0139] Device **1** can have an indicator LED to inform the user the state of the device. The indicator LED can be on, off, and it can be modulated between on and off in a pattern. The state and the pattern of the indicator LED can represent the state of device **1**. The state of device **1** can be off, on, awaiting sample, processing sample, requesting more sample, analysis complete and error.

Optic Cavity

[0140] Reflector **6** can be mounted on AOW **4** using an optic tape **67**. Optic tape **67** can be a double-sided tape. Between reflector **6** and AOW **4** there can be a channel or vent **68** to let air or filtrate pass. There can be a plurality of vents **68**. There can be one vent **68** for every well **19** on AOW **4** in device **1**. One or a plurality of surfaces of the vent **68** can be hydrophobic or coated with a hydrophobic reagent. One or a plurality of surfaces of the vent **68** can be hydrophilic or coated with a hydrophilic reagent. Vent **68** can resist the flow of filtrate **24** or plasma **17**. Vent **68** can promote the flow of filtrate **24** or plasma **17**.

[0141] Evaporation can be a big problem for the reaction **35** as it can force accumulation of the reporter molecule **56** in filtrate **17**. Vent **52**, vent **68** or surface capillary **22** can be lengthened to eliminate or reduce mass transport of air or water or reporter molecule **56**. Vent **52**, vent **68** or capillary **22** can be longer than 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm or

more than 10 mm. One metric for reducing mass transport is length divided by cross-sectional area. The length divided by the cross-sectional area of vent **52**, vent **68** or capillary **22** can be greater than $100 \cdot m.\text{sup.}-1$, $1000 \cdot m.\text{sup.}-1$, $10000 \cdot m.\text{sup.}-1$, $100000 \cdot m.\text{sup.}-1$, $1000000 \cdot m.\text{sup.}-1$, or $10000000 \cdot m.\text{sup.}-1$.

[0142] Cover **64** can have a protrusion **50** and a lens **51** that can contact the plasma **17** or filtrate **24** in well **19** first to avoid the creation of bubbles. Cover **64** can be the output lens **51** of reflector **6**. Cover **64** or reflector **6** can have an optical cavity **69**. An optical cavity **69** can be a pocket of air between reflector **6** and AOW **4** or between cover **64** and AOW **4**. Optical cavity **69** can be formed by optical tape **67**. The optical cavity **69** can be a light guide that guides or concentrates light **21** to the output lens **51**. The optical cavity **69** can be a light guide that guides or concentrates light **21** from an optical element in reflector **6** to the output lens **51**. Optical cavity **69** can have a conical shape **70**. Conical shape **70** can be above well **19** and lens **51**. Light **21** can pass through conical shape **70** before lens **51** or well **19**. The conical shape **70** can concentrate light **21** onto output lens **51**. The conical shape **70** can direct light **21** that is not incident on output lens **51** away from the aperture at the top of well **19**. The conical shape **70** can reduce or eliminate the amount of light **21** entering well **19** that is not incident on output lens **51**. The conical shape **70** and output lens **51** can minimize the variation in path length **39**. Output lens **51** can be flat. Cover **64** can have an optical cavity **69** with a conical shape **70** and an output lens **51**. The optical cavity **69** can eliminate the existence on bubbles between the output lens **51** and the filtrate **24** or plasma **17** in well **19**. The optical cavity **69** can permit output lens **51** to contact plasma **17** or filtrate **24** in well **19** and can prevent plasma **17** or filtrate **24** in well **19** from wicking into optical cavity **69**. Optical cavity **69** can be a fluidic stop gap that can prevent plasma **17** or filtrate **24** in well **19** from flowing into optical cavity **69** or into vent **68**. The inner surface of optical cavity **69** can be hydrophobic or coated with a hydrophobic coating to avoid condensation from plasma **17** or filtrate **24** in well **19**. The inner surface of cavity **69** can be polished to reduce or avoid condensation from plasma **17** or filtrate **24** in well **19**. The inner surface area of cavity **69** can be minimized to reduce or avoid condensation from plasma **17** or filtrate **24** in well **19**. Reflector **6** can be constructed from a hydrophobic material.

Filter Module

[0143] Filter **2** and prefilter **59** can be laminated into a filter module **71**. Filter module **71** can comprise a filter **2**, a prefilter **59** and one or a plurality of lamination surfaces **84**. Prefilter **59** can be a porous membrane impregnated with prefilter reagents **54**. Prefilter **59** can touch or crush filter **2** to ensure proper flow of sample **18**, whole blood **16**, plasma **17** or filtrate **24** from prefilter **59** into filter **2**. Prefilter **59** can be fluidically connected to filter **2**. Prefilter **59** can have larger or smaller pore size than filter **2**. Prefilter **59** can have similar pore size to filter **2**. Filter **2** or prefilter **59** can block red blood cells from passing while allowing plasma **17** to pass.

[0144] Filter module **71** can comprise one or a plurality of sample bypass stops **84**. A sample bypass stop **84** can be a feature that restricts or blocks the passage of whole blood **16** or sample **18** from inlet **66** into surface capillary **22** without traversing filter module **71** or filter **2**. A sample bypass stop **84** can be a feature that ensures passage of whole blood **16** or sample **18** through filter module **71** or filter **2**. A sample bypass **84** can be gap **12**, **11** barrier **13** or a notch in filter **2** or prefilter **59**. Filter **2** and prefilter **59** can be laminated on a lamination surface **84**. Lamination surface **84** can be a pressure sensitive adhesive, a transfer adhesive, or other flat material.

[0145] Lamination surface **84** can adhere to filter **2** or prefilter **59** and hold them in contact with each other. Lamination surface **84** can be placed flat on surface **11**, PCB **3** or tape **10**.

[0146] Lamination surface **84** can be a sample bypass stop **84**. Lamination surface **84** can be hydrophobic. The backing of lamination surface **84** can be hydrophobic. Lamination surface **84** can have portions that are hydrophobic. Lamination surface **84** can have an adhesive that is hydrophobic such as a silicone adhesive. Lamination surface **84** can have a cut edge that is hydrophobic. One or a plurality of edges of lamination surface **84** can be aligned with one or a

plurality of the edges of filter **2** or prefilter **59**. Lamination surface **84** can have a thickness. The thickness of lamination surface **84** can be greater than 5 μm , 10 μm , 15 μm , 25 μm , 50 μm , 100 μm , 200 μm or 500 μm . The thickness of lamination surface **84** can be less than 5 μm , 10 μm , 15 μm , 25 μm , 50 μm , 100 μm , 200 μm or 500 μm . Lamination surface **84** can be placed between surface **11** or tape **10** and filter **2** or prefilter **59**. Lamination surface **84** can prevent the sample **18** in filter **2** or prefilter **59** from flowing onto or contacting surface **11** or tape **10**. Lamination surface **84** can block, control or reduce sample bypass.

[0147] Filter module **71** can have two or more lamination surfaces. Filter module **71** can have a first lamination surface **84** on the bottom and a second lamination surface **85**. Lamination surface **85** can be positioned on the top of filter module **71**. Lamination surface **85** can be a sample bypass stop. Lamination surface **85** can promote passage of sample **18** or whole blood **16** laterally through filter **2** or prefilter **59**. Lamination surface **85** can promote incubation of sample **18** or whole blood **16** with filter reagents **32** or prefilter reagents **54**. The dimensions of lamination surface **85** can modulate the amount of sample **18** and whole blood **16** incubate with filter reagents **32** or prefilter reagents **54**. Lamination surface **85** can reduce or eliminate passage of sample **18** or whole blood **16** over or around filter **2** or prefilter **59**. Lamination surface **85** and lamination surface **84** can overlap across a section of module **71** to ensure sample **18** or whole blood **16** wick laterally through filter **2** or prefilter **59** and dissolve the appropriate amount of filter reagents **32** or prefilter reagents **54**. A portion of filter **2** or prefilter **59** in filter module **71** can be mounted directly onto surface **11** or tape **10**, without lamination surface **84** in between. A portion of filter **2** or prefilter **59** can be exposed, without lamination surface **85** above it so it can be crimped or notched. A portion of filter **2** or prefilter **59** can be exposed, without lamination surface **85** above it so that a barrier **13** can be integrated. A portion of filter **2** or prefilter **59** can be exposed, without lamination surface **85** above it so that it can be placed under AOW **4**.

[0148] Filter module **71** can be manufactured or laminated in a long filter module strip. The filter module strip can comprise a filter material strip, a prefilter material strip, a first lamination surface strip and a second lamination surface strip. The filter module strip can be singulated by scissors, guillotine or slit into individual filter modules **71**. The length of the filter module **71** can be determined by the width of the filter module strip width. The length of the filter module **71** can be less than 10 mm, 9 mm, 8 mm, 7 mm, 6 mm, 5 mm, 4 mm, 3 mm, 2 mm or 1 mm. The edges of the lamination surfaces **84** and **85** can be aligned to the edge of the filter **2** and/or the edge of prefilter **59**. The singulation of the filter module strip can align the edges of the lamination surfaces **84** and **85** and the edge of the filter **2** and/or the edge of prefilter **59**. The edges of filter **2** and prefilter **59** can be aligned. The singulation of the filter module strip can determine the width of the filter module **71**. The width of the filter module **71** can be less than 10 mm, 9 mm, 8 mm, 7 mm, 6 mm, 5 mm, 4 mm, 3 mm, 2 mm or 1 mm. The filter module strip can be manufactured by standard lamination processes. The filter module strip can be manufacturing by layering or overlapping a filter material strip, a prefilter material strip and a first and second lamination surface material strip. The filter module strip can be manufactures in a web-to-web process wherein the filter material strip, prefilter material strip, first lamination surface material strip and second lamination surface material strip are overlapped and laminated in a continuous web-to-web process. A roller or press can crush the prefilter material strip into the filter material strip, either before or after either one or both first and second surface lamination material strips are laminated. A roller or press can adhere one or a plurality of lamination material strips to the prefilter material strip and/or the filter material strip. Filter module **71** can accept less than 10 μL , 9 μL , 8 μL , 7 μL , 6 μL , 5 μL , 4 μL , 3 μL , 2 μL or 1 μL before filter **2** or prefilter **59** or filter module **71** becomes saturated. A crimp or notch to create barrier **13** can be added into filter **2** of filter module **71** before the filter module strip is singulated. The crimp or notch acting as barrier **13** can be made by a press or a drum or a roller. The depth of the crimp or notch or barrier **13** can be controlled by a precise mechanical spacer.

[0149] Filter module **71** can comprise a filter **2** with first and second lamination surfaces **84** and **85**,

without a prefilter **59**. Filter module **71** can comprise a plurality of filters and prefilters. Filter **2** or prefilter **59** can be whole blood filters. Prefilter **59** can be a sintered plastic material. Prefilter **59** can distribute sample **18** or whole blood **16** evenly across filter **2**. Filter **2** or prefilter **59** can be impregnated with an amino acid, such as alanine, glycine or aspartate to promote the separation of plasma **17** from whole blood **16**. Filter module **71** can contact AOW **4**. Filter module **71** can be separated from AOW **4** by a gap **12**. Filter module **71** can be above surface **11** or tape **10**. Filter module **71** can be mounted on surface **11** using tape **10**.

[0150] Filter module **71** or filter **2** can have a plurality of barriers **13**. Filter module **71** or filter **2** can have a first barrier **13** around part or all of its perimeter. The first barrier **13** can prevent whole blood cells from leaking out the side of filter module **71** or filter **2** onto surface **11** or tape **10** or into surface capillary **22**. The first barrier **13** can be a crimp or a notch or a hydrophilic coating. The crimp generating the first barrier **13** can be applied after the filter module **71** or filter **2** are applied on surface **11** or tape **10**. Filter module **71** or filter **2** can have a second barrier **13** on a portion of filter module **71** or filter **2**. The second barrier **13** can be a crimp or a notch or a hydrophobic coating. The second barrier **13** can contact AOW **4**.

[0151] Filter module **71** can be separated from AOW **4** by a gap **12**. Filter module **71** or filter **2** can be in contact with AOW **4**. Filter module **71** or filter **2** can be under AOW **4**. Filter module **71** or filter **2** can be between surface **11** or tape **10** and AOW **4**. The second barrier **13** can be between surface **11** or tape **10** and AOW **4**. AOW **4** can crush or overlap filter module **71** or filter **2** in a crush region. Channel **25** can have an enlargement **86** around the crush region wherein AOW **4** crushes or overlaps filter **2** or filter module **71**. The enlargement **86** can allow plasma **17** or filtrate **24** to circumvent the region. Channel **25** can be wider than the crush region. The crush region can promote the wicking of plasma **17** or filtrate **25** into surface capillary **22**. A corner of AOW **4** can crush filter **2** or filter module **71** to minimize the crush region. The crush region can be smaller than 9mm.sup.2, 4mm.sup.2, 1mm.sup.2 or 0.25mm.sup.2. Channel **25** can traverse the region wherein AOW **4** crushes filter **2** or filter module **71**. Channel **25** can be below the crush region. AOW **4** can have one or a plurality of extensions **87** that protrude from the portion of AOW **4** that forms the wells. A portion or all of extension **87** can crush or overlap filter **2** or filter module **71** and form the crush region. The extensions **87** can be less than 5 mm, 4 mm, 3 mm, 2 mm, 1 mm, 0.5 mm wide and less than 5 mm, 4 mm, 3 mm, 2 mm, 1 mm, 0.5 mm long. The extensions **87** can facilitate the positioning of the filter **2** or filter module **71** with respect to AOW **4**. AOW **4** can have a plurality of extensions with different lengths and widths. Device **1** can have a plurality of filters **2** or filter modules **71** of different size. Device **1** can have a plurality of filters **2** or filter modules **71** of length and width. The shape of filter **2** and filter module **71** can be rectangular or square or a parallelogram.

Assay Control

[0152] Device **1** can have a sample electrode **90**. Sample electrode **90** can detect the presence of a sample **18**, whole blood **16**, plasma **17** or filtrate **24** on surface **11**, or PCB **3** or IC **9**. Sample electrode **90** can be capacitive, wherein sample electrode **90** can detect a change in dielectric constant of the medium in contact with sample electrode **90**. Sample electrode **90** can be resistive, wherein sample electrode **90** can detect a change in the resistance of the medium in contact with sample electrode **90**. Sample electrode **90** can be acoustic wherein sample electrode **90** can detect a change in the acoustic properties of the medium in contact with sample electrode **90**. The medium in contact with sample electrode **90** can be air, sample **18**, plasma **17**, whole blood **16**, filtrate **24** or any other material that constitute device **1**. Sample electrode **90** can be first exposed to air. Sample electrode **90** be subsequently exposed to sample **18**, plasma **17**, whole blood **16**, filtrate **24**. Sample electrode **90** can detect contact with sample **18**, plasma **17**, whole blood **16**, filtrate **24**. Sample electrode **90** can detect the transition from one medium to another. Sample electrode **90** can be made of gold, platinum or any other material that can detect contact of sample **18**, plasma **17**, whole blood **16**, filtrate **24**. Sample electrode **90** can be made of a material that doesn't corrode.

Sample electrode **90** can be on surface **11**. Sample electrode **90** can be an exposed pad or lead of PCB **3** or IC **9**. PCB **3** or IC **9** can have gold electroplated pads or leads. Sample electrode **90** can be gold electroplated pads or leads. Sample electrode **90** can be positioned under, above, laterally, in contact or in proximity to sample inlet **66**, sampling capillary **65**, filter module **71**, filter **2**, channel **25**, AOW **4**, tape **10**, gap **12**, capillary channel **22** or IC **9**.

[0153] Sample electrode **90** can be formed by two pads in proximity. The distance between two pads can be less than 1 mm, 100 μm , 30 μm , 10 μm , 5 μm or 1 μm . Sample electrode **90** can comprise interdigitated pads. One pad of sample electrode **90** can be electrically connected to a resistor. The resistor in contact with one pad of sample electrode **90** can be larger than 1 k Ω , 1 M Ω , 10 M Ω . One pad of sample electrode **90** can be connected to ground or a power supply. The voltage across or current through sample electrode **90** can change when sample **18**, whole blood **16**, plasma **17** or filtrate **24** is applied. IC **9** or electronics on PCB **3** can detect a change of voltage across or current through sample electrode **90**. A change of voltage across or current through sample electrode **90** can turn on or activate device **1**, IC **9**, the power management or the power control system in device **1**.

[0154] Sample electrode **90** can detect the application of sample **18**, whole blood **16**, plasma **17** or filtrate **24** on device **1**. Device **1** can detect the sample application time corresponding to the application of sample **18**, whole blood **16**, plasma **17** or filtrate **24** on inlet **66** using sample electrode **90**. IC **9** or device **1** can record or store the sample application time when the sample **18** was applied. The sample application time can be part of the assay information. Device **1** can have a plurality of sample electrodes **90**. The information from one or a plurality of sample electrodes can be combined to measure device **1** timing information. The timing information from one or a plurality of sample electrodes **90** can be subtracted by IC **9** or device **1**. Timing information can be assay information. Two sample electrodes can be placed on opposite sides of filter **2** or filter module **71** to measure or estimate the sample dwell time. The sample dwell time can be assay information. Sample dwell time can be the time sample **18**, whole blood **16**, plasma **17** or filtrate **24** dwells in filter **2** or filter module **71**.

[0155] Device **1** or system **100** can detect the sample arrival time corresponding with the arrival of plasma **17** or filtrate **24** in well **19**. Device **1** or system **100** can detect the sample arrival time by detecting the increase in absorbance due to the arrival of plasma **17** or filtrate **24** in well **19**. The sample arrival time can be assay information. The sample application time can be subtracted from the sample arrival time to measure, estimate or approximate the sample dwell time. The concentration of dissolved reagents **33** in plasma **17** or filtrate **24** can have a dwell time correlated to the sample dwell time. Dwell time correlation can be assay information. IC **9** or device **1** can combine the sample dwell time and dwell time correlation arithmetically to correct the assay measurements for departures from a nominal sample dwell time.

[0156] Device **1**, IC **9** or reader **100** can serially measure the absorbance of the filtrate **24** or plasma **17** in well **19** at high frequency. The high frequency at which device **1**, IC **9** or reader can serially measure the absorbance of the filtrate **24** or plasma **17** in well **19** can be higher than 1 Hz, 10 Hz, 50 Hz, 100 Hz, or 1 kHz. Serial measurements of the absorbance of the filtrate **24** or plasma **17** in well **19** can be taken at high frequency and can be combined to determine a sample slope. The sample slope can be positive while plasma **17** or filtrate **24** enters well **19**, corresponding to an increase in the absorbance of the filtrate **24** or plasma **17** in well **19**. The sample slope can become abruptly or highly negative when the filtrate **24** or plasma **17** contacts the protrusion **50** or lens **51**, corresponding to the elimination of the reflector **6** to air and air to plasma **17** or air to filtrate **24** interfaces. Device **1** or reader **100** can generate a sample slope signal when sample slope breaches a threshold or changes polarity. A sample slope signal can indicate that well **19** is full, that the path length **39** is stable and that the measurement of analyte **36** can proceed. Analyte **36** in filtrate or plasma **17** can be measured in well **19** when a sample slope signal is produced. Device **1** or reader can produce a plurality of sample slope signals. Device **1** or reader **100** can produce one sample

slope signal for each well. The results of device **1** can be invalidated if one sample slope signal is not produced. Device **1** or reader **100** can prompt a use to provide more sample **18** or whole blood **16** until one or all the sample slope signals are produced. A sample slope can also be employed to measure rate reaction constants and by extension the activity of enzymes. Device **1** or IC **9** can contain a data buffer with past absorbance measurements of plasma **17** or filtrate **24** in well **19**. Device **1** or IC **9** can perform regression analyses on the past absorbance measurements in the data buffer. Examples of regression analyses include least square fits, linear regressions, power law regressions, exponential regressions or other numerical regressions.

[0157] LED **5** or LED **109** can emit light **21** with varying power. Device **1** or reader **100** can have a power reference photodetector. Light **21** can travel from LED **5** or LED **109**, can travel through reflector **6** or reflector **114** and light **21** can be incident on the reference power photodetector, without traversing through plasma **17** or filtrate **24**. The power reference photodetector can produce a power reference measurement. To mitigate the effects of the varying power of light **21**, the power reference measurement can be arithmetically combined with the measurement from photodetector **8** or photodetector **113**. The power reference measurement can be subtracted from the measurement of photodetector **8** or photodetector **113**. The measurement of photodetector **8** or photodetector **113** can be divided by the power reference measurement.

[0158] Device **1** can have one or a plurality of power reference photodetectors for each LED **5**. Reader **100** can have one or a plurality of power reference photodetectors for each LED **109**.

[0159] Device **1** can have a plurality of temperature sensors. A temperature sensor can be integrated in IC **9**. A temperature sensor can be mounted on PCB **3**. Device **1** can have a plurality of heaters.

[0160] A heater can be integrated in IC **9**. A heater can be mounted on PCB **3**. A heater can be a resistor with resistance value less than 200 Ω , or 100 Ω , or 50 Ω , or 20 Ω , or 10 Ω . The one or plurality of heaters on device **1** can be controlled in a closed loop using the feedback from temperature measurements from the one or plurality of temperature sensors on device **1**. The one or plurality of heaters on device **1** can be controlled in an open loop using the temperature measurements from the one or plurality of temperature sensors on device **1** and heating information stored on device **1**. The heating information can include look-up tables or predictive models providing the total thermal energy required to reach a desired reaction temperature. Temperature information from the temperature sensors can be used to compensate for any difference between the reaction temperature of reactions **35** and the desired reaction temperature. The one or plurality of heaters on device **1** can be configured in an open loop using the temperature measurements from the one or plurality of temperature sensors on device **1** and heating information stored on device **1** to take reaction temperature of reaction **35** to or near to the desired reaction temperature. The one or plurality of heaters on device **1** can be configured in a closed loop using feedback from the temperature measurements from the one or plurality of temperature sensors on device **1** to keep the reaction temperature of reaction **35** at or near the desired reaction temperature.

[0161] In some reactions **35**, a precise amount of a critical reagent must be dispensed. The variable dwell time through filter **2** or filter module **71** can preclude placing critical reagent in the filter **2** or filter module **71**. Critical reagent can be dispensed and dried on the surface of the photodetector **8** or surface **11** or inside well **19**. Critical reagent can be placed and dried on the surface of the protrusion **50** that can contact the filtrate **24** or plasma **17** in well **19**. Critical reagent can be placed and dried on the surface of the lens **51** that contact the filtrate **24** or plasma **17** in well **19**. Critical reagent can include magnetic particles. Critical reagent can be placed using contact dispense or print dispense. The amount of critical reagent dispensed can accurate to within 10%, 7%, 5%, 4%, 3%, 2%, 1% or 0.5%.

System Integration

[0162] Device **1** can comprise a housing **44**. Housing **44** can comprise a top housing **91** and a bottom housing **92** that snap or press fit together. Top housing **91** can have one or a plurality of posts **93** that can slot into one or a plurality of holes **94** in the bottom housing **92**. Posts **93** can

extend through PCB 3 via through-holes 96 in PCB 3. Posts 93 can register top housing 91 to PCB 3 in one, two or three dimensions. Post 93 can have a foot 95 to register top housing 91 to PCB 3 in the z-axis. Posts 93 can be concentric to and similar in diameter with through-holes in PCB 3 to register top housing 91 to PCB 3 in the x-y plane. Posts 93 can friction fit into holes in bottom housing 92.

[0163] Top housing 91 can have an inlet 66. Inlet 66 can accept whole blood 16, plasma 17 or sample 18. The top Inlet 66 can be an opening in top housing 91. The bottom of inlet 66 or sample tool 65 can be in proximity to or contact filter 2 or filter module 71. Whole blood 16, plasma 17 or sample 18 in inlet 66 or sample tool 65 can contact one or a plurality of filters 2 or filter modules 71. Whole blood 16, plasma 17 or sample 18 in inlet 66 or sample tool 65 can flow to one or a plurality of filters 2 or filter modules 71. Inlet 66 or sample tool 65 can be fluidically connected to one or a plurality of filter 2 or filter module 71. Inlet 66 or sample tool 65 can be in proximity to or contact surface 11, PCB3 or tape 10. The bottom of Inlet 66 or sample tool 65 can crush one or a plurality of filter 2 or filter module 71. Inlet 66 or sample tool 65 can apply pressure on one or a plurality of filter 2 or filter module 71. The amount inlet 66 crushes filter 2 or filter module 71 can be determined by the insertion of post 93 in hole 94. The force applied by inlet 66 on filter 2 or filter module 71 can be determined by the insertion of post 93 in hole 94. Inlet 66 or sample tool 65 can crush one or a plurality of prefilter 59 or filter module 71 to ensure the flow of whole blood 16, plasma 17 or sample 18 in inlet 66 or sample tool 65 to one or a plurality of filter 2 or filter module 71. Inlet 66 or sample tool 65 can contact prefilter 59 of filter module 71 and crush filter 2 of filter module 71. Filter 2 of filter module 71 can be softer than prefilter 59 of filter module 71. Inlet 66 or sample tool 65 can contact and crush prefilter 59 of filter module 71. Filter 2 of filter module 71 can be harder than prefilter 59 of filter module 71. Inlet 66 can be separate from top housing 91. Inlet 66 or sample tool 65 can be a capillary to collect whole blood 16, plasma 17 or sample 18. Inlet 66 or sample tool 65 can be inserted into an opening in top housing 91. Inlet 66 or sample tool 65 can be manufactured from a hydrophilic polymer such as cellulose acetate or PMMA. Inlet 66 or sampling tool 65 can be hydrophilically coated. The inner diameter of inlet 66 or sample tool 65 can be more than 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. Inlet 66 can accept a sampling tool 65. Sampling tool 65 can be inserted into inlet 66. Sampling tool 65 can be a pipette, a pipette tip or a capillary. When inserted into inlet 66, sampling tool 65 can be fluidically connected to one or a plurality of filter 2 or filter module 71. Sampling tool 65 can have a hash mark indicating the minimum sample required. Sample tool 65 can be a transparent capillary. Sample tool 65 can have a flow stop feature to avoid overflow.

Sensor Integration

[0164] Multiple types of sensors can be integrated into PCB 3. The multiple types of sensors can include general chemistry sensors, immuno-assay sensors, nucleic acid sensors, electrochemical sensors, coagulation sensors, or general sample indication sensors. The top exposed surface of an electrochemical IC or the top exposed surface of a magnetic sensing IC 83 can be planar with surface 11 or PCB 3. One or a plurality of IC 9, one or a plurality of electrochemical IC, one or a plurality of magnetic sensing IC 83 can be inserted in a single opening in PCB 3 and planarized with epoxy. One or a plurality of IC 9, one or a plurality of electrochemical IC, one or a plurality of magnetic sensing IC 83 can be inserted in a plurality opening in PCB 3 and planarized with epoxy. Each IC can be inserted into a dedicated opening in PCB 3. All the exposed ICs planar with PCB 3 can be wirebonded to PCB 3. All the ICs can be planar with PCB 3 to within 100 μm , 50 μm , 25 μm , 10 μm , 5 μm , 3 μm , 2 μm or 1 μm .

[0165] Device 1 can also integrate strip based electrochemical sensors. A strip-based electrochemical sensor can detect glucose, creatinine, lactate or other indications. A strip based electrochemical sensor can be attached to PCB 3 with adhesive. Wirebonds can electrically connect electrical leads on a strip based electrochemical sensor to pads on a PCB 3. Device 1 can contain the electronics to interface with a strip based electrochemical sensor. Device 1 can contain an

ammeter, voltmeter and power management system to measure an analyte using a strip based electrochemical sensor mounted on PCB 3. Device 1 can store the calibration information for a lot of strip based electrochemical sensor. Inlet 66 can fluidically connect to the inlet on one or more strip based electrochemical sensor. The strip based electrochemical sensor can detect an analyte in whole blood.

[0166] Device 1 can be circular to integrate multiple types of sensors to multiple types of analytes. One or a plurality of sensors can collect whole blood from the same inlet 66. A plurality of sensors can be arranged in a circle around a common inlet 66.

[0167] A plurality printed circuit boards connected to different sensors can be mounted or connected to surface 11 or PCB 3. A common inlet 66 can fluidically connect to a plurality of printed circuit boards through capillary action. A central capillary in inlet 66 can split and turn 90° into a plurality of capillaries that deliver sample to a plurality of sensors integrated on one or a plurality of PCBs.

[0168] FIG. 1A presents a cross-sectional side view of device 1 that can comprise a filter 2, a surface 11 and a spectrophotometer 15. Filter 2 can be mounted on top of surface 11 using tape 10. Surface 11 can be the surface of PCB 3. Barrier 13 can be a notch in filter 2. Plasma 17 can flow directly from surface 11 into well 19. AOW 4 can be mounted on top of surface 11 using tape 10. Surface 11 can be hydrophilic. Surface 11 can be capable of fluidically connecting filter 2 to well 19, wherein plasma 17 can flow on surface 11 across gap 12 and into capillary 22. IC 9 can integrate photodetector 8. IC 9 can be incorporated into surface 11. Protrusion 50 and lens 51 can contact plasma in well 19. Reflector 6 can contain an input lens 58 to collect light 21 from LED 5. Reflector 6 can contain optical elements 28 and 29 to redirect light 21 from LED 5 through well 19 and onto photodetector 8. Display 41 and a battery 40 can be electrically connected to PCB 3. PCB 3 can have a top and bottom side. Display 41 can be mounted on the top side or bottom side of PCB 3. Battery 40 can be mounted on the top side or bottom side of PCB 3. FIG. 1B is a cross-sectional top view of IC 9 and LED 5 mounted on PCB 3. LED 5 can be mounted on surface 11. LED 5 can be mounted on the top side of PCB 3. IC 9 can contain 2 28 photodetectors, whose surfaces can be incorporated with surface 11. FIG. 1C presents a cross-sectional top view of tape 10 with channels 23 and 25 mounted on PCB 3. Tape 10 can be double sided tape and can be used to generate channels 23 and 25. Channels 23 and 25 can be fluidically isolated from one another. FIG. 1D shows a cross-sectional top view of filter 2, filter 55 and AOW 4 mounted on tape 10. Whole blood 16 can be applied to both filter 2 and 55. Channels 23 and 25 can be capable of channeling plasma from filters 55 and 2, respectively, to wells 7 and 19, respectively. AOW 4 can contain 2 wells, 7 and 19. FIG. 1E is the top view of device 1 with reflector 6. The battery 40 and display 41 are omitted from FIG. 1B through 1E for simplicity. In the implementation presented in FIG. 2, plasma 17 can flow up well 19 towards protrusion 50 and lens 51. Moreover, light 21 can travel down through well 19 and through plasma 17, through surface 11 and onto photodetector 8.

[0169] FIG. 2 presents a cross-sectional side view of device 1 with IC 9 and filter 2 mounted above AOW 4. Filter 2 can be mounted above AOW 4 using tape 10. The top surface of AOW 4 can be surface 11. Barrier 13 can be a notch in filter 2. Plasma 17 can flow directly from the top surface of AOW 4 into well 19. IC 9 can be mounted above AOW 4 using tape 10. The top surface of AOW 4 can be hydrophilic. The top surface of AOW 4 can be capable of fluidically connecting filter 2 to well 19, wherein plasma 17 can flow on the top surface of AOW 4 across gap 12 and into well 19. Gap 12 can be generated by the gap between filter 2 and IC 9. IC 9 can integrate photodetector 8. Protrusion 50 and lens 51 can contact plasma in well 19. Reflector 6 can contain an input lens 58 to collect light 21 from LED 5. Reflector 6 can contain optical elements 28 and 29 to redirect light 21 from LED 5 through well 19 and onto photodetector 8. PCB 3, display 41 and battery 40 were omitted from FIG. 2 for simplicity. LED 5 can be mounted into a flexible PCB 62. IC 9 can be mounted into a flexible PCB 63. A flexible PCB can be manufactured out of a flexible material such as Kapton. A flexible PCB can be connected to a standard PCB by a hot bar reflow process,

taping, adhering or wirebonding. Flexible PCBs **62** and **63** can be hot bar reflowed onto PCB **3** which can contain display **41** and battery **40**. The use of flexible PCBs can allow easy alignment of the IC **9** to well **19** and of LED **5** to input lens **58**, respectively. LED **5** can be mounted onto reflector **6** for superior alignment of LED **5** and reflector **6**. Superior alignment of IC **9** to well **19** and of LED **5** to input lens **58**, respectively, can lead to lower path length errors. In the implementation presented in FIG. **2**, plasma **17** can flow down well **19** towards protrusion **50** and lens **51**. Moreover, light **21** can travel up through well **19** and through plasma **17**, through the surface of photodetector **8**. A vent **52** can be used to allow air in well **19** to escape as the plasma **17** enters.

[0170] FIG. **3** is a cross-sectional side view of device **1** wherein a transparent cover **64** can be used to eliminate the meniscus effects in well **19**. Plasma **17** can flow through well and create an ideal transmission interface with cover **64**. Cover **64** can be transparent to the optical frequency of detector. Cover **64** can be over molded, adhered using double sided tape, glued or heat staked on AOW **4**.

[0171] FIG. **4A** shows an implementation of device wherein filter **2** can be mounted on AOW **4** and AOW **4** can be mounted on PCB **3**. Filter capillary **27** can draw plasma directly from the bottom of filter **2** and can be fluidically connected with surface capillary **22**, such that plasma **17** from filter **2** can flow through filter capillary **27** and into surface capillary **22**.

[0172] FIG. **4B** presents a cross-sectional side view of an implementation of device **1** with two LEDs, LED **5** and LED **26** emitting light into the same well **19**. LED **5** can emit light with a first optical spectrum and a second LED **26** can emit light with a second optical spectrum, different from the first optical spectrum. The first LED **5** and the second LED **26** can be activated intermittently or concurrently. A reflector **6** can direct the light from LED **5** and LED **26** into well **19**. Photodetector **8**, exposed at the bottom of well **19**, can detect the first optical intensity of the first optical spectrum from the first LED **5** minus the spectral absorption of the plasma **17** with reagents in well **19**. Photodetector **8**, exposed at the bottom of well **19**, can detect the second optical intensity of the second optical spectrum from the second LED **26** minus the spectral absorption of the plasma **17** and reagents in well **19**. The first optical intensity measured at different time points can be used to quantify the rate of or the amount of reagent reacted in reaction **35**. The difference between the first optical intensity and the second optical intensity measured at different time points can be used to quantify the rate of or the amount of reagents reacted in reaction **35**.

[0173] The first LED **5** can produce a narrow band spectrum centered around a first frequency and the second LED **26** can produce a narrow band spectrum centered around a second frequency, different from the first frequency. Reaction **35** can alter the absorptivity of plasma **17** at the first frequency. By measuring light emitted from the first LED **5**, and accounting for the time elapsed, a rate or endpoint measurement of reaction **35** can be calculated. By subtracting the measurements from light emitted from the first LED **5** and second LED **26**, and accounting for the time elapsed, a rate or endpoint measurement of reaction **35** can be calculated. First LED **5** and second LED **26** can illuminate different wells.

[0174] FIG. **4B** also provides an implementation of reflector **6** using external reflection or mirrors. Optical elements **28** and **29** are mirror and redirect light **21** from LED **5** into plasma **17** of well **19**.

[0175] FIG. **5** shows the cross-sectional side view of a reflectance spectrophotometer implementation of device **1**. Filter **2** can be placed in proximity or in contact to a reflectance surface **81**. LED **5**, IC **9** and photodetector **8** can be mounted in PCB **3**. PCB **3**, LED **5**, reflector **6** and IC **9** can be placed on opposite sides of the reflectance surface **81** with respect to filter **2**. Plasma **17** from whole blood **16** can mix with filter reagents **32** in filter **2**. Chemical reaction **35** can proceed in plasma **17** with dissolved reagents **33**. Plasma **17** can contact reflectance surface **81**. Reflector **6** can direct light from LED **5** onto plasma **17** on reflectance surface **81**. Light **21** can reflect off plasma **17** and change in spectral composition by doing so according to the concentration of reporter molecule **56** in plasma **17**. Light **21** reflected off of plasma **17** can reflect

onto photodetector 8 of IC 9. Light 21 reflected off of plasma 17 can reflect onto reflector 6. Reflector 6 can redirect light 21 reflected off of plasma 17 onto photodetector 6. Photodetector 8 can measure the changes in the light 21 reflected off of plasma 17 over time at optical detection frequency 60 to determine the concentration of the reporter molecule 56 in plasma 17. Reflector 6 can redirect light from LED 5 to multiple reflectance surfaces. Reflector 6 can redirect light 21 reflected off of plasma 17 from a plurality of reflectance surfaces to a plurality of photodetectors. The light 21 reflected off of plasma 17 reflected from a plurality of reflectance surface can be detected and measured by a plurality of photodetectors. Filter 2 can be contained in a well 19. Well 19 can contain plasma 17. A plurality of wells can be mounted on a plurality of reflectance surfaces. A plurality of reflectance surfaces can be combined into a carrier surface.

[0176] FIG. 6 is a cross-sectional side view of device 1 wherein filter 2 is in capillary 22. AOW 4 can contact, crush or depress filter 2 thereby generating the barrier 13. Capillary 22 can be partially or completely full with filter 2.

[0177] The device can include a reflector which may be implemented using external reflective surfaces, or using total internal reflective surfaces, or using total internal reflection and redirecting light from a single LED.

[0178] The device which can comprise a membrane separation filter, mounted on a surface. The surface can be the surface of a printed circuit board (PCB) or the surface of an IC. One or more array of wells (AOW) can be mounted on the surface. The AOW can be placed in proximity or adjacent to a filter. One or more light emitting diodes (LED) can be mounted on the PCB. A reflector can redirect light produced by an LED into a well. A photodetector can be placed below the well such that the photodetector can detect or measure light traversing through the well, from the top to the bottom of the well. The photodetector can be integrated in an integrated circuits (IC). The IC can be embedded in, above or below the PCB. The IC can be mounted parallel to or flush with the surface and the PCB. The AOW can be mounted on the IC or the surface using double sided tape. The filter can be mounted on the surface using tape. The filter and AOW can be separated by a gap, wherein the surface under the gap is exposed or uncovered. The gap can also be filled with an impermeable material or a material that blocks red blood cells. The filter can have a notch along the edge adjacent to the gap to block red blood cells from flowing into the gap and into the well. A prefilter can be placed above or adjacent to the filter. The filter can contact the AOW.

[0179] The surface beneath the gap can be coated with a hydrophilic reagent, such as surface reagents. The filter can be coated or impregnated with filter reagents. The prefilter can be coated or impregnated with prefilter reagents. The well can be coated on the inside with well reagents. The bottom surface of the AOW can be coated with surface reagents or well reagents. Additional reagents can be dried in the form of a dried sphere. The dried sphere can be placed at the top of the well, at the bottom of well, below the filter, above the filter or in the gap. The dried sphere can be manufactured through lyophilization. The diameter of the dried sphere can be less than 2 mm, 1.5 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm, 0.2 mm, or 0.1 mm. The dried sphere can dissolve when contacted with fluid, such as the plasma.

[0180] The filter can be square, circular or any other shape. The AOW can contain between 1 and 100 wells. The tape can have between 1 and 100 slots that channel plasma from a filter to a well. Different slots can be fluidically isolated from one another on the surface of the PCB 3. Each slot can form separate reaction chambers, wherein different reactions can be performed. Separate slots can contact separate filters or they can contact a shared filter. Separate filters can contact separate prefilters, or they can contact a shared prefilter. 2 or more diodes can be placed on the same side or either side of the AOW.

[0181] A drop of whole blood from a fingerstick or venous whole blood draw can be applied on a filter or prefilter. The whole blood can mix with prefilter reagents or with filter reagents. A filter can trap the blood cells in the whole blood and let plasma pass through. Plasma can mix with filter reagents. Plasma can flow from the bottom of a filter onto a surface. Plasma can wick or sheet on a

surface, across a gap, within a slot. A hydrophilic reagent can promote plasma sheeting or wicking across a gap into a surface capillary. A surface capillary can be formed between the AOW and a surface, i.e. the surface of the PCB, or between the AOW and the IC. Plasma can mix with surface reagent. A surface capillary can connect to a well such that plasma can flow from the surface capillary and into the well. The plasma can flow up the well due to capillary action and can cease to flow once it reaches the top of the well. The plasma can mix with or dissolve surface reagents, hydrophilic reagents, filter reagents, prefilter reagents, well reagents and additional reagents.

[0182] The surface reagents, hydrophilic reagents, filter reagents, prefilter reagents, well reagents and additional reagents can be dried reagents that cause a reaction involving endogenous compounds in the plasma. Reactions can change the optical characteristics of the plasma in well. For example, reactions can modify the absorption of the plasma in the well at one or more optical frequencies. A reaction can change the concentration of a reporting reagent. A reporting reagent can absorb light at one or more specific and/or narrowband optical frequencies. A reporting reagent can be included in the surface reagents, hydrophilic reagents, filter reagents, prefilter reagents, well reagents and additional reagents. Different surface reagents, hydrophilic reagents, filter reagents, prefilter reagents, well reagents and additional reagents can be applied or dissolved in different reaction chambers.

[0183] Endogenous compounds can be the rate limiting reagents in a reaction. A reaction can be a zero-order, a first order or a higher order chemical reaction. In a rate measurement, the rate of a reporter reagent consumed or produced can be measured. This rate can be proportional to a physiological concentration or one or more endogenous compounds. In an endpoint measurement, the amount of reporter reagent consumed or produced can be measured. This amount can be proportional to a physiological concentration or one or more endogenous compounds.

[0184] The device can contain a first LED emitting light with a first optical spectrum and a second LED emitting light with a second optical spectrum, different from the first optical spectrum. The first LED and the second LED can be activated intermittently or concurrently. A reflector can direct the light from the first LED and the second LED into a well. A photodetector, exposed at the bottom of the well, can detect the first optical intensity of the first optical spectrum from the first LED minus the spectral absorbance of the plasma with reagents in the well. A photodetector, exposed at the bottom of a well, can detect the second optical intensity of the second optical spectrum from the second LED minus the spectral absorbance of the plasma and reagents in the well. The first optical intensity measured at different time points can be used to quantify the rate of or the amount of reagent reacted in a reaction. The difference between the first optical intensity and the second optical intensity measured at difference time points can be used to quantify the rate of or the amount of reagents reacted in the reaction.

[0185] The first LED can produce a narrowband emission spectrum centered around a first frequency and the second LED can produce a narrowband emission spectrum centered around a second frequency, different from the first frequency. A reaction can alter the absorptivity of plasma at the first frequency. By measuring light emitted from the first LED, and accounting for the time elapsed, a rate or endpoint measurement of a reaction can be calculated. By subtracting the measurements from light emitted from the first LED and second LED, and accounting for the time elapsed, a rate or endpoint measurement of a reaction can be calculated. The first LED and the second LED can illuminate different wells.

[0186] The LED can be a surface mounted LED. The LED can be packaged with a lens to direct or concentrate the light towards the first optical element in a reflector. The LED can be packaged using plastic or quartz or be a package-free bare die. The LED can be flipped chip bonded onto a PCB and the illumination can emit from the backside of the LED, opposite the bonding pads. Plastic packages degrade in UV light, but since the device is a single-use disposable, long term degradation of the package is not a concern. The LED can be a laser diode emitting a laser or coherent light. The LED can emit light with narrowband wavelength. The center frequency of

emission of the LED can be anywhere in the ultra-violet, visible and infra-red spectrum. The LED can emit light with a spectral line half width of less than 50 nm, 25 nm, 20 nm, 15 nm, 10 nm, 5 nm, 2 nm or 1 nm. The LED can emit with center frequencies at 340 nm, 405 nm, 467 nm, 550 nm, 600 nm, 850 nm or other frequency.

[0187] The reflector can be an injection molded from an injection moldable plastic. The Reflector can contain multiple optical elements. A first optical element can reflect the light from an LED to a second optical element. The second optical element can reflect the light from the first optical element into a well. The reflector can direct the light from 1, 2, 3 or 4 different diodes into a well. The reflector can comprise fully or partially reflective surfaces, total internal reflective surfaces or a waveguide. However, for directing shorter wavelength lights like 340 nm and 405 nm light, the material from which the light-pipe or waveguide is manufactured can be transparent or translucent to ultra-violet light, such as cyclic olefin copolymers. The reflector can be incorporated in a housing. The reflector can be composed of multiple optical elements, optical splitters, combiners, mirror surface, lenses, apertures and other features to control or direct light from one or more diodes.

[0188] An alternative implementation can be a device in which the filter is mounted on top of the AOW. In this case a filter capillary can traverse the AOW and can deliver plasma from the bottom of the filter into a surface capillary. In this implementation, there is no need for a notch or a gap. **11**

[0189] The light from first LED can be redirected into a well by a first optical element and a second optical element. A protrusion in the reflector can channel or direct the light from a second optical element, through a lens and into the plasma in a well. The protrusion can contain a lens that focuses the light from the LEDs onto the bottom of a well. The lens can be flat or concave. The lens can also be convex to avoid bubbles being trapped underneath it when a well fills by capillary action from the bottom up. The reflector can have a third optical element to collect all the light from the LED. The reflector can comprise a waveguide that redirects the light from the LEDs through a protrusion and into a lens.

[0190] The protrusion and lens can be mounted above a well. The protrusion and lens can be centered with the well. The protrusion or lens can contact plasma at the top of the well. The protrusion or lens can contact the sidewalls or top of the well. A vent can be formed between the protrusion or lens and the sidewall or top of the well. The vent can allow air inside the well to exhaust out the top of the well to maintain capillary action. The protrusion and lens can be in proximity to the well without contacting the well. The width of the vent can be less than 1 mm, 0.5 mm, 0.25 mm, 0.1 mm, 0.05 mm, 0.025 mm, 0.01 mm, 0.005 mm, or 0.001 mm. The vent can be an annulus around the top rim of the well.

[0191] The assay measurement can begin when the plasma contacts the lens or protrusion. The amount of light that reaches the photodetector at the bottom of the well can increase, decrease or change arbitrarily when plasma contacts the lens or protrusion. The change in the amount of light that reaches the photodetector when plasma contacts the lens or the protrusion can be measured and used to begin the assay measurement in the well. The assay measurements in different wells can begin at different times. The change or lack thereof in the amount of light that reaches the photodetector when plasma contacts the lens or the protrusion can be used to indicate under-fill situations where not enough sample was applied to the filter.

[0192] The lens or the protrusion can be above the plasma and avoid contacting it. The lens can focus light onto the top of the well. The top aperture of the well can be minimized to reduce the optical influence of the meniscus of the plasma on the illumination of the photodetector. The diameter of the top aperture of the well can be less than 2 mm, 1.5 mm, 1 mm, 0.75 mm, 0.5 mm, 0.4 mm, 0.3 mm, 0.2 mm, or 0.1 mm. The sidewalls of the well can be tapered to improve capillary flow, eliminate light reflecting off the sidewalls and to reduce the diameter of the top aperture of the well. The diameter of the top aperture of the well can be smaller than the diameter of the bottom aperture of the well.

[0193] The device can be implemented with only one LED. The reflector can be implemented using total internal reflection and can contain one or more protrusions and lenses. The reflector can direct the light from the LED into multiple wells for analysis.

[0194] The device can contain a blank filter which can produce plasma without a reporter reagent. The device can contain a blank well which can accumulate plasma produced by a blank filter, to measure the absorbance of plasma without a reporter reagent, or blank measurement. The blank measurement can be used to determine the concentration of a reporter reagent dissolved in plasma, or the intrinsic absorbance of plasma or both. The blank measurement can be subtracted from the absorbance measurements in other wells. The blank measurement and NADH-blank measurement can be combined to measure endpoint reactions by providing the concentration of the reporter reagent before and after a reaction may occur.

[0195] The device can be configured to perform two or more multiplexed chemistry assays with a control. A chemistry test that can have medical relevance is alanine aminotransferase (ALT) and aspartate aminotransferase (AST). The device can be configured so that ALT and AST measurements are performed separately and concurrently in two wells.

[0196] A reaction for measuring ALT can comprise 1) ALT in plasma catalyzing the transfer of an amino group from L-alanine to alpha-ketoglutarate to form L-glutamate and pyruvate, and 2) lactate dehydrogenase (LDH) catalyzing the conversion of pyruvate to lactate and the oxidation of Nicotinamide adenine dinucleotide (NADH) to NAD⁺. A reaction for measuring AST can comprise 1) AST catalyzing the conversion of L-aspartate and alpha-ketoglutarate into oxaloacetate and L-glutamate, and 2) Malate dehydrogenase (MDH) catalyzing the conversion of oxaloacetate into malate and the oxidation of NADH to NAD⁺. The substrates for measuring AST and ALT can be introduced in abundance so the rate of the reactions can be limited by the rate of endogenous AST and ALT in plasma.

[0197] The reporter reagent for both ALT and AST measurements can be NADH. NADH has an absorption peak at 340 nm, so the amount or rate of NADH consumed in the reaction can be measured by illuminating the wells, with light from a first LED with an emission peak at 340 nm. In a rate measurement, the rate of change of the absorbance at 340 nm can be due to the conversion of NADH to NAD⁺ and can be proportional to the amount of ALT or AST present in the plasma. A photodetector can measure the change in the amount of light transmitted through plasma in the well over time, and can determine from calibration values stored on the IC the corresponding concentration of endogenous ALT. A second LED with an emission peak at 405 nm can be used to provide a constant control illumination intensity.

[0198] Filter reagents can comprise dried 1-alanine, NADH, alpha-ketoglutarate, 1-aspartate, MDH, LDH and excipients. The prefilter reagents can comprise dried 1-alanine, 1-aspartate, NADH, alpha-ketoglutarate, MDH, LDH and excipients. The surface reagents can comprise 1-alanine, 1-aspartate, NADH, alpha-ketoglutarate, MDH, LDH and excipients. The well reagents can comprise hydrophilic reagents to maximize the capillary force, 1-alanine, 1-aspartate, NADH, alpha-ketoglutarate, MDH, LDH and excipients. The additional reagents can comprise 1-alanine, 1-aspartate, NADH, alpha-ketoglutarate, MDH, LDH and excipients. To limit the ALT reactions to a well, LDH can be dried exclusively in a slot, or in the well. To limit the ALT reactions to a well, LDH can be exclusively included in the surface reagents, hydrophilic reagents, well reagents or additional reagents. To limit the AST reactions to a well, MDH can be dried exclusively in a slot, or in the well. To limit the AST reactions to a well, MDH can be exclusively included in the surface reagents, hydrophilic reagents, well reagents or additional reagents.

[0199] By sharing a filter, the slots can channel plasma into the wells with the same or similar reporter reagent concentration, or NADH concentration.

[0200] Each slot can be in contact with a separate filter to decouple the reactions in wells.

However, in a decoupled situation, the concentrations of the reporter reagents may vary from well to well.

[0201] The dominant source of noise in this assay can be the natural oxidation of NADH into NAD⁺ by endogenous reactions. The well can be used as a NADH-blank well to measure the natural oxidation of NADH, or NADH-blank measurement. The NADH-blank measurement can be subtracted from the ALT, AST measurements in the wells, respectively, or from other chemistry measurements, to eliminate the contribution of the natural oxidation of NADH or other sources of noise. MDH and LDH can be omitted from the fluid path from the drop of whole blood to the blank well, such that the intended reaction cannot run in the well and only the natural oxidation of NADH is measured in the blank well. The NADH can be included in filter reagents and prefilter reagents wherein the filter and prefilter are shared between the measurement all measurement wells.

[0202] The design can be configured to measure the plasma concentrations of albumin, blood urea nitrogen (BUN), calcium, carbon dioxide (bicarbonate), chloride, creatinine, glucose, potassium, sodium, total bilirubin, total protein, alanine, aminotransferase (ALT), alkaline phosphatase (ALP) and aspartate aminotransferase (AST). The center frequency of the narrowband emission of the LEDs can be selected according to the color shift or spectral absorptivity that yields the highest signal to noise ratio.

[0203] The device can also include a desiccant, a liquid crystal display (LCD) and one or more batteries to provide power, an IC and an LCD. The device can include a plastic housing to encase the device and all the components. The housing can have branding and test identifiers and a QR code printed or molded on its exterior. The device can have a button or a pull tab to activate. The device can also have a sample capillary that collects whole blood from a finger and wicks it to the filter or prefilter. The device can be configured to accept less than 15 uL of whole blood, or less than 10 uL of whole blood or less than 5 uL of whole blood. The results from the measurement from the device can be displayed on the LCD or wirelessly transmitted to a nearby wireless device. In the cases where the change in amount of the spectral density of the light transmitted through the plasma changes quickly, the device can report results as soon as they are available. Results can be reported in less than 15 minutes, or less than 10 minutes, or less than 5 minutes, or less than 3 minutes, or less than 1 minute.

[0204] The filter can be manufactured from polyethersulfone/polyvinylpyrrolidone (PES/PVP) and have graduated porosity. The filter can be coated with glycine to minimize cell leakage and lysis. The area of the filter can be less than 10 mm.sup.2 or 30 mm.sup.2, or 100 mm.sup.2 in order to accept less than 15 uL of whole blood.

[0205] The AOW can be machined or injection molded. The AOW can be manufactured from an injection moldable plastic such as Polymethylmethacrylate (PMMA), Acrylonitrile butadiene styrene (ABS) or hydrophilic polymers. The AOW can be transparent, translucent or opaque. The AOW can have mounting points or through holes for a reflector. The PCB can have mounting points or through holes for the AOW and the reflector.

[0206] The inner volume of the well can be less than 2 uL, or 1 uL, 0.5 uL, or 0.25 uL, or 0.1 uL of plasma. The diameter of the well can be less than 1 mm, or 0.5 mm, or 0.25 mm. The height of the well can be less than 2 mm, or 1 mm, or 0.5 mm or 0.25 mm. The well can be vertical or positioned at an angle vis-a-vis the surface. The well can have tapered sidewall to promote capillary action.

[0207] The angle of the tapered sidewall with respect to a vertical can be more than 1 degree, more than 2 degrees, more than 3 degrees, more than 4 degrees, more than 5 degree, more than 6 degrees, more than 7 degrees, more than 8 degrees, more than 9 degrees, or more than 10 degrees. The angle of the tapered sidewalls of the well can be larger or equal to the highest angle off vertical of the light incident in the well to avoid from reflecting off the sidewalls of the well.

[0208] The photodetector can be a Complementary Metal Oxide Semiconductor (CMOS) photodiode. The photodetector can be an active pixel sensor. The photodetector can be connected to a charge integrator such as a capacitor, embedded on the IC. The charge integrator can be connected to an amplifier or a comparator, embedded on the IC. The IC can generate a first reference voltage for the comparator. The IC can drive a reference current through the LED. The IC

can discharge the charge integrator or pre-charge the charge integrator to a second reference voltage, drive the reference current through the LED and measure the time until the charge integrator voltage reaches the first reference voltage and triggers the comparator. The charge integrator voltage or the input of the comparator can be chopped to minimize $1/f$ noise. The time until the charge integrator voltage reaches the first reference voltage and triggers the comparator can correspond to the amount of light incident on the photodetector, and by extension corresponds to the concentration or activity of an endogenous compound being measured. The IC can integrate a microcontroller to control the state of the device, memory to store calibration data and results, a power management unit to drive the LEDs and source power from the battery. The device can have a boost converter to increase the power supply voltage above what the batteries can provide. The IC can integrate a bandgap to generate reference currents and compensate the measurement for temperature differences. The IC can incorporate a heater and a temperature surface temperature sensor to heat the wells to a predetermined temperature during the reaction.

[0209] The area of the photodetector can be larger than or equal to the aperture at the bottom of the well. The area of the photodetector can be smaller than the aperture at the bottom of the well to ensure that light incident on the edges of the photodetector does not travel a path length this is difference from the path length traveled by light incidence on the center of the photodetector by more than 20%, 15%, 10%, 5%, 4%, 3%, 2%, 1% or 0.5%. Multiple photodetector can be placed below each well. The photodetectors can be manufactured using different material or have optical filters patterned on them to discriminate different colors of light. The passivation and dielectric layers above the photodetector can be thinned or etched to minimize attenuation of light before reaching the embedded photodetector. The surface of the IC can be coated with an anti-reflective coating (ARC) to minimize the amount of light that reflects off the surface of the IC before reaching the photodetector.

[0210] Double-sided tape can be hydrophobic or hydrophilic. The tape can be hydrophobic to avoid delamination after prolonged exposure to plasma. Also, the use of hydrophobic tape can facilitate spotting of different surface reagents spotted in different slots by eliminating unwanted mixing. The tape can be thin to minimize the dead volume of plasma and therefore to reduce the amount of whole blood needed to run the device. The thickness of the tape can be less than 1 mm, 0.1 mm, 0.05 mm, 0.025 mm or 0.01 mm. Multiple slots can connect to multiple fluidically isolated filters but channel multiple plasmas to the same AOW or to same well in AOW. Multiple slots can connect to a single filter.

[0211] A gap between AOW and the filter can eliminate red blood cells from wicking into plasma via the capillary effects at the interface between the filter and the AOW. The length of the gap can be less than 5 mm, 2 mm, 1 mm, 0.5 mm, 0.2 mm, 0.1 mm, 0.05 mm, or 0.025 mm. The gap can be eliminated provided there is a notch or barrier for whole blood cells on the edge of the filter.

[0212] A notch can reduce or eliminate the flow of whole blood cells from the top of the filter into plasma in the gap via the edge of the filter. The presence of red blood cells in the well can interfere with the chemistry measurements. The notch can be a depression, an indent, or any feature in the filter that reduces or eliminate the lateral flow of red blood cells through the edge of the filter or over the top of the filter. The notch can be manufactured by crushing the filter wherein blood cells are blocked from traveling laterally through the crush region. The crush region can be less than 5 mm, 2 mm, 1 mm, or 0.5 mm or 0.25 mm from the edge of the filter. The notch can be substituted by a hydrophobic dam or barrier on the edge of the filter or a physical dam or barrier on the edge of the filter that prevents red blood cells from reaching plasma in the gap via the edge of the filter.

[0213] The output power of the LED can vary according to lot number and other factors. Small tolerance changes in the position of the reflector can affect the amount of light it directs into the wells. The sensitivity of the photodetector can vary according to a variety of factors. For endpoint measurements, it can be necessary to calibrate the optical system, or to calibrate the amount of light incident on the photodetector and the signal that it corresponds. The system can be calibrated in air,

where the wells are filled with air. In this case, the optical power transmitted out of the LED, through the reflector and into the photodetector with air in the well can be the same as the optical power transmitted out of the LED, through the reflector and into the photodetector with fluid in the well. Due to changes in refractive indices, the optical power transmitted out of the LED, through the reflector and into the photodetector with air in the well can be a deterministic function of the optical power transmitted out of the LED, through the reflector and into the photodetector with fluid in the well. Alternatively, the optical power transmitted out of the LED, through the reflector and into the photodetector can be measured using a calibration fluid in the well, such as a coating reagent. Alternatively, the sensitivity of the photodetector can be calibrated, and the optical power transmitted out of the LED, through the reflector and into the photodetector can be measured during the assay.

[0214] Temperature is an important factor that can alter the optical power emitted by the LED or the sensitivity of the photodetector or the activity of enzymes. The current through the LED can be temperature compensated so the output power of the LED is constant or nearly constant with respect to temperature. The reference voltage for the comparator can be compensated so the integration time of the photocurrent is constant or nearly constant with respect to temperature. The IC can have a memory block that stores temperature calibration data to calibrate the assay measurements for changes in temperature. A heater integrated in the IC or on the PCB to maintain the well at a constant and predictable temperature.

[0215] The LED can be flip chip bonded onto the PCB. PCB feature registration and the flip-chip bonding process can result in LED positional errors. To overcome these errors, the LED can be placed on the PCB first and the IC, AOW and reflector can be placed on PCB subsequently to the LED and registered to the LED. In some cases, components will be mounted on the other side of the PCB. The LED can be registered to a through-feature like one or more vias or one or more edges of the PCB, and IC, AOW and reflector can be registered to the same through-features.

[0216] The device can contain electrochemical sensors that function either in plasma or whole blood. Platinum electrodes and permselective films can be patterned on separate electrochemical IC to enable electrochemical sensing on the device. Ion selective electrodes can be integrated in the electrochemical IC. The device can contain a magnetic sensing IC that performs magnetic particle labeled immuno-assays, wherein magnetic particles conjugated to antibodies can capture soluble target proteins in plasma. The magnetic particles can sediment via gravity to the antibody coated surface of the magnetic sensing IC to which they can bind strongly in the presence of the target proteins. Magnetic sensing IC can integrate current carrying conductors adjacent to magnetic particle sensors. The current carrying conductors can remove magnetic particles weakly bound to the surface of the magnetic sensing IC from atop the magnetic particle sensors, while the magnetic particles sensors can detect magnetic particles that remain strongly bound to surface of the magnetic sensing IC above magnetic particle sensors. Magnetic particles can be loaded and stored in a dry state in a well. Plasma can rehydrate and release the dried magnetic particles which incubate with plasma, capture the target proteins and sediment to the surface of the magnetic sensing IC. The magnetic particle sensors can be implemented as photodetectors embedded in the magnetic sensing IC. The device can contain one IC to perform chemistry tests and another IC to perform immuno-assays. The device can contain one or more ICs, one or more electrochemical ICs and one or more magnetic sensing ICs. Electrochemical IC and magnetic sensing IC can be integrated on or parallel or flush with the PCB. The IC, electrochemical IC and magnetic sensing IC can have digital interfaces for communication like I^{sup}.2C or SPI.

[0217] The device can be integrated into a blood collection system that is fitted onto a patient and take whole blood from the patient. The device can be integrated into the blood collection system and can take whole blood from the blood collections system for analysis. The blood collection may or may not have an LCD to display the assay results. The assay results can be transmitted wirelessly to a nearby mobile device.

[0218] FIG. 7 presents a cross-sectional view of device 1 inserted into port 101 of reader 100. The reader 100 can contain one or a plurality of LEDs 109. The reader 100 can contain one or a plurality of reflectors 114 for redirecting the light 21 through one or a plurality of wells 19 in AOW 4 in device 1. The reader 100 can contain one or a plurality of photodetectors 113 to detect light 21. Reader 100 can contain heater 102, a digital display 105, and battery 104. Device 1 can be inserted into port 101. Reader 1 can contain one or a plurality of optical apertures 116 and blinds 121 to avoid cross illumination between wells. Cover 64 can be used to avoid evaporation from well 19. Reflector 114 can redirect light 21 from LED 109 and through cover 64. LED 109 can have all the characteristics of LED 5. Photodetector 113 can have all the characteristics of photodetector 8. Reflector 114 can have all the characteristics of reflector 6.

[0219] FIG. 8. presents the top view of device 1 wherein the cross section of the well 19 in the AOW 4 are square, rectangular, trapezoidal or a parallelogram. AOW 4 can be transparent. Light 21 can pass through AOW 4 laterally, or parallel to surface 11. Blinds 121 on either side of AOW 4 can reduce or eliminate illumination cross talk. Apertures 116 on either side of AOW 4 can reduce or eliminate illumination cross talk. Light 21 can be detected by photodetector 8 or photodetector 113. Well 19 can have two inner parallel inner surfaces to define and control path length 39. Photodetector 8 can be mounted above surface 11 to receive light 21 directly. Photodetector 8 can be mounted parallel with surface 11 and an additional reflector can redirect light 21 from AOW 4 to photodetector 8. Reflector 114 and photodetector 113 can be on opposite sides of well 19. LED 109 and photodetector 113 can be on opposite sides of well 19. Blind 121, aperture 116 and diffuser 115 can be mounted in reader 100 or device 1. AOW 4 can comprise a reflector to guide light 21 onto photodetector 8 or photodetector 113.

[0220] FIG. 9. shows a cross-sectional side view of vial 103 mounted on device 1. Filter 2 can be any porous material for releasing dissolved reagents into filtrate 24. Vial 103 can contain vial reagents in wet or dry state. Vial 103 can have a cap or opening to insert sample 16. Sample 16 can mix with vial reagents in vial 103. Vial 103 can have a mechanism to push or pop wherein sample 16 can incubate with vial reagents before the push or pop action releases the mixture through filter 2.

[0221] FIG. 10 presents a cross-sectional side view of device 1. A filter module 71 can contain prefilter 59 and filter 2 along with two lamination surfaces, namely lamination surface 84 and lamination surface 85. For an ALT reaction, prefilter 59 can contain NADH, alpha-ketoglutarate and excipients in a dry form. Filter 2 can contain 1-alanine, LDH and excipients in a dry form. For an AST reaction, prefilter 89 can contain NADH, alpha-ketoglutarate and excipients in a dry form. Filter 55 can contain aspartate or similar molecule, LDH, MDH and excipients in a dry form. Pyridoxal phosphate can be added in either prefilter or filter.

[0222] FIG. 11 presents the cross-sectional top view of tape 10 with channel 25 and enlargement 86 on surface 11. The enlargement can be wider than channel 25 and can allow the plasma 17 or filtrate 24 to circumvent the crush region 88 and enter surface capillary 22. The crush region 88 can be restrictive to the flow of plasma 17 or filtrate 24.

[0223] FIG. 12 presents the cross-sectional top view of filter module 71 integrated with AOW 4. Device 1 can contain one or a plurality of filter modules. The space between filter modules can be less than 5 mm, 4 mm, 3 mm, 2 mm, 1 mm, 0.5 mm. A space between filter modules can reduce or eliminate fluidic cross talk. Two or more filter modules can share a prefilter to facilitate flow from inlet 66 to the two or more filter modules.

[0224] FIG. 13 shows the cross-sectional side view of reflector 6 with cavity 69 mounted on AOW 4 with optic tape 67. Optic tape 67 can be thin to ensure good registration of lens 51 with surface 11. The path length 39 can be defined by the distance from lens 51 to surface 11. The thickness of optic tape 67 can be less than 100 μm , 50 μm , 30 μm , 20 μm or 10 μm .

[0225] FIG. 14 presents the cross-sectional side view of top housing 91 which can be fitted into bottom housing 92 and can apply pressure and crush filter module 71. Inlet 66 can be a capillary.

The bottom of inlet **66** can contact or crush filter module **71** or filter **2**. The bottom of inlet **66** can contact surface **11**, PCB **3** or tape **10**. Sample electrode **90** can be exposed and in contact with the sample **18** or whole blood **16** in inlet **66**. Sample **18** or whole blood **16** can flow from inlet **66** into prefilter **59** of filter module **71**. Prefilter reagents in prefilter **59** can dissolve into sample **18** or whole blood **16**. Prefilter reagents and sample **18** can flow into or onto filter **2**. Lamination surfaces **85** and **84** can prevent sample **18** from bypassing prefilter **59** or filter **2**.

Claims

1. A spectrophotometer device for measuring the concentration or activity of one or more analytes in a plasma comprising: a light emitting diode (LED) configured to emit a light with a narrow band optical spectrum; a photodetector configured to be sensitive to the light; an array of wells (AOW) comprising a first well; a reflector with an output lens configured to redirect the light through the plasma in the first well and onto the photodetector, wherein the reflector has a protrusion that contacts the plasma in the first well; a reporter molecule in the first well, wherein the reporter molecule is configured to absorb part or all of the light; and dried critical reagents on the surface of the protrusion.
 2. The device of claim 1, wherein the protrusion has a lens and wherein the dried critical reagents are on the surface of the lens.
 3. The device of claim 1, further comprising an immuno-assay integrated circuit and wherein the critical reagents comprise magnetic particles.
 4. The device of claim 1, further comprising a sample electrode configured to detect a presence of the plasma.
 5. A system comprising the device of claim 1 and a reader, wherein the device is in the reader.
 6. The system of claim 5, wherein the reader comprises an imaging system configured to detect, count, estimate or measure particles.
 7. The system of claim 6, wherein the device comprises a transparent surface.
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