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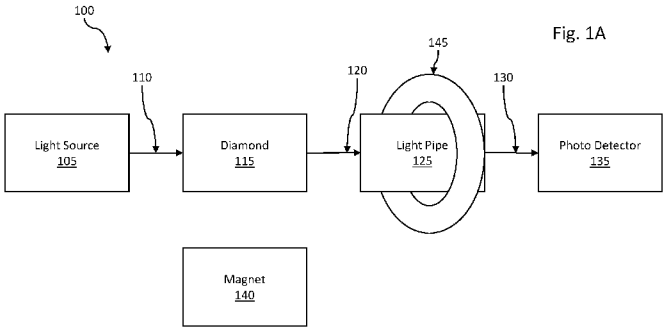


Fig. 1A

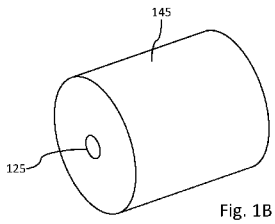


Fig. 1B

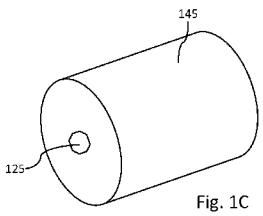


Fig. 1C

(57) Abstract: A device includes a diamond assembly. The diamond assembly includes a diamond with a plurality of nitrogen vacancy centers and electrical components that emit electromagnetic waves. The device also includes a light source configured to emit light toward the diamond and a photo detector configured to detect light from the light source that traveled through the diamond. The device further includes an attenuator between the diamond assembly and the photo detector. The attenuator is configured to attenuate the electromagnetic waves emitted from the electrical components of the diamond assembly.

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MAGNETOMETER WITH LIGHT PIPE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to co-pending U.S. Application No. __/___,_____, filed January 21, 2016, titled "MAGNETOMETER WITH A LIGHT EMITTING DIODE," Atty. Dkt. No. 111423-1033, U.S. Application No. __/___,_____, filed January 21, 2016, titled "DIAMOND NITROGEN VACANCY SENSOR WITH COMMON RF AND MAGNETIC FIELDS GENERATOR," Atty. Dkt. No. 111423-1034, U.S. Application No. __/___,_____, filed January 21, 2016, titled "DIAMOND NITROGEN VACANCY SENSOR WITH DUAL RF SOURCES," Atty. Dkt. No. 111423-1035, U.S. Application No. __/___,_____, filed January 21, 2016, titled "IMPROVED LIGHT COLLECTION FROM DNV SENSORS," Atty. Dkt. No. 111423-1047, each of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates, in general, to nitrogen vacancy centers in diamonds. More particularly, the present disclosure relates to using light pipes to transmit light to or from a diamond with one or more nitrogen vacancies.

BACKGROUND

[0003] The following description is provided to assist the understanding of the reader. None of the information provided or references cited is admitted to be prior art. Some diamonds have defects in the crystal structure that may contain nitrogen. A light source can be used to excite the defect. In some instances, transmission of light within a device with the diamond may be difficult or inefficient.

SUMMARY

[0004] An illustrative device includes a diamond with a nitrogen vacancy and a light source configured to transmit light toward the diamond. The device may also include a first sensor configured to sense a first portion of the light transmitted from the light source. The first portion of the light may not travel through the diamond. The device may further include a second sensor configured to sense a second portion of the light transmitted from the light source. The second portion of the light may travel through the diamond. The device may also include a first light pipe configured to direct the second portion of the light from the

diamond to the second sensor and a first waveguide cutoff filter surrounding the first light pipe that is configured to attenuate electromagnetic waves.

[0005] An illustrative device includes a diamond with a nitrogen vacancy and a light source configured to transmit light toward the diamond. The device may further include a first sensor configured to sense a first portion of the light transmitted from the light source. The first portion of the light may not travel through the diamond. The device may also include a second sensor configured to sense a second portion of the light transmitted from the light source. The second portion of the light may travel through the diamond. The device may further include a light pipe configured to direct the second portion of the light from the light source to the diamond and a waveguide cutoff filter surrounding at least a portion of the light pipe.

[0006] An illustrative method includes providing power to a light source. The light source may be configured to emit light toward a diamond with a nitrogen vacancy. A first portion of the light may not travel through the diamond and a second portion of the light may travel through the diamond and through a first light pipe. The method may also include receiving, at a processor, a first signal from a first sensor. The first signal may indicate a strength of the first portion of the light with a first wavelength. The method may further include receiving, at the processor, a second signal from a second sensor. The second signal may indicate a strength of the second portion of the light with a second wavelength. The method may also include comparing, at the processor, the strength of the first portion of the light with the first wavelength and the strength of the second portion of the light with the second wavelength to determine a strength of a magnetic field applied to the diamond.

[0007] An illustrative method includes emitting, from a light source, a first light portion and a second light portion; sensing, at a first sensor, the first light portion; and sensing, at a second sensor, the second light portion. The second light portion may have traveled through a light pipe and a diamond with a nitrogen vacancy. The method may also include comparing the first light portion to the second light portion to determine a strength of a magnetic field applied to the diamond.

[0008] An illustrative device includes a diamond assembly. The diamond assembly may include a diamond with a plurality of nitrogen vacancy centers and electrical components that emit electromagnetic waves. The device may also include a light source configured to emit light toward the diamond and a photo detector configured to detect light

from the light source that traveled through the diamond. The device may further include an attenuator between the diamond assembly and the photo detector. The attenuator may be configured to attenuate the electromagnetic waves emitted from the electrical components of the diamond assembly.

[0009] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the following drawings and the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1A is a block diagram of a magnetometer with a light pipe in accordance with an illustrative embodiment.

[0011] Figs. 1B and 1C are isometric views of a light pipe and a shield in accordance with illustrative embodiments.

[0012] Fig. 2 is a block diagram of a magnetometer with two light pipes in accordance with an illustrative embodiment.

[0013] Fig. 3 is a block diagram of a magnetometer with two light pipes in accordance with an illustrative embodiment.

[0014] Fig. 4 is a block diagram of a computing device in accordance with an illustrative embodiment.

[0015] Fig. 5 is a flow diagram of a method for measuring a magnetic field in accordance with an illustrative embodiment.

[0016] The foregoing and other features of the present disclosure will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

DETAILED DESCRIPTION

[0017] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

[0018] Nitrogen-vacancy centers (NV centers) are defects in a diamond's crystal structure, which can purposefully be manufactured in synthetic diamonds. In general, when excited by light (e.g., green light) and microwave radiation, the NV centers cause the diamond to generate red light. When an excited NV center diamond is exposed to an external magnetic field, the frequency of the microwave radiation at which the diamond generates red light and the intensity of the light change. By measuring this change and comparing the frequency of the microwave radiation of which the diamond generates red light when exposed to the external magnetic field to the microwave frequency at which the diamond generates red light at when not in the presence of the external magnetic field, the NV centers can be used to accurately detect the magnetic field strength.

[0019] In many instances, a light source is used to provide light to the diamond. The more light that is transmitted through the diamond, the more light can be detected and analyzed to determine the amount of red light emitted from the diamond. The amount of red light can be used to determine the strength of the magnetic field applied to the diamond. In some instances, photo detectors used to detect the amount of red light (or any suitable wavelength of light) are sensitive to electromagnetic interference (EMI). However, in some cases electromagnetic signals can be emitted from electrical components near the diamond. In such cases, EMI from the diamond assembly can affect the photo detectors.

[0020] In some cases, EMI glass can be used to block and/or absorb EMI signals from the diamond assembly (or associated electronics or signals). Thus, if EMI glass is placed between the diamond and the photo detector, the amount of EMI affecting the photo detector can be reduced. To increase the sensitivity of the magnetometer, the amount of light emitted

from the diamond that is sensed by the photo detector can be increased. Thus, in some instances, sensitivity of the magnetometer is reduced by inefficient transmission of light between the diamond and the photo detector. In many instances, EMI glass is an inefficient transmitter of light. For example, metal embedded in the EMI glass can absorb, block, or reflect light traveling through the EMI glass.

[0021] In some embodiments, an EMI shield can be used to block EMI from the diamond assembly. In such embodiments, the EMI shield may include a hole that allows light to pass to or from the diamond. Depending upon the size of the hole in the EMI shield, some EMI may pass through the hole. Thus, the smaller the hole, the more EMI is prevented from passing through.

[0022] In some instances, a light pipe may be used to transmit light through the hole in the EMI shield. For example, light from a light source can pass through a diamond and through a hole in an EMI shield. The light can be collected by a light pipe and travel through the light pipe to a photo detector. In general, light pipes are efficient at transmitting light. Thus, a relatively high percentage of light that is emitted from the diamond can be transferred to the photo detector. Any suitable light pipe (e.g., a homogenizing rod) can be used.

[0023] Fig. 1A is a block diagram of a magnetometer with a light pipe in accordance with an illustrative embodiment. An illustrative magnetometer 100 includes a light source 105, a diamond 115, a light pipe 125, a photo detector 135, and a shield 145. In alternative embodiments, additional, fewer, and/or different elements may be used.

[0024] As explained above, the magnitude of the magnetic field applied to the diamond 115 by, for example, a magnet 140 can be determined by measuring the amount of red light in the light emitted from the diamond 115. The light source 105 emits source light 110 to the diamond 115. In some embodiments, one or more components can be used to focus the source light 110 to the diamond 115. The light passes through the diamond 115, and the modulated light 120 passes through the hole in the shield 145. To pass through the hole in the shield 145, the modulated light 120 enters and passes through the light pipe 125. The transmitted light 130, which passed through the hole in the shield 145, exits the light pipe 125 and is detected by the photo detector 135.

[0025] Any suitable photo detector 135 can be used. In an illustrative embodiment, the photo detector 135 includes one or more photo diodes. In some embodiments, the photo

detector 135 can be an image sensor. The image sensor can be configured to detect light and/or electromagnetic waves. The image sensor can be a semiconductor charge-coupled device (CCD) or an active pixel sensor in complementary metal-oxide-semiconductor (CMOS) or N-type metal-oxide-semiconductor (NMOS) technologies. Any other suitable image sensor can be used.

[0026] In some instances, the diamond 115 is surrounded by one or more components that emit EMI. For example, a Helmholtz coil can surround the diamond. In some instances, a two-dimensional or a three-dimensional Helmholtz coil can be used. For example, the Helmholtz coil can be used to cancel out the earth's magnetic field by applying a magnetic field with an equal magnitude but opposite direction of the earth's magnetic field. In alternative embodiments, the Helmholtz coil can be used to cancel any suitable magnetic field and/or apply any suitable magnetic field to the diamond. In another example, a microwave generator and/or modulator can be located near the diamond to use microwaves to excite the NV centers of the diamond. The microwave generator and/or modulator can emit EMI that can interfere with the photo detectors.

[0027] The shield 145 can shield the photo detector 135 from the EMI. For example, the shield 145 can be a material that attenuates electromagnetic signals. In some embodiments, the shield 145 can be solid metal such as a metal foil. In alternative embodiments, materials such as glass, plastic, or paper can be coated or infused with a metal. Protecting the photo detector 135 from EMI allows the magnetometer to be more sensitive because the reduction in EMI reduces the amount of noise in the signal received from the photo detector 135. In some instances, protecting the photo detector 135 from EMI protects the fidelity of the magnetometer because the signal received from the photo detector 135 is more accurate. That is, protecting the photo detector 135 from EMI helps to ensure that a reliable and accurate signal is received from the photo detector 135 because there is less noise in the signal. For example, the noise may include a direct current (DC) offset.

[0028] The light pipe 125 can be made of any suitable material. For example, the light pipe 125 can be made of quartz, silica, glass, etc. In an illustrative embodiment, the light pipe 125 is made of optical glass such as BK7 or BK9 optical glass. In alternative embodiments, any suitable material can be used.

[0029] In some embodiments, one or more of the faces of the light pipe 125 can include a filter. For example, the face of the light pipe 125 can filter out non-green light and

allow green light to pass through the light pipe 125, for example, to the diamond 115. In another example, light from diamond can pass through a face of the light pipe 125 that filters out non-red light and permits red light to pass through the light pipe 125 to the photo detector 135. In alternative embodiments, any suitable filtering mechanism can be used.

[0030] Figs. 1B and 1C are isometric views of a light pipe and a shield in accordance with illustrative embodiments. In alternative embodiments, additional, fewer, and/or different elements may be used. As shown in Fig. 1B, the light pipe 125 is surrounded axially by the shield 145. In an illustrative embodiment, the light pipe 125 and the shield 145 are coaxial. The cross-sectional shape of the light pipe 125 can be any suitable shape. In the embodiment illustrated in Fig. 1B, the cross-sectional shape of the light pipe 125 is circular. In the embodiment illustrated in Fig. 1C, the cross-sectional shape of the light pipe 125 is octagonal. In alternative embodiments, the cross-sectional shape of the light pipe 125 can be triangular, square, rectangular, or any other suitable shape. Similarly, in the cross-sectional shape of the shield 145 can be any suitable shape. In an illustrative embodiment, the outer shape of the shield 145 is suited to fit against the wall of a housing that houses the diamond 115, the photo detector 135, the light pipe 125, etc.

[0031] In the embodiments illustrated in Figs. 1B and 1C, the length of the light pipe 125 is the same as the length of the shield 145. In alternative embodiments, the light pipe 125 can be longer than the shield 145. For example, the light pipe 125 may extend beyond the end surface of the shield 145 at one or both ends. In an illustrative embodiment, the shield 145 is one inch long. In alternative embodiments, the shield 145 can be shorter or longer than one inch long. For example, in embodiments in which greater attenuation is beneficial, such as with a more sensitive photo detector 135, the shield 145 can be longer. In an illustrative embodiment, the light pipe 125 can be two inches long. In alternative embodiments, the light pipe 125 can be shorter or longer than two inches long. For example, the light pipe 125 can be a length suitable to fit within a housing or arrangement of elements.

[0032] In some embodiments, the light pipe 125 can be tapered along the length of the light pipe 125. For example, the diameter of the light pipe 125 at one end can be large than the diameter of the light pipe 125 at the opposite end. Any suitable ratio of diameters can be used. In an illustrative embodiment, a light pipe 125 can be used to transmit light from the light source 105, which can be a light emitting diode, to the diamond 115. Using a tapered light pipe 125 can help to focus the light exiting the light pipe 125 to enter the diamond 115 at a more perpendicular angle than if a non-tapered light pipe 125 were to be

used. In such an example, the narrow end can be adjacent to the light source 105 and the wide end can be adjacent to the diamond 115.

[0033] The size of the aperture in the middle of the shield 145 can be sized to block one or more particular frequencies of EMI. For example, the diameter of the light pipe 125 can be between five and six millimeters. In alternative embodiments, the diameter of the light pipe 125 can be less than five millimeters or greater than six millimeters. In an illustrative embodiment, the light pipe 125 is sized to have a cross-sectional area that is the same size or slightly larger than a cross-sectional diameter of the diamond 115. In such embodiments, the light pipe 125 is sized to capture as much of the light emitted from the diamond 115 as possible while minimizing the inner diameter of the shield 145 (and, therefore, maximizing the shielding effect of the shield 145).

[0034] In an illustrative embodiment, light from an LED that enters the light pipe 125 in an uneven pattern can exit the light pipe 125 in a more uniform pattern. That is, the light pipe 125 can evenly distribute the light over the surface area of the diamond 115 or the photo detector 135. The light pipe 125 can prevent the light from diverging. Thus, in some embodiments, the light pipe 125 can be used in place of a lens.

[0035] The outer diameter of the shield 145 can be any suitable size. For example, the outer diameter of the shield 145 can be sized to block or attenuate electromagnetic signals from the diamond apparatus thereby protecting the photo detector.

[0036] As illustrated in Figs. 1A-1C, the light pipe 125 passes through the shield 145. That is, the shield 145 surrounds the light pipe 145 along at least a length of the light pipe 125. In some embodiments, the shield 145 surrounds the length of the light pipe 125.

[0037] Fig. 2 is a block diagram of a magnetometer with two light pipes in accordance with an illustrative embodiment. An illustrative magnetometer 200 includes two light pipes 125, two shields 145, a diamond 115, a photo detector 135, and a photo detector 150. In alternative embodiments, additional, fewer, and/or different elements may be used.

[0038] The magnetometer 200 includes a light source 105 that sends source light 110 into a light pipe 125. Some of the light transmitted from the light source 105 can be sensed by the photo detector 150. In some embodiments, the light sensed by the photo detector 150 is transmitted through the light pipe 125. In alternative embodiments, the light sensed by the photo detector 150 does not travel through the light pipe 125. As discussed above with

regard to the magnetometer 100, the diamond 115 may be associated with electrical components that emit EMI that may interfere with the performance of the photo detector 150. In such instances, one of the shield 145 may be placed between the diamond 115 and the photo detector 150. Light from the light source 105 may travel through the light pipe 125, through the hole in the shield 145, and into the diamond 115.

[0039] As discussed with regard to the magnetometer 100 of Fig. 1, a shield 145 may be used to protect the photo detector 135 from EMI emitted from circuitry associated with the diamond 115. Thus, the magnetometer 200 includes a shield 145 on either side of the diamond 115 and the electrical components associated with the diamond 115.

[0040] Fig. 3 is a block diagram of a magnetometer with two light pipes in accordance with an illustrative embodiment. The magnetometer 300 includes a light source 105, a diamond 115, two light pipes 125 with associated shields 145, and two photo detectors 135. In alternative embodiments, additional, fewer, and/or different elements may be used. In the embodiment illustrated in Fig. 3, the source light 110 from the light source 105 passes through the diamond 115. The light that enters the diamond 115 can be split and can exit the diamond 115 in two streams of modulated light 120. In some embodiments, the two streams of modulated light 120 are in opposite directions. In alternative embodiments, the two streams of modulated light 120 are in any suitable orientation to one another. In some embodiments, the two streams of modulated light 120 exit the diamond 115 in directions orthogonal to the direction in which the source light 110 enters the diamond 115.

[0041] Fig. 3 illustrates a magnetometer with two light streams exiting the diamond 115. In alternative embodiments, the magnetometer can be used with three or more light streams that exit the diamond 115. For example, if the diamond 115 is a cube, light can enter the diamond 115 on one of the six sides. In such an example, up to five light streams can exit the diamond 115 via the five other sides. Each of the five light streams can be transmitted to one of five photo detectors 135. Using two or more light streams that exit the diamond 115, which are sensed by associated photo detectors 135, can provide increased sensitivity. Each of the light streams contains the same information. That is, the light streams contain the same amount of red light. Each light stream provides one of the multiple photo detectors a sample of the light. Thus, in embodiments in which multiple light streams from the diamond are used, multiple samples of the same light are gathered. Having multiple samples provides redundancies and allows the system to verify measurements. In some embodiments, the

multiple measurements can be averaged or otherwise combined. The combined value can be used to determine the magnetic field applied to the diamond.

[0042] Fig. 4 is a block diagram of a computing device in accordance with an illustrative embodiment. An illustrative computing device 400 includes a memory 410, a processor 405, a transceiver 415, a user interface 420, a power source 425, and an magnetometer 430. In alternative embodiments, additional, fewer, and/or different elements may be used. The computing device 400 can be any suitable device described herein. For example, the computing device 400 can be a desktop computer, a laptop computer, a smartphone, a specialized computing device, etc. The computing device 400 can be used to implement one or more of the methods described herein.

[0043] In an illustrative embodiment, the memory 410 is an electronic holding place or storage for information so that the information can be accessed by the processor 405. The memory 410 can include, but is not limited to, any type of random access memory (RAM), any type of read only memory (ROM), any type of flash memory, etc. such as magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips, etc.), optical disks (e.g., compact disk (CD), digital versatile disk (DVD), etc.), smart cards, flash memory devices, etc. The computing device 400 may have one or more computer-readable media that use the same or a different memory media technology. The computing device 400 may have one or more drives that support the loading of a memory medium such as a CD, a DVD, a flash memory card, etc.

[0044] In an illustrative embodiment, the processor 405 executes instructions. The instructions may be carried out by a special purpose computer, logic circuits, or hardware circuits. The processor 405 may be implemented in hardware, firmware, software, or any combination thereof. The term "execution" is, for example, the process of running an application or the carrying out of the operation called for by an instruction. The instructions may be written using one or more programming language, scripting language, assembly language, etc. The processor 405 executes an instruction, meaning that it performs the operations called for by that instruction. The processor 405 operably couples with the user interface 420, the transceiver 415, the memory 410, etc. to receive, to send, and to process information and to control the operations of the computing device 400. The processor 405 may retrieve a set of instructions from a permanent memory device such as a ROM device and copy the instructions in an executable form to a temporary memory device that is generally some form of RAM. An illustrative computing device 400 may include a plurality

of processors that use the same or a different processing technology. In an illustrative embodiment, the instructions may be stored in memory 410.

[0045] In an illustrative embodiment, the transceiver 415 is configured to receive and/or transmit information. In some embodiments, the transceiver 415 communicates information via a wired connection, such as an Ethernet connection, one or more twisted pair wires, coaxial cables, fiber optic cables, etc. In some embodiments, the transceiver 415 communicates information via a wireless connection using microwaves, infrared waves, radio waves, spread spectrum technologies, satellites, etc. The transceiver 415 can be configured to communicate with another device using cellular networks, local area networks, wide area networks, the Internet, etc. In some embodiments, one or more of the elements of the computing device 400 communicate via wired or wireless communications. In some embodiments, the transceiver 415 provides an interface for presenting information from the computing device 400 to external systems, users, or memory. For example, the transceiver 415 may include an interface to a display, a printer, a speaker, etc. In an illustrative embodiment, the transceiver 415 may also include alarm/indicator lights, a network interface, a disk drive, a computer memory device, etc. In an illustrative embodiment, the transceiver 415 can receive information from external systems, users, memory, etc.

[0046] In an illustrative embodiment, the user interface 420 is configured to receive and/or provide information from/to a user. The user interface 420 can be any suitable user interface. The user interface 420 can be an interface for receiving user input and/or machine instructions for entry into the computing device 400. The user interface 420 may use various input technologies including, but not limited to, a keyboard, a stylus and/or touch screen, a mouse, a track ball, a keypad, a microphone, voice recognition, motion recognition, disk drives, remote controllers, input ports, one or more buttons, dials, joysticks, etc. to allow an external source, such as a user, to enter information into the computing device 400. The user interface 420 can be used to navigate menus, adjust options, adjust settings, adjust display, etc.

[0047] The user interface 420 can be configured to provide an interface for presenting information from the computing device 400 to external systems, users, memory, etc. For example, the user interface 420 can include an interface for a display, a printer, a speaker, alarm/indicator lights, a network interface, a disk drive, a computer memory device, etc. The user interface 420 can include a color display, a cathode-ray tube (CRT), a liquid crystal display (LCD), a plasma display, an organic light-emitting diode (OLED) display, etc.

[0048] In an illustrative embodiment, the power source 425 is configured to provide electrical power to one or more elements of the computing device 400. In some embodiments, the power source 425 includes an alternating power source, such as available line voltage (e.g., 120 Volts alternating current at 60 Hertz in the United States). The power source 425 can include one or more transformers, rectifiers, etc. to convert electrical power into power useable by the one or more elements of the computing device 400, such as 1.5 Volts, 8 Volts, 12 Volts, 24 Volts, etc. The power source 425 can include one or more batteries.

[0049] In an illustrative embodiment, the computing device 400 includes a magnetometer 430. In other embodiments, magnetometer 430 is an independent device and is not integrated into the computing device 400. The magnetometer 430 can be configured to measure magnetic fields. For example, the magnetometer 430 can be the magnetometer 100, the magnetometer 200, the magnetometer 300, or any suitable magnetometer. The magnetometer 430 can communicate with one or more of the other components of the computing device 400 such as the processor 405, the memory 410, etc. For example, one or more photo detectors of the magnetometer 430 can transmit a signal to the processor 405 indicating an amount of light detected by the photo detector. The signal can be used to determine the strength and/or direction of the magnetic field applied to the diamond of the magnetometer 430. In alternative embodiments, any suitable component of the magnetometer 430 can transmit a signal to other components of the computing device 400 (e.g., the processor 405), such as a Helmholtz coil, a source light photo detector, one or more modulated light photo detectors, a light source, etc.

[0050] Fig. 5 is a flow diagram of a method for measuring a magnetic field in accordance with an illustrative embodiment. In alternative embodiments, additional, fewer, and/or different operations may be performed. Also, the use of a flow chart and arrows is not meant to be limiting with respect to the order or flow of operations. For example, in some embodiments, one or more of the operations can be performed simultaneously.

[0051] In an operation 505, light is generated by a light source. Any suitable light source can be used. For example, lasers or light emitting diodes can be used. In some embodiments, sunlight or environmental light can be used as the light source. In an illustrative embodiment, the light generated by the light source is green light or blue light. In some embodiments, a filter can be used to filter out undesirable light frequencies (e.g., red light).

[0052] In an operation 510, light from the light source is sensed. In an illustrative embodiment, the light can be sensed using a photo detector. In some embodiments, the photo detector is sensitive to electromagnetic interference. In some embodiments, the operation 510 is not performed. For example, in some embodiments, light from the diamond is sensed and the sensed light signal is compared to a pre-determined reference value.

[0053] In an operation 515, light from the light source is transmitted through a first light pipe. In embodiments in which light from the light source is sensed using a photo detector located between the light source and the diamond, the first light pipe can be surrounded by a material that attenuates EMI. In such embodiments, EMI from electrical components near the diamond can be attenuated via the material such that the photo detector is not affected by or is less affected by the EMI. In some embodiments, such as those in which the operation 510 is not performed, the operation 515 may not be performed.

[0054] In an operation 520, light from the light source is transmitted through the diamond. In embodiments in which the operation 515 is performed, light from the first light pipe is transmitted through the diamond. As mentioned above, the diamond can include NV centers that are affected by magnetic fields. The amount of red light emitted from the diamond (e.g., via the NV centers) can change based on the applied magnetic field.

[0055] In an operation 525, light emitted from the diamond is transmitted through a second light pipe. In an operation 530, light from the second light pipe is sensed. In an illustrative embodiment, the light is sensed via a light detector that is sensitive to EMI. In such embodiments, the light pipe can be surrounded by material that attenuates EMI from electrical components near the diamond, such as a Helmholtz coil or a microwave generator/modulator.

[0056] In an operation 535, a magnetic field point is determined. In an illustrative embodiment, the magnetic field point is a vector with a magnitude and a direction. In alternative embodiments, the operation 535 includes determining a magnitude or a direction. In embodiments in which operation 510 is performed, the operation 535 can include comparing the amount of green light (or any other suitable wavelength) emitted from the light source with the amount of detected red light (or any other suitable wavelength) that was transmitted through the second light pipe. In alternative embodiments, the amount of detected red light that was transmitted through the second light pipe is compared to a baseline

amount. In alternative embodiments, any suitable method of determining the magnetic field point can be used.

[0057] In an illustrative embodiment, any of the operations described herein can be implemented at least in part as computer-readable instructions stored on a computer-readable memory. Upon execution of the computer-readable instructions by a processor, the computer-readable instructions can cause a node to perform the operations.

[0058] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable," to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0059] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0060] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such

recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, unless otherwise noted, the use of the words “approximate,” “about,” “around,” “substantially,” etc., mean plus or minus ten percent.

[0061] The foregoing description of illustrative embodiments has been presented for purposes of illustration and of description. It is not intended to be exhaustive or limiting with respect to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the disclosed embodiments. It is

intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

WHAT IS CLAIMED IS:

1. A device comprising:

a diamond with a nitrogen vacancy;

a light source configured to transmit light toward the diamond;

a first sensor configured to sense a first portion of the light transmitted from the light source, wherein the first portion of the light does not travel through the diamond;

a second sensor configured to sense a second portion of the light transmitted from the light source, wherein the second portion of the light travels through the diamond;

a first light pipe configured to direct the second portion of the light from the diamond to the second sensor; and

a first waveguide cutoff filter surrounding the first light pipe that is configured to attenuate electromagnetic waves.

2. The device of claim 1, wherein the first light pipe comprises a first end surface, a second end surface, and a side wall surface, wherein the second portion of the light travels through the first end surface and through the second end surface, and wherein the second portion of the light does not travel through the side wall surface.

3. The device of claim 1, wherein the second sensor is located remotely from the diamond.

4. The device of claim 3, further comprising a circuit board surrounding at least a portion of the diamond, wherein the circuit board emits electromagnetic interference.

5. The device of claim 1, further comprising:

a third sensor configured to sense a third portion of the light, wherein the third portion of the light travels through the diamond to the third sensor;

a second light pipe configured to direct the third portion of the light from the diamond to the third sensor; and

a second waveguide cutoff filter surrounding the second light pipe.

6. The device of claim 5, wherein the first light pipe and the second light pipe are aligned along a central axis.

7. The device of claim 6, wherein the light source is configured to emit the second portion of the light and the third portion of the light in a direction that is perpendicular to the central axis.

8. The device of claim 5, wherein the first light pipe is located on an opposite side of the diamond as the second light pipe.

9. The device of claim 1, further comprising:

a third light pipe configured to direct the second portion of the light from the light source to the diamond; and

a third waveguide cutoff filter surrounding at least a portion of the third light pipe.

10. The device of claim 1, wherein the light source is configured to emit light that is substantially green.

11. The device of claim 1, wherein the light source comprises a laser device or a light emitting diode.

12. The device of claim 1, further comprising a red filter between the diamond and the first light pipe.

13. The device of claim 1, further comprising a red filter between the first light pipe and the second sensor.

14. The device of claim 1, wherein the first light portion comprises a first beam of light, and wherein the second light portion comprises a second beam of light.

15. The device of claim 1, further comprising a processor operatively coupled to the first sensor and the second sensor, wherein the processor is configured to:

receive, from the first sensor, a first signal indicating a strength of the first portion of the light with a first wavelength;

receive, from the second sensor, a second signal indicating a strength of the second portion of the light with a second wavelength; and

compare, based on the first signal and the second signal, the strength of the first portion of the light with the first wavelength and the strength of the second portion of the light with the second wavelength to determine a strength of a magnetic field applied to the diamond.

16. A device comprising:

a diamond with a nitrogen vacancy;

a light source configured to transmit light toward the diamond;

a first sensor configured to sense a first portion of the light transmitted from the light source, wherein the first portion of the light does not travel through the diamond;

a second sensor configured to sense a second portion of the light transmitted from the light source, wherein the second portion of the light travels through the diamond;

a light pipe configured to direct the second portion of the light from the light source to the diamond; and

a waveguide cutoff filter surrounding at least a portion of the light pipe.

17. A method comprising:

providing power to a light source, wherein the light source is configured to emit light toward a diamond with a nitrogen vacancy, wherein a first portion of the light does not travel through the diamond and a second portion of the light travels through the diamond and through a first light pipe;

receiving, at a processor, a first signal from a first sensor, wherein the first signal indicates a strength of the first portion of the light with a first wavelength;

receiving, at the processor, a second signal from a second sensor, wherein the second signal indicates a strength of the second portion of the light with a second wavelength; and

comparing, at the processor, the strength of the first portion of the light with the first wavelength and the strength of the second portion of the light with the second wavelength to determine a strength of a magnetic field applied to the diamond.

18. The method of claim 17, further comprising receiving, at the processor, a third signal from a third sensor, wherein the third signal indicates a strength of a third portion of the light with the second wavelength, wherein said providing the power to the light source causes the light source to transmit the third portion of the light through the diamond and through a second light pipe.

19. A method comprising:

emitting, from a light source, a first light portion and a second light portion;

sensing, at a first sensor, the first light portion;

sensing, at a second sensor, the second light portion, wherein the second light portion traveled through a light pipe and a diamond with a nitrogen vacancy; and

comparing the first light portion to the second light portion to determine a strength of a magnetic field applied to the diamond.

20. The method of claim 19, wherein said emitting the second light portion comprises causing the second light portion to travel through a third light pipe before the second light portion travels through the diamond.

21. The method of claim 19, further comprising:

emitting, from the light source, a third light portion through a diamond and through a second light pipe; and

sensing, at a third sensor, the third light portion.

22. The method of claim 19, wherein said comparing the first light portion to the second light portion comprises comparing a strength of the first light portion with a first wavelength to a strength of the second light portion with a second wavelength.

23. The method of claim 22, wherein the first light portion with the first wavelength is a green color, and wherein the second light portion with the second wavelength is a red color.

24. A device comprising:

a diamond assembly comprising:

a diamond with a plurality of nitrogen vacancy centers, and

electrical components that emit electromagnetic waves;

a light source configured to emit light toward the diamond;

a photo detector configured to detect light from the light source that traveled through the diamond; and

an attenuator between the diamond assembly and the photo detector, wherein the attenuator is configured to attenuate the electromagnetic waves emitted from the electrical components of the diamond assembly.

25. The device of claim 24, further comprising a light pipe, wherein the attenuator surrounds at least a portion of the light pipe.

26. The device of claim 25, wherein the light pipe is configured to transfer light from the diamond to the photo detector.

27. The device of claim 25, wherein the light pipe and the attenuator are coaxial.

28. The device of claim 25, wherein the light pipe is tapered.

29. The device of claim 28, wherein a cross-sectional area of a first end of the light pipe is smaller than a cross-sectional area of a second end of the light pipe, and wherein the light enters the light pipe from the diamond at the first end.

30. The device of claim 24, wherein the light pipe has a diameter of between five millimeter and six millimeters.

31. The device of claim 24, wherein the attenuator comprises a metal.

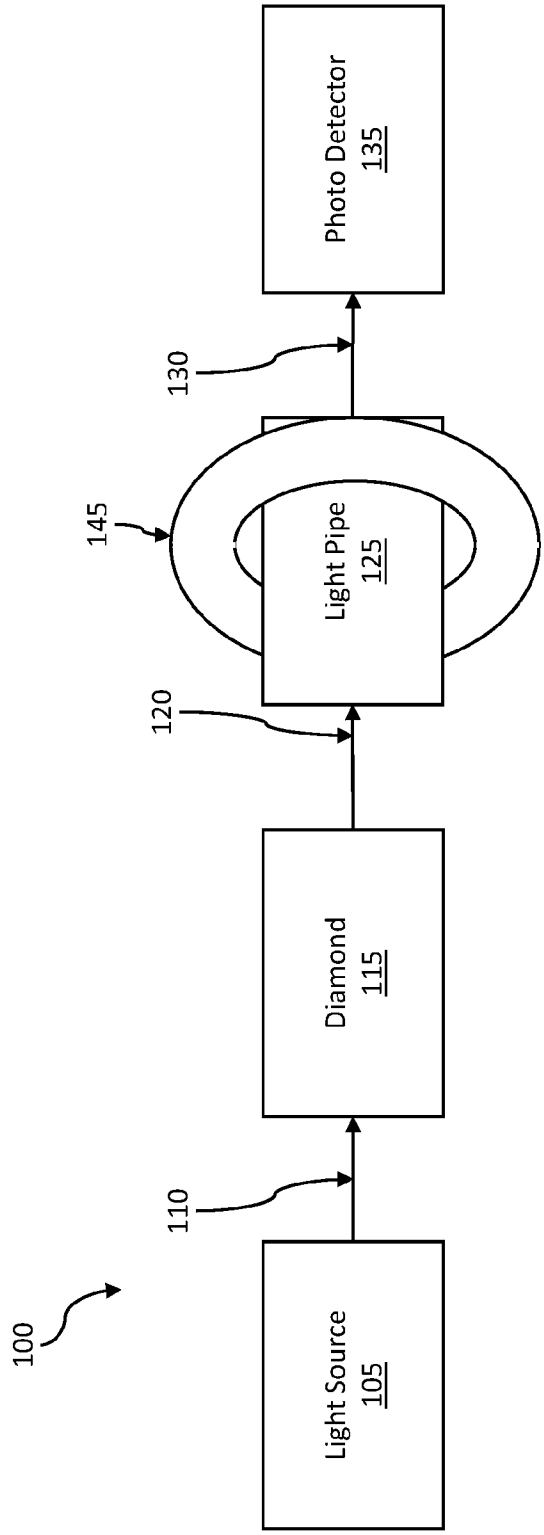

Photo Detector
135
130
145
Light Pipe
125
120
Diamond
115
Magnet
140
110
Light Source
105
100

Fig. 1A

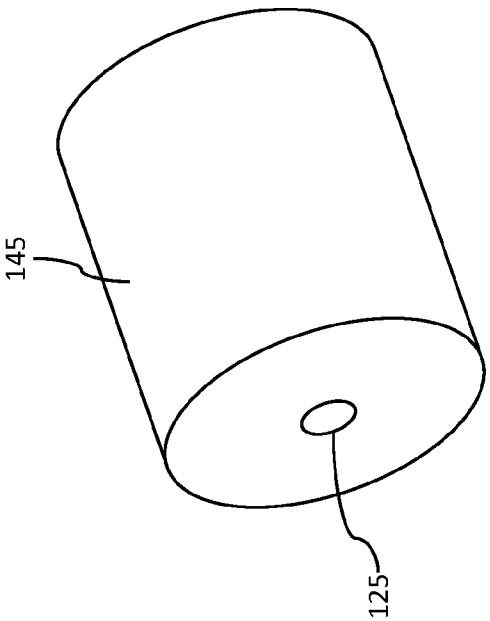


Fig. 1B

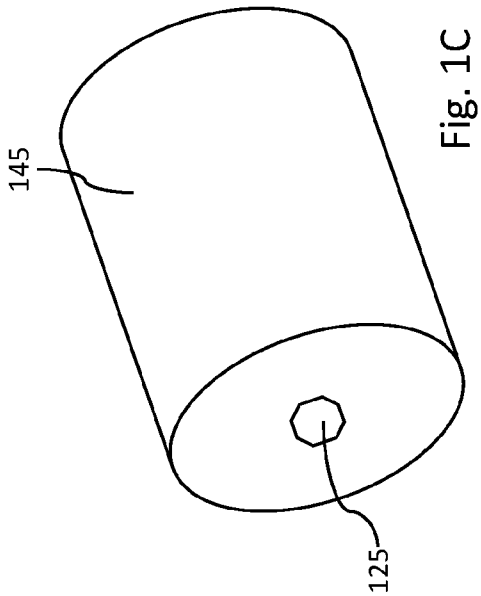


Fig. 1C

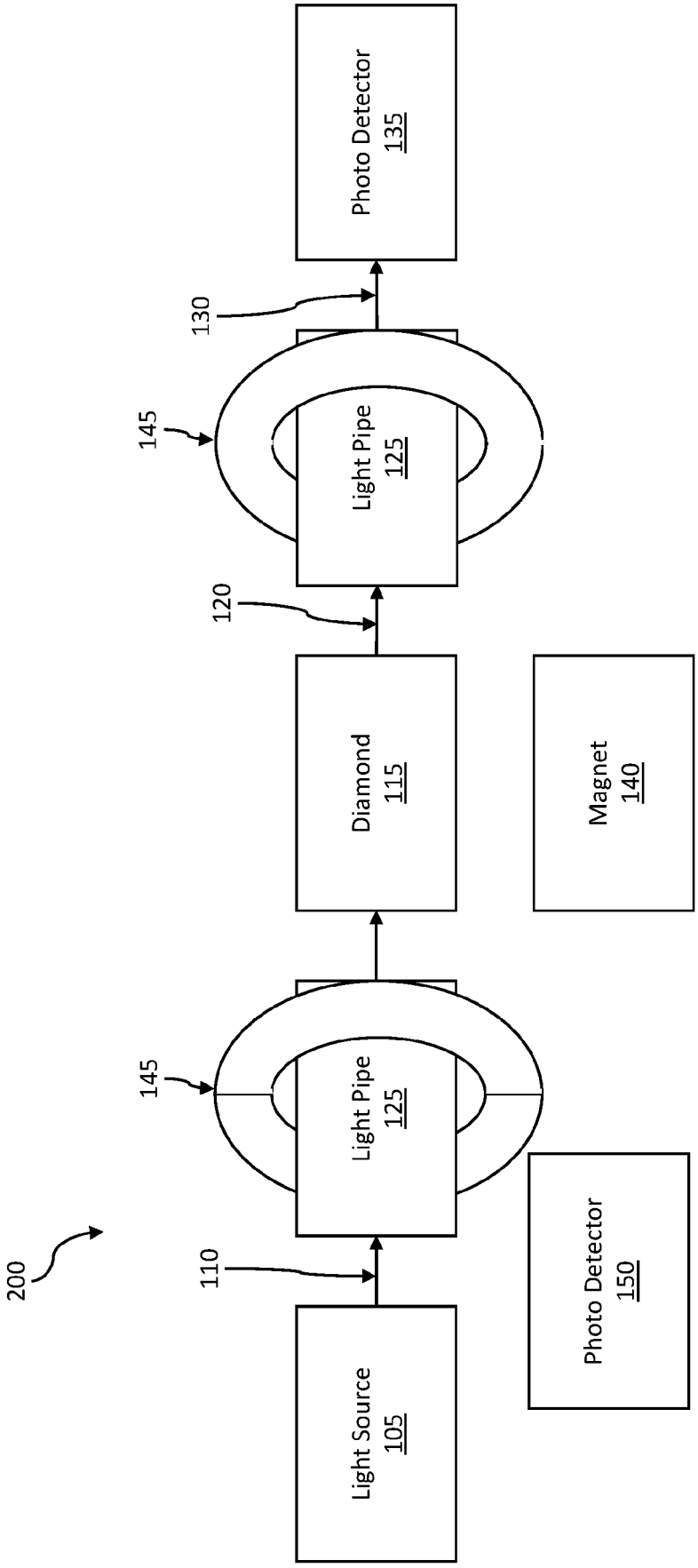

200
Light Source
105
110
Light Pipe
125
145
Photo Detector
150
Diamond
115
120
Light Pipe
125
145
Magnet
140
130
Photo Detector
135

Fig. 2

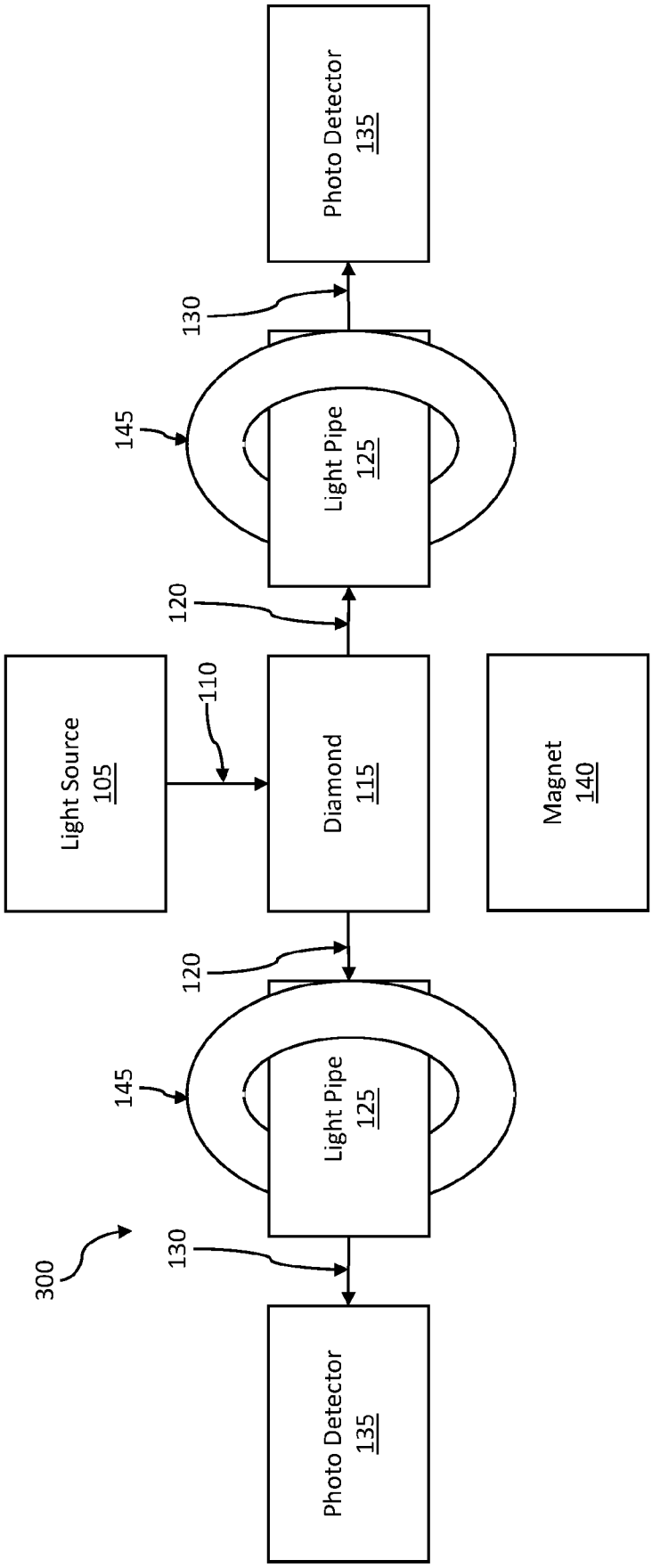

Photo Detector
135
130
145
Light Pipe
125
120
Light Source
105
110
Diamond
115
Magnet
140
120
145
Light Pipe
125
300
130
Photo Detector
135

Fig. 3

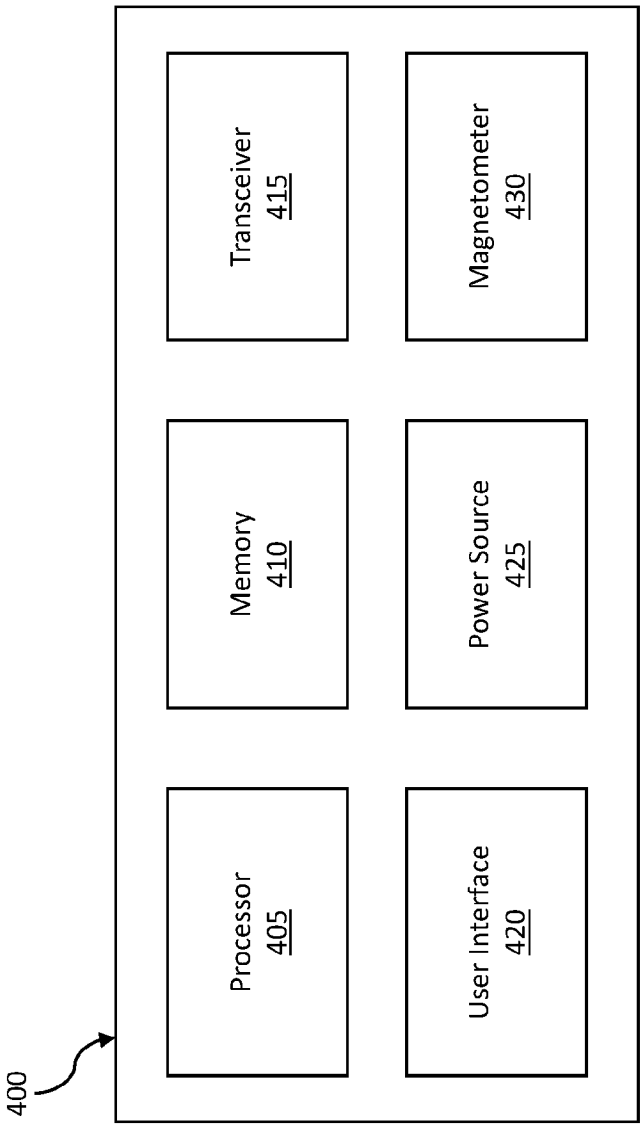

400
Processor
405
Memory
410
Transceiver
415
User Interface
420
Power Source
425
Magnetometer
430

Fig. 4

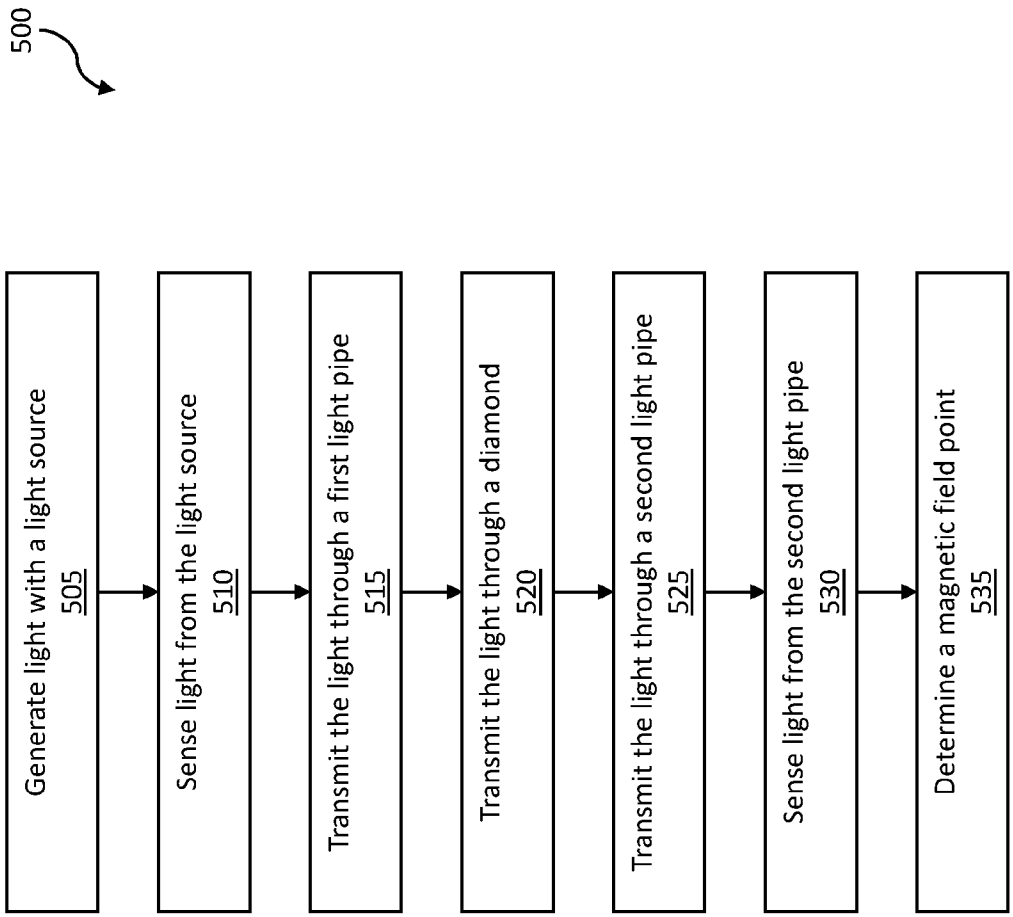

500
Generate light with a light source
505
Sense light from the light source
510
Transmit the light through a first light pipe
515
Transmit the light through a diamond
520
Transmit the light through a second light pipe
525
Sense light from the second light pipe
530
Determine a magnetic field point
535

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/14386

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01L 33/00, H01L 29/15 (2016.01)
CPC - H01L 33/641, H01L 33/025, H01L 33/34, H01L 33/0079
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
CPC: H01L33/641; H01L33/025; H01L33/34; H01L33/0079; G01N21/00; H01L 29/15; H01L 33/00; G11B5/455; G11B2005/0021
IPC(8): H01L 33/00, H01L 29/15 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 257/77; 257/103; 257/96; 257/97; 324/304; 324/307; 250/459.1; 250/226; 250/458.1; 324/244.1; 324/76.21; 356/435; 250/338.1; 250/227.11; 29/592.1; 235/470; 362/373; 235/440; 235/454; 235/384; 235/385; 235/382; 313/523; 250/338.1; 250/227.11; 29/592.1

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Pat Base (AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO), Google Patent, Google Scholar; Search terms:diamond nitrogen vacancy sensor light split pipe waveguide filter attenuate cutoff electromagnetic wave interference processor circuit red green central axis perpendicular compare defect center NV detect probe LED laser illuminate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	US 2015/0235661 A1 (HEIDMANN) 20 August 2015 (20.08.2015) para [0002], [0009], [0044]-[0046], [0048], [0050], [0061]; figure 1	1-5 and 9-16 --- 6-8
Y --- A	US 6,130,753 A (HOPKINS JR. et al.) 10 October 2000 (10.10.2000) col 1, ln 53-56; col 2, ln 59-63; col 3, ln 13-27 and ln 51-54; col 4, ln 17-30; abstract; figure 1	1-5 and 9-16 --- 6-8
Y --- A	US 4,084,215 A (WILLENBROCK) 11 April 1978 (11.04.1978) col 2, ln 20-37; col 3, ln 24-65; figure 1; claim 1	1-5 and 9-16 --- 6-8
Y --- A	US 4,514,083 A (FUKUOKA) 30 April 1985 (30.04.1985) col 2, ln 38-46; col 3, ln 14-50; figure 1; abstract	5 --- 6-8
Y	US 2011/0062957 A1 (FU et al.) 17 March 2011 (17.03.2011) para [0025], [0033], [0050]	10
Y	WO 2015/015172 A1 (THE UNIVERSITY OF WARWICK) 05 February 2015 (05.02.2015) pg 5, ln 1-2	12-13
A	US 2015/0090033 A1 (BUNKER et al.) 02 April 2015 (02.04.2015) entire document	1 and 16
A	US 7,277,161 B2 (CLAUS) 02 October 2007 (02.10.2007) entire document	1 and 16

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 May 2016	02 JUN 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/14386

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-16, directed to device with a light pipe and waveguide cutoff filter.

Group II: Claims 17-23, directed to a method for detecting the light traveled through a diamond with nitrogen vacancy.

Group III: Claims 24-31, directed to a device with a diamond with a plurality of nitrogen vacancy centers.

The inventions listed as Group I-III do not relate to a single special technical feature under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

--- Continued on supplemental pages ---

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-16

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

continuation of Box III (Lack of Unity)

Special Technical Feature:

Group I does not require providing power to a light source; a processor; the first signal indicates a strength of the first portion of the light with a first wavelength; the second signal indicates a strength of the second portion of the light with a second wavelength; and comparing, at the processor, the strength of the first portion of the light with the first wavelength and the strength of the second portion of the light with the second wavelength to determine a strength of a magnetic field applied to the diamond, as required by group II.

Group II does not require a first waveguide cutoff filter surrounding the first light pipe that is configured to attenuate electromagnetic waves, as required by Group I.

Group I does not require a plurality of nitrogen vacancy centers; electrical components that emit electromagnetic waves; the attenuator between the diamond assembly and the photo detector, as required by group III.

Group III does not require a first sensor configured to sense a first portion of the light transmitted from the light source, wherein the first portion of the light does not travel through the diamond; a second sensor configured to sense a second portion of the light transmitted from the light source, wherein the second portion of the light travels through the diamond; a first light pipe configured to direct the second portion of the light from the diamond to the second sensor; and the attenuator is a first waveguide cutoff filter surrounding the first light pipe, as required by Group I.

Group II does not require a plurality of nitrogen vacancy centers; electrical components that emit electromagnetic waves; an attenuator between the diamond assembly and the photo detector, wherein the attenuator is configured to attenuate the electromagnetic waves emitted from the electrical components of the diamond assembly, as required by group III.

Group III does not require providing power to a light source; wherein the light source is configured to emit light toward a diamond with a nitrogen vacancy, wherein a first portion of the light does not travel through the diamond and a second portion of the light travels through the diamond and through a first light pipe; receiving, at a processor, a first signal from a first sensor, wherein the first signal indicates a strength of the first portion of the light with a first wavelength; receiving, at the processor, a second signal from a second sensor, wherein the second signal indicates a strength of the second portion of the light with a second wavelength; and comparing, at the processor, the strength of the first portion of the light with the first wavelength and the strength of the second portion of the light with the second wavelength to determine a strength of a magnetic field applied to the diamond, as required by Group II.

Common Technical Features:

Group I and II share the technical feature of a light source, wherein the light source is configured to emit light toward a diamond with a nitrogen vacancy, wherein a first portion of the light does not travel through the diamond and a second portion of the light travels through the diamond and through a first light pipe; sensing, at a first sensor, the first light portion; sensing, at a second sensor, the second light portion. However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being obvious over US 2015/0090033 A1 to Budker et al. (hereinafter Budker), in view of US 6,130,753 A to Hopkins Jr. et al. (hereinafter Hopkins), in further view of US 20010055098 A1 (Chen). Budker teaches a light source (para [0052]; figure 3; claim 16; light source 22), wherein the light source is configured to emit light toward a diamond with a nitrogen vacancy (para [0052], [0046]; figure 5; claim 16; A light source such as a laser or light emitting diode (LED) with wavelength can be used to polarize the diamond sample 18 containing an ensemble of nitrogen-vacancy (NV) centers); and a second portion of the light travels through the diamond and; sensing, at a second sensor, the second light portion (para [0052]; figure 5; claim 16; photodetectors 24 are used to measure the resulting fluorescence intensity over time). Budker teaches that the sample where the light travels through is diamond (para [0052]; figure 3; claim 16); however, Budker does not teach that a first portion of the light does not travel through the sample; sensing, at a first sensor, the first light portion; and that the light travels through a first light pipe. Hopkins, on the other hand, teaches that a first portion of the light does not travel through the sample; sensing, at a first sensor, the first light portion (col 3, ln 13-27; abstract; figure 1; The beam splitter divides light from a laser source into a reference beam (first light portion) and a sample beam (second light portion). The use of reference detector (first sensor) and a sample detector (second sensor) to measure the optical density). Chen further teaches that the light travels through a first light pipe (para [0011]; a light source to generate light and to guide the light to the light pipe, and an image device to produce an image using the light gathered by the light pipe). Therefore, it would have been obvious to one ordinary skilled in the art to split the beam into a reference beam and a sample beam, as taught by Hopkins; with using a light pipe, as taught by Chen; with measuring the light that travels through a diamond with nitrogen vacancy that Budker teaches; in order to compare the intensities of the two detectors and measure optical density of highly absorptive materials (Hopkins; abstract). Further, because light pipes are designed to reduce the light leaking from the light pipes while maintaining a small light angle. Thus, the light gathering efficiency is improved, and the light intensity is increased (Chen; para [0009]).

Group I and III share the technical feature of a device; a diamond with a nitrogen vacancy; a light source configured to emit light toward the diamond; a photo detector/sensor configured to detect light from the light source that traveled through the diamond; and an attenuator configured to attenuate the electromagnetic waves. However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being obvious over Budker, in view of US 5,032,811 A to Nishikawa et al. (hereinafter Nishikawa). Budker teaches a device (figure 5); a diamond with a nitrogen vacancy (para [0046]; figure 5; claim 16; diamond sample 18 containing an ensemble of nitrogen-vacancy centers); a light source configured to emit light toward the diamond (para [0052], [0046]; figure 5; claim 16; A light source such as a laser or light emitting diode (LED) with wavelength can be used to polarize the diamond sample 18 containing an ensemble of nitrogen-vacancy (NV) centers); a photo detector/sensor configured to detect light from the light source that traveled through the diamond (para [0052]; figure 5; claim 16; photodetectors 24 are used to measure the resulting fluorescence intensity over time). Budker does not teach an attenuator configured to attenuate the electromagnetic waves. Nishikawa, on the other hand, teaches an attenuator configured to attenuate the electromagnetic waves (abstract; col 1, ln 55-59; Electromagnetic wave in the attenuation band of the magnetostatic wave filter (attenuator) is attenuated by this waveguide). Therefore, it would have been obvious to one ordinary skilled in the art to split attenuate the electromagnetic waves, as taught by Nishikawa; with measuring the light that travels through a diamond with nitrogen vacancy that Budker teaches; because unnecessary electromagnetic waves in the attenuation band are attenuated by the waveguide (Nishikawa; col 1, ln 60-61).

please see the next page for continuation

continuation of previous page: Box III (Lack of Unity)

Group II and III share the tochnical feature of a diamond with a nitrogen vacancy; a light source configured to emit light toward the diamond; a photo detector/sensor configured to detect light from the light source that traveled through the diamond. However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being anticipated by Budker. Budker teaches Budker teaches a diamond with a nitrogen vacancy (para [0046]; figure 5; claim 16; diamond sample 18 containing an ensemble of nitrogen-vacancy centers); a light source configured to emit light toward the diamond (para [0052], [0046]; figure 5; claim 16; A light source such as a laser or light emitting diode (LED) with wavelength can be used to polarize the diamond sample 18 containing an ensemble of nitrogen-vacancy (NV) centers); a photo detector/sensor configured to detect light from the light source that traveled through the diamond (para [0052]; figure 5; claim 16; photodetectors 24 are used to measure the resulting fluorescence intensity over time).

Groups I-III share the technical feature of a diamond with a nitrogen vacancy; a light source configured to emit light toward the diamond; a photo detector/sensor configured to detect light from the light source that traveled through the diamond. Budker. However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being anticipated by Budker. Budker teaches Budker teaches a diamond with a nitrogen vacancy (para [0046]; figure 5; claim 16; diamond sample 18 containing an ensemble of nitrogen-vacancy centers); a light source configured to emit light toward the diamond (para [0052], [0046]; figure 5; claim 16; A light source such as a laser or light emitting diode (LED) with wavelength can be used to polarize the diamond sample 18 containing an ensemble of nitrogen-vacancy (NV) centers); a photo detector/sensor configured to detect light from the light source that traveled through the diamond (para [0052]; figure 5; claim 16; photodetectors 24 are used to measure the resulting fluorescence intensity over time).

As the shared technical features were known in the art at the time of the invention, they cannot be considered common technical features that would otherwise unify the groups. Therefore, Groups I-III lack unity under PCT Rule 13.