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- (71) **Applicant:** **INTERNATIONAL BUSINESS MACHINES CORPORATION** [US/US]; New Orchard Road, Armonk, New York 10504 (US).
- (71) **Applicants (for MG only):** **IBM UNITED KINGDOM LIMITED** [GB/GB]; PO Box 41, North Harbour, Portsmouth Hampshire PO6 3AU (GB). **IBM (CHINA) INVESTMENT COMPANY LIMITED** [CN/CN]; 25/

F, Pangu Plaza, No.27, Central North 4th Ring Road, Chaoyang District, Beijing 100101 (CN).

- (72) **Inventors:** **BALAGURUSAMY, Venkat**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US). **PEAR, Brian, Robert**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US). **MAGGIACOMO, Edward**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US). **PICUNKO, Thomas**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US). **LIGMAN, Joseph**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US). **DILLENBERGER, Donna, N Eng**; IBM Corporation, PO Box 218, 1101 Kitchawan Road, Yorktown Heights, New York 10598 (US).
- (74) **Agent:** **LITHERLAND, David**; IBM United Kingdom Limited, Intellectual Property Law, Hursley Park, Winchester Hampshire SO21 2JN (GB).

(54) **Title:** PORTABLE HIGH-RESOLUTION GEM IMAGING SYSTEM

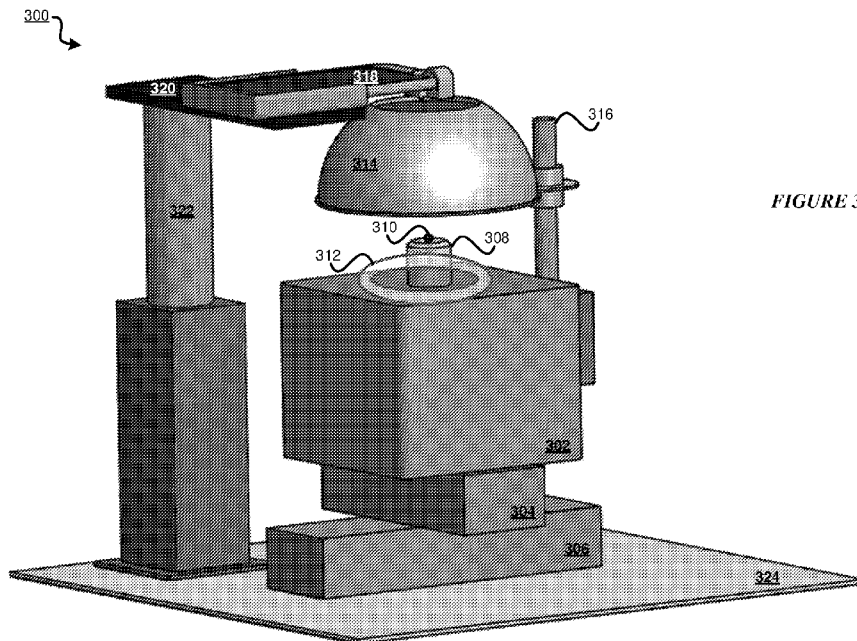


FIGURE 3

(57) **Abstract:** The present invention provides a system (300), a method and a computer program product for imaging a gem (310), the system (300) comprising: a stage (302) having a platform (308) configured to hold an object (310); a light source (312) configured to illuminate the object (310); and a housing (314) configured to at least partially enclose the object (310), wherein the housing (314) is configured to position a mobile device (318) such that a camera lens of the mobile device (318) is aligned with the object (310).



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PORTABLE HIGH-RESOLUTION GEM IMAGING SYSTEM

TECHNICAL FIELD

[0001] The present invention relates generally to a method, system, and computer program product for making a low-cost microscope using existing camera-enabled mobile devices. More particularly, the present invention relates to a method, system, and computer program product for a portable high-resolution gem imaging system.

BACKGROUND

[0002] Currently there are a large number of smart phone users around the world. Many of these smart phones are provided with high computing power, video streaming capabilities, high quality image capture capabilities and other processing capabilities. This presents an unprecedented opportunity for developing applications based on these capabilities, especially for sensing and imaging applications.

[0003] Diamond is a non-limiting example of a gemstone (gem) contemplated herein. There are a number of diamond imaging systems that are used for commercial applications for evaluating and characterizing diamond and gem stone quality and value. However, low-cost cellular phone-based portable imaging systems are quite rare and highly inadequate for commercial grading of gemstones.

SUMMARY

[0004] The illustrative embodiments provide a method, system, and computer program product. An embodiment of a gem imaging system includes a stage having a platform configured to hold an object. In an embodiment, the system further includes a light source configured to illuminate the object. In an embodiment, the system further includes a housing configured to at least partially enclose the object, wherein the housing is configured to position a mobile device such that a camera lens of the mobile device is aligned with the object.

[0005] In an embodiment, the system includes a microlens adapter configured to removably couple to the mobile device. In an embodiment, the system includes a microlens positioned in an aperture of the housing. In an embodiment, the microlens is one of a ball lens, a hemispherical lens, a hyperbolic lens, or an aspheric lens. In an embodiment, the system includes a second platform configured to support the mobile device.

[0006] In an embodiment, the second platform is movable relative to the stage. In an embodiment, the system includes an arm coupled to the housing. In an embodiment, the arm is configured to move the housing relative to the stage. In an embodiment, the stage is movable in increments of 10 to 100 microns.

[0007] In an embodiment, the housing includes a light reflector oriented relative to the platform such that light from the light source is reflected from the light reflector onto the object. In an embodiment, the light source is a lighting panel coupled to the housing.

[0008] In an embodiment, the system includes a motorized mechanism to move the platform in at least one direction to change a position of the gemstone relative to the mobile device. In an embodiment, the platform is configured to hold the object at a focal plane of a microlens.

[0009] An embodiment includes a computer usable program product. The computer usable program product includes one or more computer-readable storage devices, and program instructions stored on at least one of the one or more storage devices.

[0010] An embodiment includes a computer system. The computer system includes one or more processors, one or more computer-readable memories, and one or more computer-readable storage devices, and program instructions stored on at least one of the one or more storage devices for execution by at least one of the one or more processors via at least one of the one or more memories.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Certain novel features characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of the illustrative embodiments when read in conjunction with the accompanying drawings, wherein:

[0012] **Figure 1** depicts a block diagram of a network of data processing systems in which illustrative embodiments may be implemented;

[0013] **Figure 2** depicts a block diagram of a data processing system in which illustrative embodiments may be implemented;

[0014] **Figure 3** depicts an example configuration of a gem imaging system in accordance with an illustrative embodiment;

[0015] **Figure 4** depicts an example configuration of a dome reflector in accordance with an illustrative embodiment;

[0016] **Figure 5** depicts an example configuration of another gem imaging system in accordance with an illustrative embodiment;

[0017] **Figure 6A** depicts an example configuration of another gem imaging system in accordance with an illustrative embodiment;

[0018] **Figure 6B** depicts an example configuration of another gem imaging system in accordance with an illustrative embodiment;

[0019] Figure 7 depicts an example configuration of a housing of a gem imaging system in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

[0020] Gemstone grading is a highly manual process, dependent upon the artisan's skill, level of experience, familiarity with gemstones and gemstone producing regions and techniques, and many other variables. Consequently, the grading of gemstones is often non-uniform and unreliable owing to the human-dependent variations in the grading process. Although grading standards have been developed and implemented by gemstone grading laboratories around the world, the grading process even with the standards is still very much human-dependent. For example, only a small fraction of the gems that are produced annually pass through those labs and an even smaller fraction is selected for grading according to the standards, not all standards are uniformly applied by human inspectors in each case, natural variations in gems render the grading to become highly subjective regardless of the standards, or some combination of these and other difficulties in standards-based grading. A need exists in the gemstone making and quality assurance technologies, for reliable, high-speed, and uniform gem grading system.

[0021] Various embodiments include a microlens adapter for mobile devices that enable high resolution image capture. In particular embodiments, the microlens adapter includes a microlens that enables image capture of micron sized (millionth of a meter) objects using a mobile device having high magnification of, for example, 15x or larger (for comparison a human hair width is 100 micron). Various embodiments provide for a wide range of image capture and processing applications such as tracking microbead motion within a fluid, diamond defect mapping and imaging, imaging bacterial and other cellular organisms and counterfeit goods detection and protection.

[0022] Presently available microscopes with 1-micron or better resolution are generally custom equipment that cost many thousands of dollars and are difficult to move or relocate from one observation site to another as they are quite bulky. The illustrative embodiments recognize that the presently available tools or solutions do not provide for portable gem imaging systems at a retailer. The illustrative embodiments recognize that the presently available tools or solutions do not address these needs/problems or provide adequate solutions for these needs/problems. The illustrative embodiments used to describe the invention generally address and solve the above-described problems and other related problems by providing a microlens adapter for mobile devices.

[0023] An embodiment includes a method that can be configured to produce many microlens configurations that have a micron optical resolution and a magnification from 15x and higher. Achieving similar optical resolution presently requires a microscope that costs approximately \$15,000 in the market. Moreover, the whole setup of an embodiment is quite compact and easily portable for on-field applications relative to presently available high-resolution microscopes.

[0024] In particular embodiments, the microlens of the microlens adapter can distinguish micro particles that are of size 1 micron (1 millionth of a meter) which is not achievable by other lens adapters. In one or more embodiments, the microlens adapter includes a housing (interchangeably referred to herein as a body) having a ball lens in an aperture of the housing, and the housing is configured to be coupled to a mobile device to position a lens of a camera of the mobile device in alignment with the ball lens and an object to be imaged. In particular embodiments, the ball lens that has short focal length in the range of 0.5 to a few mm (millimeters) and is constructed of glass. In an embodiment, the microlens adapter is constructed, formed, or machined to accommodate the ball lens at a particular location to hold the ball lens in place. In one or more embodiments, the microlens adapter includes an opening through which light from the object enters the ball lens to form an image on the back side of the ball lens. The microlens adapter further includes a recess on an outer surface dimensioned to accept an insert having an aperture hole therethrough. In a particular embodiment, the recess and insert are of a rectangular shape. In particular embodiments, the aperture hole has a diameter of 0.9 mm acting as an aperture to achieve both an optical resolution of 1 micron as well to limit spherical and other aberrations in optical imaging. In one or more embodiments, the aperture hole is in alignment with the lens of the camera of the mobile device to allow one or more images of the object to be captured from the ball lens through the aperture hole with minimal image distortion.

[0025] In particular embodiments, the microlens of the microlens adapter can distinguish micro particles that are of size 1 micron (1 millionth of a meter) which is not achievable by other lens adapters. In one or more embodiments, the microlens adapter includes a housing (interchangeably referred to herein as a body) having an aspheric lens in an aperture of the housing, and the housing is configured to be coupled to a mobile device to position a lens of a camera of the mobile device in alignment with the aspheric lens and an object to be imaged. In particular embodiments, the aspheric lens that has a short focal length in the range of 5 to 30 mm (millimeters) and a diameter in the range of 10 to 25 mm and is constructed of glass or plastic. In an embodiment, the microlens adapter is constructed, formed, or machined to accommodate the aspheric lens at a particular location to hold it in place. In one or more embodiments, the microlens adapter includes an opening through which light from the object enters the aspheric lens to form an image on the back side of the aspheric lens. The microlens adapter further includes a recess on an outer surface dimensioned to accept an insert having an aperture hole there through. In a particular embodiment, the recess and insert are of a circular shape. In particular embodiments, the aperture hole has a diameter of 8 mm acting as an aperture to limit the cone of rays that form the image to limit spherical and other aberrations in optical imaging. It also helps to adjust or obtain the desired depth-of-field of the object under imaging. In one or more embodiments, the aperture hole is in alignment with the lens of the camera of the mobile device to allow one or more images of the object to be captured from the aspheric lens through the aperture hole with minimal image distortion.

[0026] Suitable forms of microlens adapter are described for example in published PCT application WO2018/215823.

[0027] An embodiment creates an image of a gem, e.g., a diamond, with the mobile device through a lens apparatus described herein, e.g., a wide-field lens. The embodiment captures one or more table-top images of the gem. An embodiment records different Z-sections of the gem. The embodiment creates a Z-composite image of the imaged gemstone to produce a view through the entirety of the gemstone.

[0028] Another embodiment uses one or more of the images described herein to uniquely identify gemstones that are being traded, e.g., by a sizeable client to a retailer. An embodiment provides specialized Artificial Intelligence (AI) techniques to identify the gemstones with the images recorded with a gem imager described herein, the images being recorded either previously or contemporaneously at the time of the trade. With the availability of a low-cost system formed by one or more embodiments, a gemstones retailer can provide a verification service - verifying the gemstones a consumer brings in for trade or some other service. Diamond and gems can be imaged at the point-of-sale and added to a database. When the customer wants to resell or verify the source with the retailer at a later point in time the gem images stored in the original seller's database can be used along with the AI algorithms provided by an embodiment. In one embodiment, an AI algorithm is optimized for gem identification or verification operation.

[0029] Any reference to an iPhone, cell phone, mobile phone, smart phone, or a variant thereof is a reference to a portable computing device having a form factor suitable for placement in a pocket of a garment. Such a portable device may, but need not, include the capability to conduct telephonic communications.

[0030] Any reference to an LED (light emitting diode) illumination, illuminator, light source, or some variant thereof is only depicted and intended as a non-limiting example. Any light source of a comparable form factor and amount of illumination can be used within the scope of the illustrative embodiments.

[0031] A reference to wide-field lens or some variant thereof is only depicted and intended as a non-limiting example. A lens of a form factor that allows it to be used in conjunction with a portable device contemplated herein, and having a field of view that is at least equal to or wider than the lenses found on commercial mobile phones, can be used within the scope of the illustrative embodiments.

[0032] A depicted enclosure or adapter may be omitted in an implementation of an embodiment. A motorized component can be configured to be movable by other mechanisms. A reflector shape and material can be altered to be other than a dome shape, e.g., a box shape, fabric reflector, and the like. An image contemplated herein may be black-and-white or color depending on the implementation and a specific circumstance of use.

[0033] Any reference to comparative words or adjectives, e.g., tightly/firmly, gently/strongly, small/large, fast/slow, and many others are with reference to respective thresholds as applicable to the term being qualified by the adjective. The threshold should be selected to avoid an undesirable effect related to the term. For example, "to press gently"

should be interpreted as “to press while applying a force of less than a threshold force where the threshold force can undesirably deform or displace the object that is being pressed”. As another example, “to tightly close (a light ring)” should be interpreted as “to close (the light ring) to a distance from the illuminated object where the distance is greater than a threshold distance where the threshold distance can undesirably cast shadows on the object that is being illuminated”.

[0034] With reference to the figures and in particular with reference to **Figures 1** and **2**, these figures are example diagrams of data processing environments in which illustrative embodiments may be implemented. **Figures 1** and **2** are only examples and are not intended to assert or imply any limitation with regard to the environments in which different embodiments may be implemented. A particular implementation may make many modifications to the depicted environments based on the following description.

[0035] **Figure 1** depicts a block diagram of a network of data processing systems in which illustrative embodiments may be implemented. Data processing environment **100** is a network of computers in which the illustrative embodiments may be implemented. Data processing environment **100** includes network **102**. Network **102** is the medium used to provide communications links between various devices and computers connected together within data processing environment **100**. Network **102** may include connections, such as wire, wireless communication links, or fiber optic cables.

[0036] Clients or servers are only example roles of certain data processing systems connected to network **102** and are not intended to exclude other configurations or roles for these data processing systems. Server **104** and server **106** couple to network **102** along with storage unit **108**. Software applications may execute on any computer in data processing environment **100**. Clients **110**, **112**, and **114** are also coupled to network **102**. A data processing system, such as server **104** or **106**, or client **110**, **112**, or **114** may contain data and may have software applications or software tools executing thereon.

[0037] Only as an example, and without implying any limitation to such architecture, **Figure 1** depicts certain components that are usable in an example implementation of an embodiment. For example, servers **104** and **106**, and clients **110**, **112**, **114**, are depicted as servers and clients only as example and not to imply a limitation to a client-server architecture. As another example, an embodiment can be distributed across several data processing systems and a data network as shown, whereas another embodiment can be implemented on a single data processing system within the scope of the illustrative embodiments. Data processing systems **104**, **106**, **110**, **112**, and **114** also represent example nodes in a cluster, partitions, and other configurations suitable for implementing an embodiment.

[0038] Mobile device **132** is an example of a mobile device described herein. For example, mobile device **132** can take the form of a smartphone, a tablet computer, a laptop computer, client **110** in a stationary or a portable form, a

wearable computing device, or any other suitable device. Any software application described as executing in another data processing system in **Figure 1** can be configured to execute in mobile device **132** in a similar manner. Any data or information stored or produced in another data processing system in **Figure 1** can be configured to be stored or produced in device **132** in a similar manner. Mobile device **132** includes an imaging application **134** configured to capture one or more images or video sequences from a camera of mobile device **132**. Mobile device **132** is further coupled to a gem imaging system **136** to facilitate capture of one or more images or videos sequences of an object through a microlens positioned within gem imaging system **136**. Gem imaging system **136** is an example of a gem imaging system described herein.

[0039] Application **105** implements an embodiment described herein. For example, application **105** controls or instructs a manufacturing apparatus (not shown) to manufacture a microlens adapter that is usable in a manner described herein.

[0040] Servers **104** and **106**, storage unit **108**, and clients **110**, **112**, and **114**, and device **132** may couple to network **102** using wired connections, wireless communication protocols, or other suitable data connectivity. Clients **110**, **112**, and **114** may be, for example, personal computers or network computers.

[0041] In the depicted example, server **104** may provide data, such as boot files, operating system images, and applications to clients **110**, **112**, and **114**. Clients **110**, **112**, and **114** may be clients to server **104** in this example. Clients **110**, **112**, **114**, or some combination thereof, may include their own data, boot files, operating system images, and applications. Data processing environment **100** may include additional servers, clients, and other devices that are not shown.

[0042] In the depicted example, data processing environment **100** may be the Internet. Network **102** may represent a collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) and other protocols to communicate with one another. At the heart of the Internet is a backbone of data communication links between major nodes or host computers, including thousands of commercial, governmental, educational, and other computer systems that route data and messages. Of course, data processing environment **100** also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for the different illustrative embodiments.

[0043] Among other uses, data processing environment **100** may be used for implementing a client-server environment in which the illustrative embodiments may be implemented. A client-server environment enables software applications and data to be distributed across a network such that an application functions by using the interactivity between a client data processing system and a server data processing system. Data processing environment **100** may

also employ a service-oriented architecture where interoperable software components distributed across a network may be packaged together as coherent business applications. Data processing environment **100** may also take the form of a cloud, and employ a cloud computing model of service delivery for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, network bandwidth, servers, processing, memory, storage, applications, virtual machines, and services) that can be rapidly provisioned and released with minimal management effort or interaction with a provider of the service.

[0044] With reference to **Figure 2**, this figure depicts a block diagram of a data processing system in which illustrative embodiments may be implemented. Data processing system **200** is an example of a computer, such as servers **104** and **106**, or clients **110**, **112**, and **114** in **Figure 1**, or another type of device in which computer usable program code or instructions implementing the processes may be located for the illustrative embodiments.

[0045] Data processing system **200** is also representative of a data processing system or a configuration therein, such as data processing system **132** in **Figure 1** in which computer usable program code or instructions implementing the processes of the illustrative embodiments may be located. Data processing system **200** is described as a computer only as an example, without being limited thereto. Implementations in the form of other devices, such as device **132** in **Figure 1**, may modify data processing system **200**, such as by adding a touch interface, and even eliminate certain depicted components from data processing system **200** without departing from the general description of the operations and functions of data processing system **200** described herein.

[0046] In the depicted example, data processing system **200** employs a hub architecture including North Bridge and memory controller hub (NB/MCH) **202** and South Bridge and input/output (I/O) controller hub (SB/ICH) **204**. Processing unit **206**, main memory **208**, and graphics processor **210** are coupled to North Bridge and memory controller hub (NB/MCH) **202**. Processing unit **206** may contain one or more processors and may be implemented using one or more heterogeneous processor systems. Processing unit **206** may be a multi-core processor. Graphics processor **210** may be coupled to NB/MCH **202** through an accelerated graphics port (AGP) in certain implementations.

[0047] In the depicted example, local area network (LAN) adapter **212** is coupled to South Bridge and I/O controller hub (SB/ICH) **204**. Audio adapter **216**, keyboard and mouse adapter **220**, modem **222**, read only memory (ROM) **224**, universal serial bus (USB) and other ports **232**, and PCI/PCIe devices **234** are coupled to South Bridge and I/O controller hub **204** through bus **238**. Hard disk drive (HDD) or solid-state drive (SSD) **226** and CD-ROM **230** are coupled to South Bridge and I/O controller hub **204** through bus **240**. PCI/PCIe devices **234** may include, for example, Ethernet adapters, add-in cards, and PC cards for notebook computers. PCI uses a card bus controller, while PCIe does not. ROM **224** may be, for example, a flash binary input/output system (BIOS). Hard disk drive **226** and CD-ROM **230** may use, for example, an integrated drive electronics (IDE), serial advanced technology attachment (SATA)

interface, or variants such as external-SATA (eSATA) and micro-SATA (mSATA). A super I/O (SIO) device **236** may be coupled to South Bridge and I/O controller hub (SB/ICH) **204** through bus **238**.

[0048] Memories, such as main memory **208**, ROM **224**, or flash memory (not shown), are some examples of computer usable storage devices. Hard disk drive or solid-state drive **226**, CD-ROM **230**, and other similarly usable devices are some examples of computer usable storage devices including a computer usable storage medium.

[0049] An operating system runs on processing unit **206**. The operating system coordinates and provides control of various components within data processing system **200** in **Figure 2**. The operating system may be a commercially available operating system for any type of computing platform, including but not limited to server systems, personal computers, and mobile devices. An object oriented or other type of programming system may operate in conjunction with the operating system and provide calls to the operating system from programs or applications executing on data processing system **200**.

[0050] Instructions for the operating system, the object-oriented programming system, and applications or programs, such as application **105** in **Figure 1**, are located on storage devices, such as in the form of code **226A** on hard disk drive **226**, and may be loaded into at least one of one or more memories, such as main memory **208**, for execution by processing unit **206**. The processes of the illustrative embodiments may be performed by processing unit **206** using computer implemented instructions, which may be located in a memory, such as, for example, main memory **208**, read only memory **224**, or in one or more peripheral devices.

[0051] Furthermore, in one case, code **226A** may be downloaded over network **201A** from remote system **201B**, where similar code **201C** is stored on a storage device **201D**. In another case, code **226A** may be downloaded over network **201A** to remote system **201B**, where downloaded code **201C** is stored on a storage device **201D**.

[0052] The hardware in **Figures 1-2** may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash memory, equivalent non-volatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figures 1-2**. In addition, the processes of the illustrative embodiments may be applied to a multiprocessor data processing system.

[0053] In some illustrative examples, data processing system **200** may be a personal digital assistant (PDA), which is generally configured with flash memory to provide non-volatile memory for storing operating system files and/or user-generated data. A bus system may comprise one or more buses, such as a system bus, an I/O bus, and a PCI bus. Of course, the bus system may be implemented using any type of communications fabric or architecture that provides for a transfer of data between different components or devices attached to the fabric or architecture.

[0054] A communications unit may include one or more devices used to transmit and receive data, such as a modem or a network adapter. A memory may be, for example, main memory **208** or a cache, such as the cache found in North Bridge and memory controller hub **202**. A processing unit may include one or more processors or CPUs.

[0055] The depicted examples in **Figures 1-2** and above-described examples are not meant to imply architectural limitations. For example, data processing system **200** also may be a tablet computer, laptop computer, or telephone device in addition to taking the form of a mobile or wearable device.

[0056] Where a computer or data processing system is described as a virtual machine, a virtual device, or a virtual component, the virtual machine, virtual device, or the virtual component operates in the manner of data processing system **200** using virtualized manifestation of some or all components depicted in data processing system **200**. For example, in a virtual machine, virtual device, or virtual component, processing unit **206** is manifested as a virtualized instance of all or some number of hardware processing units **206** available in a host data processing system, main memory **208** is manifested as a virtualized instance of all or some portion of main memory **208** that may be available in the host data processing system, and disk **226** is manifested as a virtualized instance of all or some portion of disk **226** that may be available in the host data processing system. The host data processing system in such cases is represented by data processing system **200**.

[0057] **Figure 3** depicts an example configuration of gem imaging system **300** in accordance with an illustrative embodiment. Gem imaging system **300** is an example of gem imaging system **136** described herein. Gem imaging system rests on a surface **324**. Gem imaging system **300** includes a platform arm **322** having a platform **320** configured to support placement of mobile device **318** upon platform arm **322**. In particular embodiments, mobile device **318** is configured to be movable relative to gem stage **302**. For example, platform arm **322** can adjust a height of the mobile device **318** relative to gem stage **302**. In particular embodiments, mobile device **318** is configured to rotate relative to gem stage **302**. For example, platform arm **322** can rotate about a longitudinal axis. In an embodiment, mobile device **318** is configured to rotate through a plane parallel to a surface of the gem stage **302**. Mobile device **318** is an example of mobile device **132** described herein.

[0058] Gem imaging system **300** further includes a dome reflector **314** configured to be placed on and movable relative to a gem stage **302**. Dome reflector **314** includes an opening at a top surface. Dome reflector **314** further includes a microlens adapter (not shown) including an aperture in alignment with a microlens (not shown). The aperture allows limiting the divergence of the light illuminating the sample from underneath to obtain better imaging conditions. In particular embodiments, dome reflector **314** is configured to be removable from gem stage **302**. Dome reflector **314** includes an adjustable arm **316**. Adjustable arm **316** is configured to move dome reflector **314** relative to gem stage **302**. For example, adjustable arm **316** can be configured to adjust a height of the dome reflector **314** relative to gem stage **302**. In particular embodiments, dome reflector **314** is configured to rotate relative to gem stage

302. For example, adjustable arm **316** can be configured to rotate about a longitudinal axis. Dome reflector **314** is configured to reflect light and illuminate a top surface of gem **310** for capturing images of gem **310** with gem imaging system **300**.

[0059] Gem stage **302** further includes a light source **312** positioned on a top surface of gem stage **302**. In particular embodiments, light source **312** includes modern LED chips mounted in a printed circuit board wired to a battery or power source. Gem stage **302** further includes gem platform **308**. Gem platform **308** is configured to support placement of gem **310** upon gem stage **302**. Gem platform **308** is configured to position gem **310** above LED ring light **312**. When dome reflector **314** is lowered to rest on gem stage **302**, dome reflector **314** reflects light from light source **312** to illuminate gem **310**. Dome reflector **314** reflects light down onto gem **310** from above, illuminating a top surface of gem **310**. In an embodiment, dome reflector **314** is a housing configured to at least partially enclose the gem **310**. Gem stage **302** further includes mechanical stages **304**, **306**. Mechanical stages **304**, **306** are motorized stages and control an x-y position of gem **310**. Gem stage **302** further includes a motor (not shown) configured to control a z-position of gem **310**. Gem stage **302** is configured to be movable in 10 – 100 micron increments to capture different z-position images of gem **310**.

[0060] **Figure 4** depicts an example configuration **400** of dome reflector **314** in accordance with an illustrative embodiment. Similar to the embodiment of **Figure 3**, dome reflector **314** further includes microlens adapter **402**. Microlens adapter **402** is removably coupled to dome reflector **314**. Microlens adapter **402** includes an aperture in alignment with a microlens (not shown). The aperture allows limiting the divergence of the light illuminating the sample from underneath to obtain better imaging conditions. Microlens adapter **402** is configured to removably couple to a mobile device, such as mobile device **318** in **Figure 3**.

[0061] Example configuration **400** further includes a light source **312** positioned below gem **310** upon gem platform **308**. Light source **312** is configured to direct light upon and/or illuminate gem **310** upward toward microlens adapter **402** and a camera lens (not shown) of mobile device **318**. In a particular embodiment, light source **312** is a light emitting diode (LED) chip light source **404**. In the embodiment, mobile device **318** is configured to capture still images and/or video images of gem **310** through microlens adapter **402** such that the images of gem **310** are magnified when captured.

[0062] **Figure 5** depicts an example configuration of another gem imaging system **500** in accordance with an illustrative embodiment. Gem imaging system **500** is an example of gem imaging system **136** described herein. Gem imaging system rests on a surface **516**. Gem imaging system **500** includes a platform arm **514** having a platform **512** configured to support placement of mobile device **510** upon platform arm **514**. In particular embodiments, mobile device **510** is configured to be movable relative to gem stage **502**. For example, platform arm **514** can adjust a height of the mobile device **510** relative to gem stage **502**. In particular embodiments, mobile device **510** is configured to

rotate relative to gem stage **502**. For example, platform arm **514** can rotate about a longitudinal axis. In an embodiment, mobile device **510** is configured to rotate through a plane parallel to a surface of the gem stage **502**. Mobile device **510** is an example of mobile device **132** described herein.

[0063] Gem imaging system **500** further includes a housing **508** configured to be placed on and movable relative to a gem stage **502**. In an embodiment, housing **508** at least partially encloses a gem. Housing **508** includes an opening at a top surface. Housing **508** further includes a microlens adapter (not shown) including an aperture in alignment with a microlens (not shown). The aperture allows limiting the divergence of the light illuminating the sample from underneath to obtain better imaging conditions. In particular embodiments, housing **508** is configured to be removable from gem stage **502**. In particular embodiments, housing **508** is configured to reflect light and illuminate a top surface of a gem for capturing images of the gem with gem imaging system **500**.

[0064] Gem stage **502** further includes mechanical stages **504**, **506**. Mechanical stages **504**, **506** are motorized stages and control an x-y position of a gem. Gem stage **502** further includes a motor (not shown) configured to control a z-position of a gem. Gem stage **502** is configured to be movable in 10 – 100 micron increments to capture different z-position images of a gem.

[0065] **Figures 6A and 6B** depict an example configuration of gem imaging system **500** in accordance with an illustrative embodiment. Gem stage **502** further includes gem platform **602**. Gem platform **602** is configured to support placement of gem **604** upon gem stage **502**.

[0066] **Figure 7** depicts an example configuration **700** of housing **508** in accordance with an illustrative embodiment. Similar to the embodiment of **Figure 5**, housing **508** further includes microlens adapter **702**. Microlens adapter **702** is removably coupled to housing **508**. Microlens adapter **702** includes an aperture in alignment with a microlens (not shown). The aperture allows limiting the divergence of the light illuminating the sample from underneath to obtain better imaging conditions. Microlens adapter **702** is configured to removably couple to a mobile device, such as mobile device **510** in **Figure 5**.

[0067] Example configuration **700** further includes a light source **704** positioned below gem **604** upon gem platform **602**. Light source **704** is configured to direct light upon and/or illuminate gem **604** upward toward microlens adapter **702** and a camera lens (not shown) of mobile device **510**. In a particular embodiment, light source **704** is coupled to housing **508**. In a particular embodiment, light source **704** is a light emitting diode (LED) side panel coupled to housing **508**. In a particular embodiment, light source **704** is a light emitting diode (LED) chip light source **706**. In the embodiment, mobile device **510** is configured to capture still images and/or video images of gem **604** through microlens adapter **702** such that the images of gem **310** are magnified when captured.

[0068] Various embodiments of microlens adapter **136** described herein can be used in a number of applications in which magnified imaging of an object is desired. Example applications include, but are not limited to imaging defects and mapping of diamonds and other gems, drug or other packet recognition and counterfeit prevention, identification of microscopic features in art work and/or manufactured parts, biological cell imaging and counting, skin tissue imaging, detecting water pollutants, toxins, and/or large agglomerates of molecules, detecting plant leaf shape and type.

[0069] An embodiment can be implemented as a software application to control, guide, or instruct a fabrication machine or apparatus, to produce a microlens adapter for ubiquitous mobile devices, such as camera-equipped cellular phones. The application implementing an embodiment, or one or more components thereof, can be configured as a modification of an existing manufacturing system – i.e., a native application in the manufacturing system, as an application executing in a data processing system communicating with an existing manufacturing system over a local area network (LAN) – i.e., a local application on the LAN, as an application executing in a data processing system communicating with an existing manufacturing system over a wide area network (WAN) – i.e., a remote application on the WAN, as a separate application that operates in conjunction with an existing manufacturing system in other ways, a standalone application, or some combination thereof.

[0070] Another embodiment is the microlens adapter itself. Still another embodiment includes an observation configuration that uses a microlens adapter according to an embodiment. Another embodiment includes an observation configuration that uses a microlens adapter that has been manufactured using a software application according to an embodiment.

[0071] The manner of constructing or using a microlens adapter for mobile devices described herein is unavailable in the presently available methods. A method of an embodiment described herein, when implemented to execute on a device or data processing system, comprises substantial advancement of the functionality of that device or data processing system in fabricating and/or using a low-cost and portable microlens adapter for a variety of mobile devices.

[0072] The illustrative embodiments are described with respect to certain types of materials, shapes, orientations, experiments, usages, configurations, mobile devices, lens structures, illumination sources, observed specimen, devices, data processing systems, environments, components, and applications only as examples. Any specific manifestations of these and other similar artifacts are not intended to be limiting to the invention. Any suitable manifestation of these and other similar artifacts can be selected within the scope of the illustrative embodiments.

[0073] Furthermore, the illustrative embodiments may be implemented with respect to any type of data, data source, or access to a data source over a data network. Any type of data storage device may provide the data to an embodiment of the invention, either locally at a data processing system or over a data network, within the scope of the invention. Where an embodiment is described using a mobile device, any type of data storage device suitable for use

with the mobile device may provide the data to such embodiment, either locally at the mobile device or over a data network, within the scope of the illustrative embodiments.

[0074] The illustrative embodiments are described using specific code, designs, architectures, protocols, layouts, schematics, and tools only as examples and are not limiting to the illustrative embodiments. Furthermore, the illustrative embodiments are described in some instances using particular software, tools, and data processing environments only as an example for the clarity of the description. The illustrative embodiments may be used in conjunction with other comparable or similarly purposed structures, systems, applications, or architectures. For example, other comparable mobile devices, structures, systems, applications, or architectures therefor, may be used in conjunction with such embodiment of the invention within the scope of the invention. An illustrative embodiment may be implemented in hardware, software, or a combination thereof.

[0075] The examples in this disclosure are used only for the clarity of the description and are not limiting to the illustrative embodiments. Additional data, operations, actions, tasks, activities, and manipulations will be conceivable from this disclosure and the same are contemplated within the scope of the illustrative embodiments.

[0076] Any advantages listed herein are only examples and are not intended to be limiting to the illustrative embodiments. Additional or different advantages may be realized by specific illustrative embodiments. Furthermore, a particular illustrative embodiment may have some, all, or none of the advantages listed above.

[0077] Thus, a computer implemented method, system or apparatus, and computer program product are provided in the illustrative embodiments for microlens adapter for mobile devices and other related features, functions, or operations. Where an embodiment or a portion thereof is described with respect to a type of device, the computer implemented method, system or apparatus, the computer program product, or a portion thereof, are adapted or configured for use with a suitable and comparable manifestation of that type of device.

[0078] While certain steps and processes are described with certain structures, it is to be understood that the steps and/or processes can be adapted to many variations of the structures described herein within the scope of the illustrative embodiments. While certain materials are used and described, it is to be understood that substitute materials or different but functionally equivalent materials can be used in place of the materials described herein within the scope of the illustrative embodiments. While certain methods have been used at certain steps, it is to be understood that a method may be omitted, added, or modified at a described step to achieve functionally similar result from the structure within the scope of the illustrative embodiments. While certain operations are described as a "step", several operations can be combined together to form a single step in a process described herein. While certain orientations have been referred to as "top," "bottom," "above," "below," "over," or "under" with reference to an example orientation of a device or component, it is to be understood that the device or component can be reoriented such that

the top and bottom become left/right or right/left, or bottom and top, or front/back or back/front, and other variations, as the reorientation case may be.

[0079] Where an embodiment is described as implemented in an application, the delivery of the application in a Software as a Service (SaaS) model is contemplated within the scope of the illustrative embodiments. In a SaaS model, the capability of the application implementing an embodiment is provided to a user by executing the application in a cloud infrastructure. The user can access the application using a variety of client devices through a thin client interface such as a web browser (e.g., web-based e-mail), or other light-weight client-applications. The user does not manage or control the underlying cloud infrastructure including the network, servers, operating systems, or the storage of the cloud infrastructure. In some cases, the user may not even manage or control the capabilities of the SaaS application. In some other cases, the SaaS implementation of the application may permit a possible exception of limited user-specific application configuration settings.

[0080] The present invention may be a system, a method, and/or a computer program product at any possible technical detail level of integration. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

[0081] The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

[0082] Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission,

routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

[0083] Computer readable program instructions for carrying out operations of the present invention may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, configuration data for integrated circuitry, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, C++, or the like, and procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

[0084] Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

[0085] These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

[0086] The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

[0087] The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the blocks may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

CLAIMS

1. A gem imaging system comprising:
a stage having a platform configured to hold an object;
a light source configured to illuminate the object; and
a housing configured to at least partially enclose the object, wherein the housing is configured to position a mobile device such that a camera lens of the mobile device is aligned with the object.
2. The system of claim 1, further comprising a microlens adapter configured to removably couple to the mobile device, wherein the microlens adapter includes a microlens, the microlens positioned in an aperture of the housing.
3. The system of claim 2, wherein the microlens is one of a bell lens, a hemispherical lens, a hyperbolic lens, or an aspheric lens.
4. The system of claim 1, further comprising a second platform configured to support the mobile device.
5. The system of claim 4, wherein the second platform is movable relative to the stage.
6. The system of claim 1, further comprising an arm coupled to the housing.
7. The system of claim 6, wherein the arm is configured to move the housing relative to the stage.
8. The system of claim 1, wherein the stage is movable in increments of 10 to 100 microns.
9. The system of claim 1, wherein the housing includes a light reflector oriented relative to the platform such that light from the light source is reflected from the light reflector onto the object.
10. The system of claim 1, wherein the light source is a lighting panel coupled to the housing.
11. The system of claim 1,
a motorized mechanism to move the platform in at least one direction to change a position of the gemstone relative to the mobile device.
12. The system of claim 1, wherein the platform is configured to hold the object at a focal plane of a microlens.
13. A method comprising:

instructing a manufacturing apparatus to fabricate a stage having a platform such that the platform is configured to hold an object and include a light source configured to illuminate the object and a housing configured to at least partially enclose the object, wherein the housing is configured to position a mobile device such that a camera lens of the mobile device is aligned with the object.

14. The method of claim 1, further comprising:

instructing the manufacturing apparatus to fabricate a microlens adapter configured to removably couple to the mobile device, wherein the microlens adapter includes a microlens, the microlens positioned in an aperture of the housing.

15. The method of claim 14, wherein the microlens is one of a bell lens, a hemispherical lens, a hyperbolic lens, or an aspheric lens.

16. The method of claim 1, further comprising:

instructing the manufacturing apparatus to fabricate a second platform configured to support the mobile device.

17. The method of claim 16, wherein the second platform is movable relative to the stage.

18. The method of claim 13, further comprising:

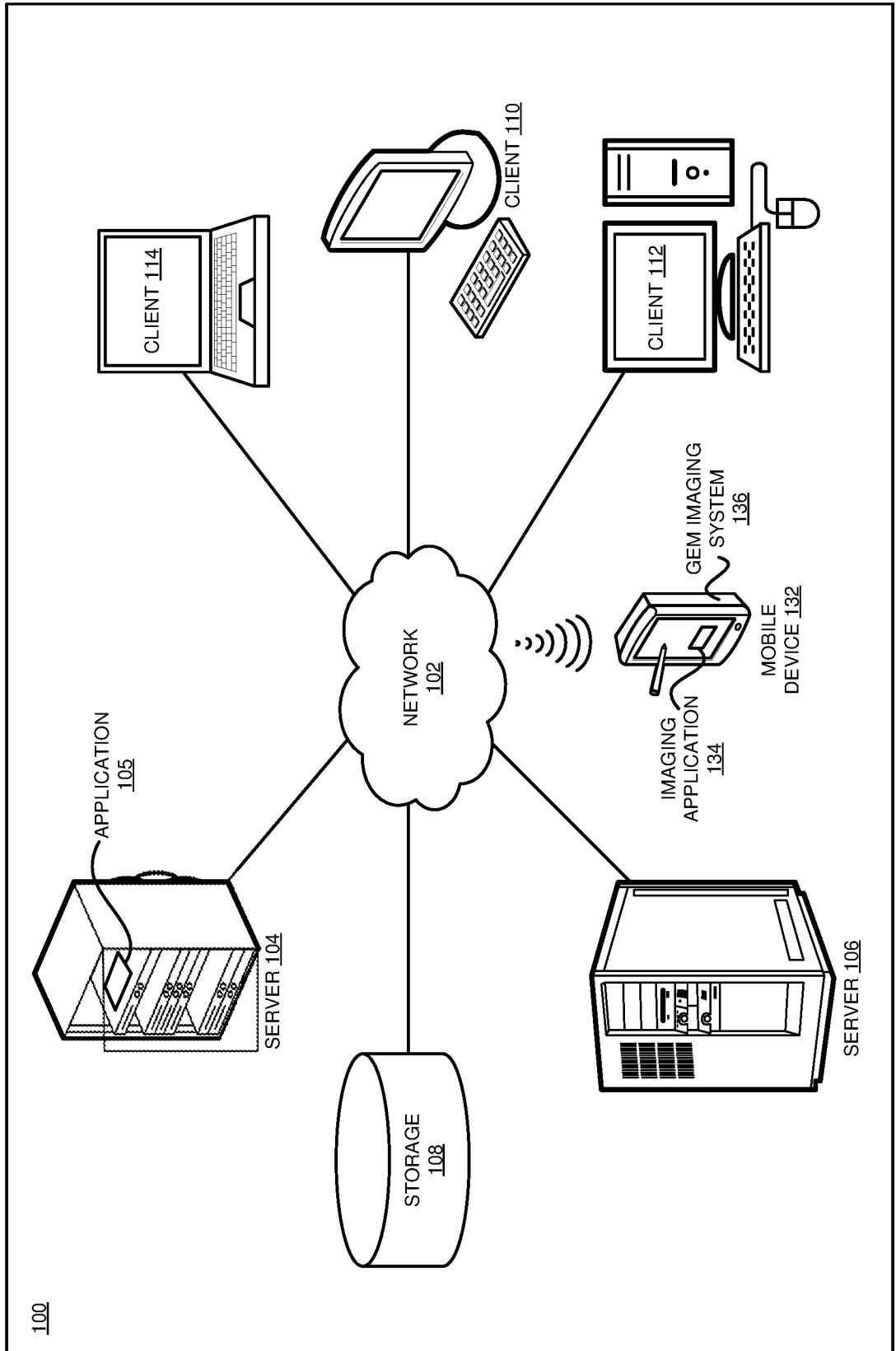
instructing the manufacturing apparatus to fabricate an arm coupled to the housing.

19. The method of claim 18, wherein the arm is configured to move the housing relative to the stage.

20. A computer usable program product comprising one or more computer-readable storage devices, and program instructions stored on at least one of the one or more storage devices, the stored program instructions comprising:

program instructions to cause a manufacturing apparatus to fabricate a stage having a platform such that the platform is configured to hold an object and include a light source configured to illuminate the object and a housing configured to at least partially enclose the object, wherein the housing is configured to position a mobile device such that a camera lens of the mobile device is aligned with the object.

FIGURE 1



100

FIGURE 2

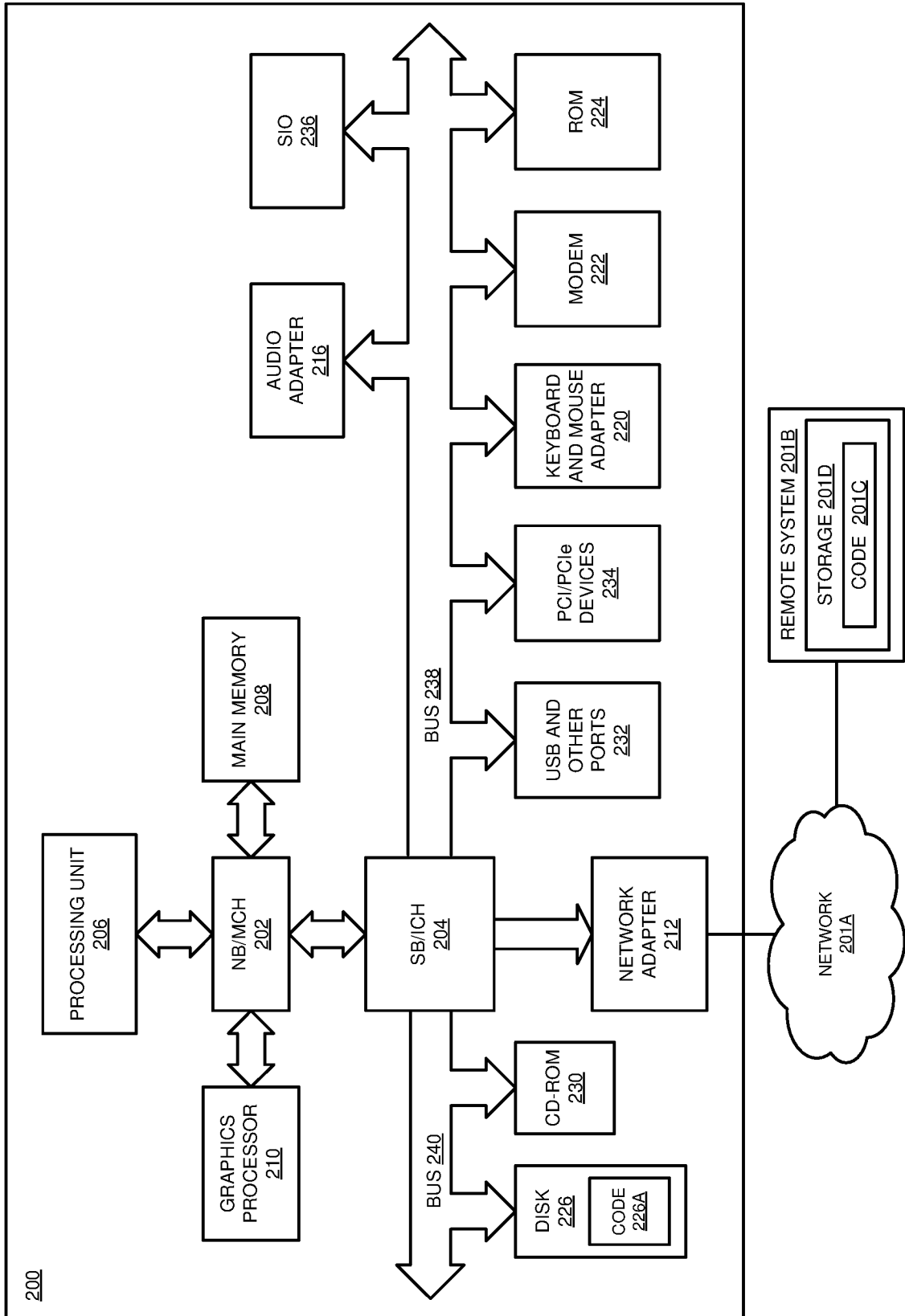


FIGURE 3

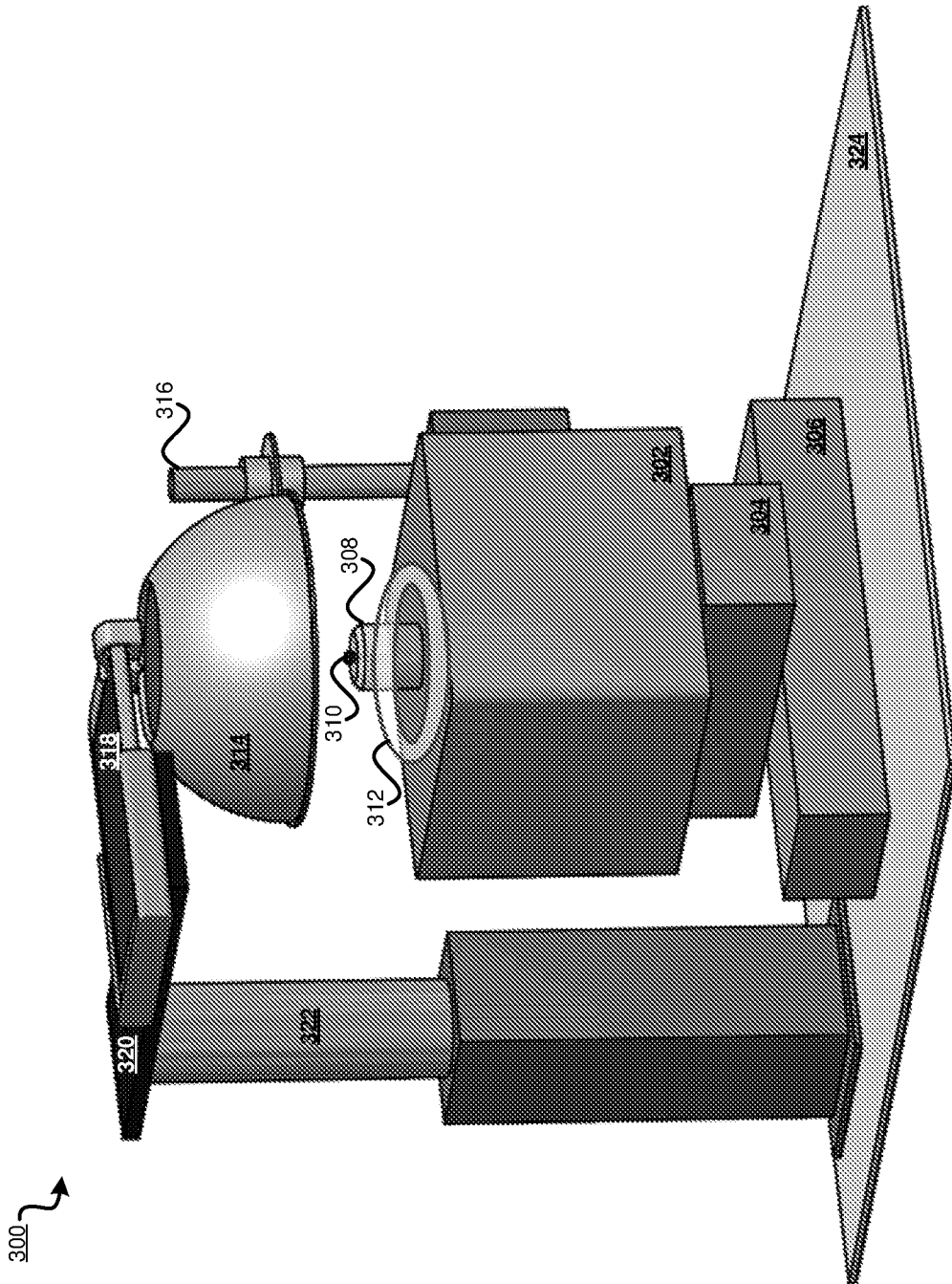


FIGURE 4

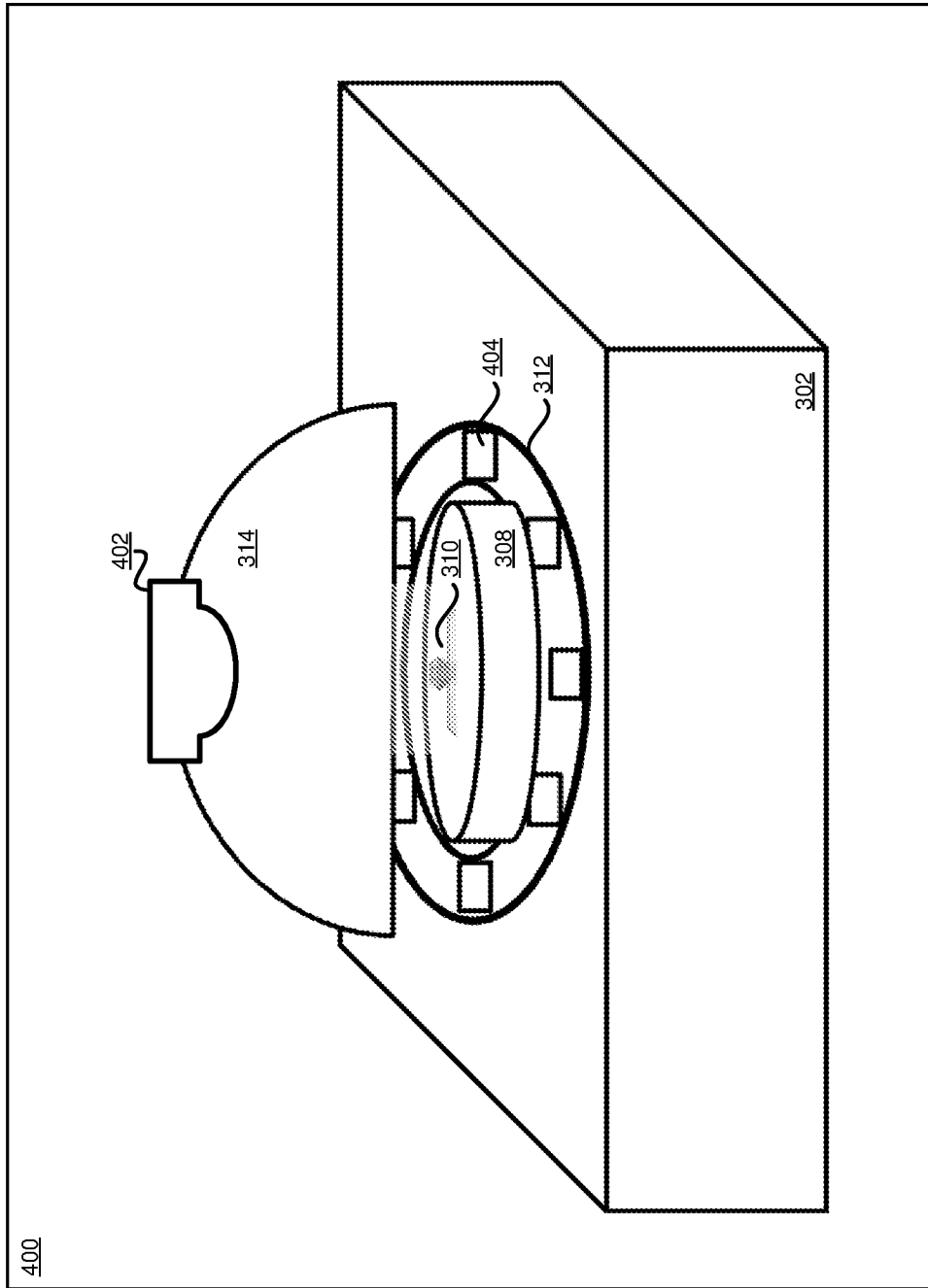


FIGURE 5

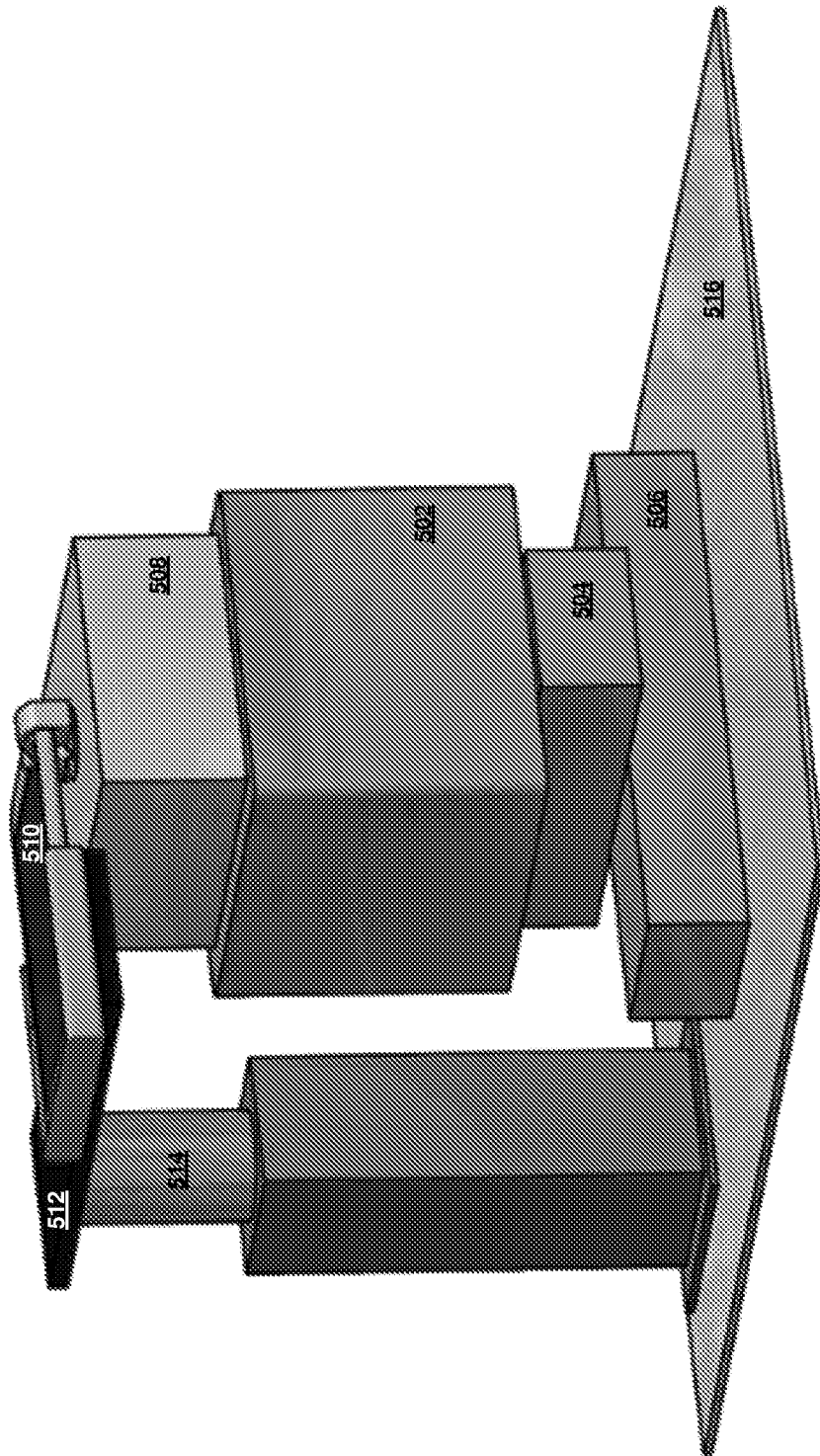


FIGURE 6A

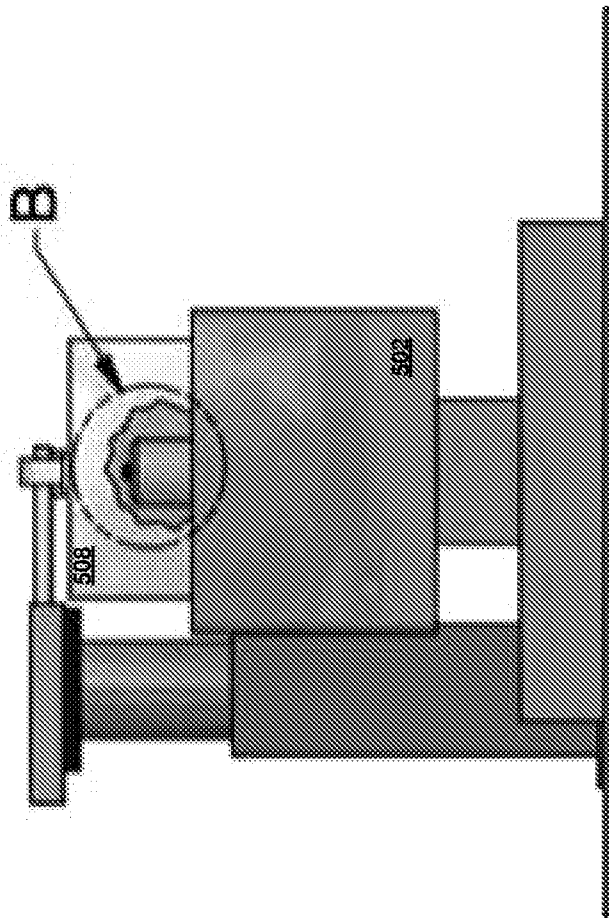


FIGURE 6B

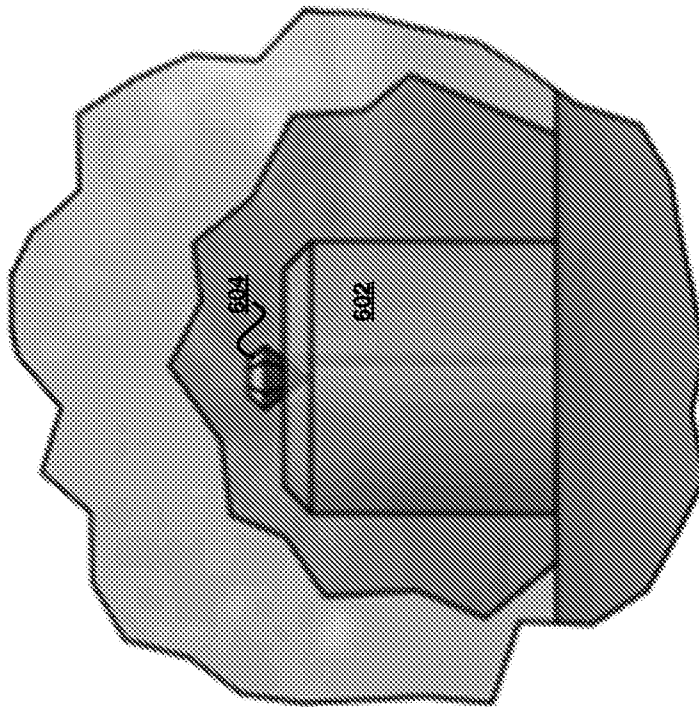
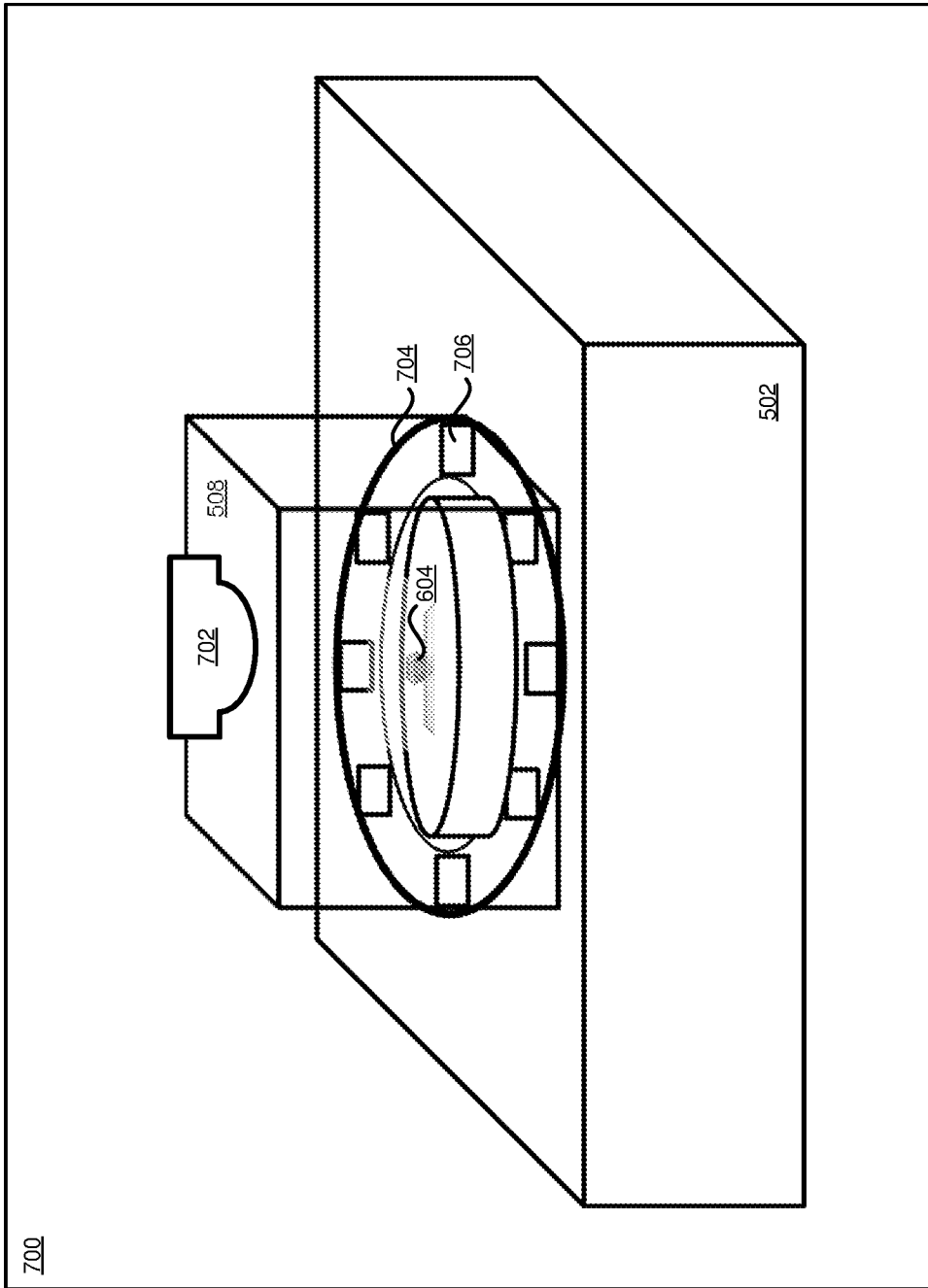


FIGURE 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2020/051594

A. CLASSIFICATION OF SUBJECT MATTER G01N 21/87(2006.01)i; G02B 21/36(2006.01)i 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) G01N; G02B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNPAT,CNKI,EPODOC,WPI: gem+,diamond+,imag+,platform+,light+,mobil+,camera+		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 108982506 A (JINZHAN TECHNOLOGY FOSHAN CO., LTD.) 11 December 2018 (2018-12-11) paragraphs [0005]-[0033] of description, figures1-2	1-20
Y	CN 106405814 A (SUZHOU HUALAI PHOTOELECTRIC INSTRUMENT CO., LTD.) 15 February 2017 (2017-02-15) paragraphs [0003]-[0021] of description, figures1-2	1-20
A	CN 102175687 A (NATIONAL GOLD&DIAMOND TESTING CENTER et al.) 07 September 2011 (2011-09-07) the whole document	1-20
A	CN 206773290 U (DALIAN MARITIME UNIVERSITY) 19 December 2017 (2017-12-19) the whole document	1-20
A	WO 2017132678 A1 (CZOPP, Nir et al.) 03 August 2017 (2017-08-03) the whole document	1-20
A	US 2016363576 A1 (SHENZHEN DIKAI IND. CO., LTD.) 15 December 2016 (2016-12-15) the whole document	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* 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 20 May 2020		Date of mailing of the international search report 04 June 2020
Name and mailing address of the ISA/CN National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451		Authorized officer JIAN, Bin Telephone No. 86-10-53961135

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IB2020/051594

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				US	2019120812	A1	25 April 2019
				US	9453808	B2	27 September 2016
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				EP	3032242	A1	15 June 2016
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				US	2015091593	A1	02 April 2015