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Digital image gemstone verification with filters

Abstract

Systems and methods here may be used for capturing images of sample gemstones under structured, filtered illumination for later comparison and image matching for authentication using networked computer systems.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION(S) (1) The present application claims priority to U.S. Provisional Patent Application No. 63/346,235 filed on May 26, 2022, the entirety of which is incorporated by reference herein.

FIELD
(1) The field includes software for creating difficult to counterfeit inscriptions and matching images of laser inscriptions on gemstones including using filters for image capture.
BACKGROUND
(2) Marking gemstones with permanent inscriptions, etchings, and/or engravings have been used to help identify stones and apply logos. However, it is possible for third parties to counterfeit a laser engraving number in order to take advantage of the relationship that one marking may have with a report, grade, or other identifying information. These drawbacks require new and improved systems and methods, described herein, for creating inscriptions that are difficult to counterfeit and also matching a gemstone image when it was graded to when it is subsequently submitted.
SUMMARY
(3) Systems and methods here may be used to match identifications in gemstones using image matching and machine learning, artificial intelligence systems and methods. In a first example embodiment, a method is provided. The method can be performed by a computer with a processor and memory. The computer can be in communication with a networked comparison server computer, a digital camera and a structured, filtered light source. The method can include causing the light source illuminate gemstone in a holder. The gemstone can include an inscription. Further, the light source can include a structured filter.
(4) The method can also include, by the computer, receiving a digital image of the gemstone and at least one identifier for the gemstone. The method can also include by the computer, retrieving at

least one previously stored digital image and its identifier using the received identifier. The previously stored image and its identifiers can include an inscription on a gemstone and its unique features. The method can also include by the computer, comparing the received digital image of the gemstone and/or identifiers with the at least one previously stored digital image retrieved using the identifier(s). The comparing the received digital image of the gemstone and/or identifier(s) with the at least one previously stored digital image can be retrieved using the identifier(s).

(5) If the comparison matches, the method can include indicating to a user interface, a match. If the comparison does not match, the method can include indicating to a user interface, no match.

(6) In another example embodiment, a system is provided. The system can include a digital camera and a structured, filtered light source. The light source can include a light source filter. The system can also include a computer comprising a processor and a memory. The memory can include instructions to cause the processor to cause the light source illuminate gemstone in a holder. The gemstone can include an inscription.

(7) The instructions can further cause the processor to receive a digital image of the gemstone and at least one identifier for the gemstone. The digital image can be captured by the digital camera. The instructions can further cause the processor to retrieve at least one previously stored digital image and its identifier using the received identifier. The previously stored image and its identifiers can include an inscription on a gemstone and its unique features.

(8) The instructions can further cause the processor to compare the received digital image of the gemstone and/or identifiers with the at least one previously stored digital image retrieved using the identifier(s). The comparing the received digital image of the gemstone and/or identifier(s) with the at least one previously stored digital image can be retrieved using the identifier(s).

(9) If the comparison matches, the instructions can further cause the processor to indicate to a user interface, a match. If the comparison does not match, the instructions can further cause the processor to indicate to the user interface, no match.

(10) In another example embodiment, a computer-implemented method is provided. The computer-implemented method can include receiving a digital image of the gemstone and at least one identifier for the gemstone.

(11) The computer-implemented method can also include retrieving at least one previously stored digital image and its identifier using the received identifier. The previously stored image and its identifiers can include an inscription on a gemstone and its unique features.

(12) The computer-implemented method can also include comparing the received digital image of the gemstone and/or identifiers with the at least one previously stored digital image retrieved using the identifier(s). The comparing the received digital image of the gemstone and/or identifier(s) with the at least one previously stored digital image can be retrieved using the identifier(s).

(13) If the comparison matches, the computer-implemented method can include indicating to a user interface, a match. If the comparison does not match, the computer-implemented method can include indicating to a user interface, no match.

(14) The computer-implemented method can be performed by a computer. The computer can be in communication with a networked comparison server computer. The computer can further be in communication with a digital camera and a structured, filtered light source. In some instances, the computer-implemented method can include causing the light source illuminate gemstone in a holder. The gemstone can include an inscription. Further, the light source can include a structured filter.

(15) In some instances, the light source filter is a horizontal filter. In some instances, the light source filter is a vertical filter. In some instances, the light source filter is a grid filter. In some instances, the light source filter is a circular filter. In some instances, the light source filter is a square filter. In some instances, the light source filter is in a particular shape correlated to a geometry of the gemstone.

(16) In some instances, the structured, filtered light source includes lines with spacing and size and

linewidth that is proportional to at least one of, a distance between the structured, filtered light source to the gemstone, a diameter of the gemstone, a spatial distance between facet junctions of the gemstone, and a height of the gemstone.
(17) In some instances, the structured, filtered light source is an optical display/projector/monitor/LEDs.
(18) In some instances, the digital camera and the light source are desk top units which are remote from the computer used for comparing with previously stored images.
(19) In some instances, the digital camera and the structured, filtered light source are in a same mobile unit which are remote from the computer used for comparing with previously stored images.
(20) In some instances, the digital camera and light source are directed along a same axis to the gemstone by a dichroic beam splitter.
(21) In some instances, the digital camera and light source are directed at opposite sides of the gemstone to provide a back light image.
(22) In some instances, the comparing the received digital image of the gemstone and/or identifier(s) with the at least one previously stored digital image retrieved using the identifier(s), includes comparing gemstone girdle profile in the images.
(23) In some instances, the comparing the previously stored digital image of the gemstone and/or identifier(s) can be replaced with a newly acquired digital image of the same gemstone and/or identifier(s).
(24) In some instances, the matching server generates a digital certificate/record of gemstone after a successful matching and the resulting digital certificate/record can be provided to a user(s).
(25) In some instances, a thickness of lines in the structured, filtered light can be vary from 1 nm to 100 mm and a spacing of lines in the structured, filtered light can be vary from 1 nm to 100 mm.
(26) In some instances, lines in the structured, filtered light have a sinusoidal gradation.
(27) In some instances, lines in the structured, filtered light are binary without gradation.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) For a better understanding of the embodiments described in this application, reference should be made to the Detailed Description below, in conjunction with the following drawings in which like reference numerals refer to corresponding parts throughout the figures.
(2) FIG. **1** is an illustration of an example inscription using certain aspects described herein;
(3) FIG. **2** is an illustration of an example inscription arrangement using certain aspects described herein;
(4) FIG. **3** is another illustration of an example inscription arrangement using certain aspects described herein;
(5) FIG. **4** is an illustration of images of example inscription arrangements using certain aspects described herein;
(6) FIGS. **5**A and **5**B are illustrations of an example optical filter arrangement using certain aspects described herein;
(7) FIGS. **6**A and **6**B are illustrations of other examples of optical filter arrangement using certain aspects described herein;
(8) FIG. **7** is an illustration of an example system with certain aspects described herein;
(9) FIG. **8** is an illustration of example holders with certain aspects described herein;
(10) FIG. **9** is an illustration of an example hardware arrangements using certain aspects described herein;
(11) FIG. **10** is an illustration of an example hardware arrangements using certain aspects described

herein;
(12) FIG. **11** is an illustration of an example hardware arrangements using certain aspects described herein;
(13) FIG. **12** is an illustration of an example hardware arrangements using certain aspects described herein;
(14) FIG. **13** is an illustration of an example hardware arrangements using certain aspects described herein;
(15) FIG. **14** is an example flow chart of certain aspects described herein;
(16) FIG. **15** is an illustration of an example flow chart using certain aspects described herein;
(17) FIG. **16** is an example flow chart for image capture according to aspects described herein;
(18) FIGS. **17**A and **17**B are images of example inscription arrangements using certain aspects described herein;
(19) FIGS. **18**A, **18**B and **18**C show user interface examples according to certain aspects described herein;
(20) FIG. **19** is an illustration of an example networked system with certain aspects described herein;
(21) FIG. **20** is an illustration of an example computing system with certain aspects described herein.

DETAILED DESCRIPTION

(22) Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a sufficient understanding of the subject matter presented herein. But it will be apparent to one of ordinary skill in the art that the subject matter may be practiced without these specific details. Moreover, the particular embodiments described herein are provided by way of example and should not be used to limit the scope of the particular embodiments. In other instances, well-known data structures, timing protocols, software operations, procedures, and components have not been described in detail so as not to unnecessarily obscure aspects of the embodiments herein.

Overview

(23) Gemstones are difficult to value, but analysis and certification from a reputable institution such as the Gemological Institute of America (GIA) and/or the European Gemological Laboratory (EGL) may allow the market to better understand the gemstones and the underlying physical properties of them to assign values. In such examples, gemstones may be submitted for analysis which is memorialized in a certificate for each gemstone with a full description including authenticity, size, shape, grading, properties, and/or record number for database and reference. Once a gemstone is certified, its record including all the above mentioned description may be stored for later use.

(24) It is also possible that a gemstone certificate can be re-issued up on customer's request. In general, customer gemstones, which are previously certified by an established organization, should be mailed to the same organization for a new certificate. This gemstone certification process is very time consuming and expansive to customer. Occasionally, customer's gemstone can be lost during shipment. Therefore, it is very natural to envision a gemstone certificate and/or verification service, which certifies a gemstone automatically with the help of the computerized gemstone verification method mentioned above.

(25) And it may also be beneficial to label gemstones with permanent markings such as ablations, engravings, and/or inscriptions of identifiers in order to track and later match such gemstones. Such an identifier can be any kind of information such as but not limited to meta data such as a record number (or inscription), gemstone color, shape, color, cut, carat weight, clarity, origin, location of inclusions, cut type, and/or girdle polish type, etc. in any combination or permutation. Such identifying markings may also be tied to a report, grade, origin information, or other background

information in a background database for lookup and later matching and identification purposes. Additionally, gemstone labelling can be done in many different forms such as barcode, unique number, unique shape, etc. But gemstones like anything else, are moved around, sent in the mail, and sold to different parties. Verification of previously certified and/or analyzed gemstones is therefore useful and desirable.

(26) However, counterfeiters may benefit from inscribing their own fake identifiers to mimic authentic inscriptions. Therefore, making inscriptions more difficult to counterfeit may be useful. Additionally, an image matching system may be useful in order to identify such faked or counterfeit inscriptions as compared to previously identified and analyzed gemstones stored in a reference database. Further, it may be useful to complete such verifications at remote locations from the location of the references storage for ease of use and access to the matching results. In such a way, a consumer may be able to image a gemstone at a mall, send the image or images by computer network to the systems described here for matching, and receive a result of the matching in relatively short time. In such a way, systems and methods here may be used for matching images of laser inscriptions on gemstones including but not limited to inscriptions on gemstones including on often inscribed gemstone girdles.

(27) Although examples of gemstones and engraved gemstones are used in this description, such terms are not intended to be limiting. The systems and methods here may be used on many multiple example matching scenarios, gemstones with laser engravings is merely one.

(28) Gemstone Inscription Background

(29) Ablating gemstones with laser beams on the surface, and/or below the surface of gemstones may be used to mark and thereby later identify a gemstone correlated to a history, grade, origin, or other background information. Such inscription may be used to inscribe anything such as, but not limited to a number, word, logo, QR code, barcode, label, code, logo, secondary encryptions, and/or three dimensional images in the gemstone for labeling and/or identification purposes, as well as for customizing gemstones with customer requested names, dates, etc. Such inscriptions may be visible with the naked eye, or hard to see with a naked eye, but under magnification provide information that may be used for tracking and identifying gemstones. Such ablation inscriptions may be hard to change and/or mimic by third parties, especially those under the surface. But because the identifying mark may be tied to a grade or report or chain-of-title, sales history, and/or other background information, and such mark may be counterfeited, faked, or forged, it is beneficial to help ensure that the inscription on a particular stone matches the inscription tied to the original and authentic grade or report stored in the background system. In such a way, an image of an inscribed gemstone report may be more closely matched and verified than by using the bare inscription characters to match.

(30) FIG. **1** shows an inscription **102** on a girdle of a cut diamond, however, such inscriptions may be made in any location on a cut diamond, the girdle example being non-limiting. FIG. **2** shows an example of a laser beam **204** focusing energy on the girdle **206** of a gemstone and ablating the gemstone one spot or point **202** at a time, according to instructions provided by and to the computer software in communication with the hardware laser system in order to create the required or requested inscriptions. Such an identifier may be matched to a background history, grade, origin, or other information for matching and informational purposes. Any such inscription design may be made, however, it is possible that a third party might inscribe another gemstone with the same identifier, trying to mimic the original.

(31) FIG. **3** shows the example gemstone **302** and detail of a girdle with inscription **318**. The diagram of the gemstone **302** shows a table **304**, facets **306** on the crown **308**, and the girdle **310**. The girdle section **310** is often, but not always, the place where gemstones are inscribed, especially in a round, brilliant style cut. The pavilion **312**, facet junctions **314** on the pavilion **312** terminating in the culet **316** are also shown.

(32) The detail **318** of the girdle is also shown with the upper girdle **320**, and lower girdle **322**

bounding the facets **324** used in cut the girdle section where the laser inscription **330** is located. In some examples, the girdle facets with vertical oriented facets **324** are not used but rough or polished, the faceted girdle is shown only as an example as it is common.

(33) The systems and methods here use other identifying features of the gemstone itself to aid in matching not only the images or designs etched into the gemstone.

Imaging Filter Examples

(34) FIG. **4** shows the girdle example comparison without **402** and with **410** and optical filter applied to the camera as described herein. The figures show how and why images taken with optical filters are easier to process using computer image analysis, pixel analysis and software to identify not only the inscriptions, but the other physical aspects of the diamond for computer image analysis. Contrast may be increased in images taken with filters and thereby aid the computer image analysis in order to decipher any of the features including inscriptions on the samples as well as facets, facet angles, facet junctions, and other physical properties.

(35) Without the optical filter **402**, facet junctions **406** are barely visible. However, the overall facet junction visibility gets dramatically improved with the images taken using an optical filter **410** as described herein. As can be seen with the filtered image **410** of the girdle and inscription **404**, that the vertical facets **406** are more clear in the image taken with the filters **410**. Also, the inscriptions are more clear **404** and the upper facet **412** and lower facet **414** junctions have better definition. Because the lines on the image taken with optical filters **410** are cleaner, clearer, better contrast and definition, computer digital image and pixel analysis may be aided and more accurate as described.

(36) FIG. **5**A shows examples of different optical filters in different orientations and patterns. Any or all of these patterned filters may be used in the embodiments described herein, in any combination with the camera used to capture images for analysis as described herein. In gemology, each of the 4Cs (Cut, Color, Clarity and Carat) play a role in determining a gemstone quality. For example, a diamond cut quality is commonly assessed by checking any oddness, irregularities, symmetry, etc. in table-up and table-down views. Therefore, it may be useful to enhance gemstone facets in digital images taken for grading purposes, especially by computer image analysis. Such filters may also be used to enhance the visibility of unique features of gemstones including facet junctions, any defects such as cracks, chips, scratches and/or inclusions.

(37) FIG. **5**A, shows example optical masking filter(s) used for gemstone imaging in a system with a complicated pattern, for example specific spacing and/or shape, which is highly correlated with any spatial frequency, for example orientation and/or shape, of a given gemstone. Once the optical pattern is projected to a given gemstone, it will optically interfere with the unique features of a given gemstone, resulting in visibility improvement of facet junctions and inclusions as shown herein, depending on the shape and pattern.

(38) The spacing in filter can be vary from gemstone to gemstone and/or imaging device to device. Such different spacing of lines and thickness of lines may enhance different aspects of each gemstone facet, geometry, and/or engraved, etched, embossed, or inscribed identifier. In some examples, the spacing may be adjusted based on a few factors, including but not limited to, distance between filter to gemstone girdle, diameter of gemstone, spatial distance between facet junctions, and/or height of gemstone, in any combination or permutation. In some examples, this may drive an adjustment of the filter pattern as well as spacing and/or height for each gemstone. FIG. **5**B shows example representatives of optical filter at different configuration. In the first example **522** of FIG. **5**B, the binary pattern **524** and sinusoidal pattern **526** are shown. In the binary pattern **524**, only white spaces and black lines are used with no gradation, with a distance between the first line and next line is 4 mm as an example. The sinusoidal pattern **526** include gradation of black to gray to white and back again. The distance could be any distance, but 4 mm is shown as a non-limiting example. Next, the thickness of the line itself **530** is shown as 2 mm. Again, the thickness of the lines could be any distance, but 2 mm is shown as a non-limiting example. The second example **532** also shows a binary pattern **534** and a sinusoidal pattern **536** with the distance

between the first line and second line in the binary pattern to be 2 mm as a non limiting example **538** and the thickness of the line being 1 mm in a non-limiting example **540**.

(39) The optical interference between facet junctions and the optical filter pattern can further be described by Moiré effect. According to this theory, it is possible to enhance (or modulate) a particular spatial frequency component when the projected optical pattern is optically convolved with the spatial frequency (e.g., facet junctions) on a given gemstone.

(40) Therefore, the pattern of optical filter pattern including spacing and shape is highly correlated with the spatial frequency components of a given gemstone. For example, the square shape optical filter **508** in FIG. **5**A is designed to enhance any vertical and horizontal facet junctions and inclusions within optical field of view. Purely vertical lined filters **502** may enhance vertical lines such as those on a faceted girdle. Purely horizontal lines **504** may enhance horizontal lines such as certain facets around the crown. A combination of horizontal and vertical lines combined **506** may enhance both vertical and horizontal facets on a gemstone.

(41) The circle shape optical filter **510** on FIG. **5**A is designed to enhance facet junctions and inclusions on a round brilliant cut (RBC) gemstone. There are many different types of gemstone cuts such as round, emerald, princess, oval, radiant, etc. but a round brilliant cut is very common in diamond.

Imaging Hardware Setup Examples

(42) FIG. **6**A shows an example light source **602** with filter with lines **604** corresponding to the vertical lines of the griddle facets. Such a filter may correspond to the vertical lines shown in FIG. **5**A as **502**, or be arranged with any kind of filter. Such a unit as shown in FIG. **6**A may be deployed remotely and include communication systems to not only illuminate a sample but also capture images and send those images to a back-end system for analysis. (See FIG. **19** for networked system and **20** for computing systems that may be integrated with or communicate with the systems in FIG. **6**A.) FIG. **6**A also shows a sample holder **610** which may be used for imaging. The camera is not shown in FIG. **6**A but may be positioned to capture images of the sample from any of various angles.

(43) As the benefits of using such filters are shown here, and the various filters that may be used, below are hardware setups that may be used to implement the described filters and capture images of gemstones for grading and/or other image analysis such as but not limited to comparisons for identification purposes.

(44) As described, during the process of inscribing a gemstone with a unique identifier that is correlated to a gemstone report, an image may be taken of the inscription on the gemstone. Such image may be of the inscription and surrounding environment such as the girdle and facets above and below the inscription. The image may include facets of the girdle itself, and the facets of the gemstone near or touching the girdle, and any imperfections found near the inscription.

(45) FIG. **6**B shows another illustration of the imaging and lighting system including a gemstone holder **610** and a display **612**. The example in FIG. **6**B shows a light source attached to a flexible arm **620**, in this example, with an optical filter as described herein. The example of FIG. **6**B also shows a stationary light source **622** also with an optical filter as described herein. Both the light sources **620**, **622** are able to illuminate the gemstone stage **610** and thereby any gemstone samples placed or held thereon. The camera (not shown) is positioned to capture images of the gemstone on the holder stage **610** and display the images on the display screen **612**. In some examples, these images may be captured, stored, and/or sent to a back-end server as described for storage and/or comparison matching. The FIG. **6**B also shows a detail of the optical filter on the stationary light **624** and optical filter on the flexible light **626**. Any kind of filter arrangement could be employed on the stationary light **622** and/or flexible light **620** in any combination or permutation as described herein including but not limited to those described in FIG. **5**A and FIG. **5**B.

(46) FIG. **7** shows an example hardware abstract of the equipment which may be utilized to employ the methods described herein. This setup allows the system to capture and analyze two images of

the gemstone: a top-view and a side-view image of the target gemstone. The side-view image would capture a profile of the diamond girdle, although any portion of a stone may be inscribed, the girdle being only a non-limiting example.
(47) The Example of FIG. **7** includes a top camera **702** and side camera **704** (with optional telecentric lens) which may be used to line up the stone **710** with illumination of the stone coming from a Blue light emitting diode (LED) **720** and Red LED **730**, each behind a respective diffuser, one for the blue light **722** and one for the red light **732** aimed at the gemstone **710**. By illuminating a gemstone from the back and bottom angles as shown, the stone girdle image is more easily analyzed by the camera and computer systems for more precise inscriptions.
(48) In the example of FIG. **7**, a red long pass filter **734** is used between the stone **710** and top camera **702**. In the example, an iris **736** is used between the stone **710** and top camera **702**. In the example, a laser mirror housing **738** is arranged above the stone. In the example a blue band pass filter **724** is arranged between the stone **710** and side camera **704**.
(49) The components in FIG. **7** that may include internal computer systems or be in communication with computer systems that include but are not limited to, the top camera **702**, side camera **704**, iris **736**, and laser mirror housing **738** as well as motors holding the stone **710** and/or stone holder. Such systems may be used to automatically focus the systems as described herein with feedback loops of images sent to the computer to make adjustments to the motors to move the holder and gemstone as described herein.
(50) Separate blue **720** and red **730** LED light may be used to illuminate the stone **710** for inscribing by inserting different color filters **724**, **734** for top **702** and side **704** camera. Lens coupled with the side camera **704** may be used to provide a clear image of the stone **710** girdle, should that be the part of the stone that is inscribed. Utilizing an iris **736** before the top camera **702** as shown in FIG. **7** to clip reflected side light may help increase the depth of view.
(51) In some examples, any or all of the diffusers shown in FIG. **7**, **722**, **732** with the lights **720**, **730** may be structured filters as described herein and shown as examples in FIGS. **5**A-**5**B and FIGS. **6**A-**6**B. In some examples, a combination of color red, blue or other color light as described, and structured filters may be used on the same camera.
(52) Such imaging systems as described herein may include or be in communication with computer systems such as but not limited to those described in FIGS. **19** and **20**. Such computer systems may be configured to control the laser parameters, cause movement by the various motors, and/or control capturing digital images to analyze for inscriptions. FIGS. **9**, **10**, **11**, **12** and **13** show further examples below.
Gemstone Holder Examples
(53) In some examples, as shown in FIG. **8**, a gemstone holder may be used to hold a gemstone for the laser to inscribe thereon, or images taken thereof. The example stone holder may be used to hold the stone to be inscribed in one place, to keep it from moving during an inscription process and allow an operator to more easily change the stones out from the inscription machine, if multiple stones are already loaded into holders, or stones are swapped out in one holder in rapid succession. Such a holder may also more easily include identifying information for the stone, so that the operator can keep track of which stones to load and inscribe with which indicia.
(54) The holder includes a frame **802** with a spring-loaded shaft **804** mounted generally parallel to two of the four sides of the frame, and a fixed end **806** opposite the spring loaded shaft **804**. Some examples include a thrust ball bearing and a thrust washer on both side of the spring **817** to facilitate the rotation of the spring-loaded shaft **804** and prevent torsional resistance. The example spring loaded shaft **804** may be pulled open by an operator to move the spring-loaded shaft **804** relative to the holder frame **802** and released to pinch a sample stone **808** between it and a fixed end **806**, held by the spring tension of the spring **817** which is biased to push out and away from the top guide set **816**. In the example, the holder includes a top guide set **816** through which the spring loaded shaft runs, with an opening to allow movement or sliding of the spring loaded shaft, for the

spring **817** to push out and away from to impart the force of the spring loaded shaft **804** on the gemstone **808** and includes two guide slots and pegs to keep the spring loaded shaft aligned with the fixed end **806** as it opens and closes. The sample stone **808** may be placed on the holder and pinched between the spring-loaded shaft **804** and fixed end **806** as the spring loaded shaft **804** is pushes away from the top guide set **816** by spring tension.

(55) FIG. **8** shows the holder securing three different sized stones, small stone **806** at **810**, medium stone **828** at **820** and larger stone **838** at **830**, as the shafts are relatively small, medium and large to fit the stones. In some examples, a small shaft may be used to hold stones between 0.03 carat and −0.1 carat, the medium shaft may be used to hold stones larger than 0.1 carat and smaller than 10 carats, and the larger shaft may be used to hold stones larger than 10 carats in size. This shows how the same arrangement may secure many sizes of gemstone for analysis. Such a stone holder is useful for inscribing many different parts of a gemstone, but especially helpful for inscribing a girdle on a gemstone.

(56) In some examples, such a holder not only pinches the stone **808** between the spring-loaded shaft **808** and the fixed end **806**, but may also include a diffusers to diffuse light used to illuminate the gemstone during inscribing process. Diffusers may be added for both top and bottom LEDs which help provide uniform lightning environment and lead to better image quality.

(57) In some examples, this may include a top blue LED diffuser paper **812**. In the example of FIG. **8**, the diffusers **812**, **814** are paper diffusers but could be made of plastic, etched glass, or any other kind of diffuser. The example holder **802** includes a friction fit slot **811** for the top blue diffuser paper **812** to be secured. In some examples, the holder may include diffuser paper **814** to diffuse bottom red LED. Stone holders with different spring-loaded shaft **804** shaft sizes may be used to fit different stone sizes.

(58) In use, the arrangement shown in FIG. **8** is then placed in the system, such that the blue LED light shines through the top diffuser paper **812** and the bottom red light shines through the bottom diffuser paper **814** leaving the stone **808** open for the cameras to view from the top and side as shown in FIG. **7** and the laser to inscribe.

(59) In some examples, the gemstone holder **810** may be placed into the inscription system and moved by the motors to allow the laser to inscribe where a software program has directed it. In such examples, a set of stepper motors or electric motors may be used to move the holder and gemstone in the x, y, and z directions while the laser system stays stationary to fire into the stone when the computer commands it to. The same arrangement may be used in the systems and methods described here for imaging a sample stone.

Imaging Systems Examples

(60) FIG. **9** shows an example schematic of a transmission mode gemstone imaging system configured to verify a gemstone at table-down view, from the culet side.

(61) In the example, the light source **920** includes an optical filter **924** as described herein. The gemstone being imaged **910** has the table side toward the light **920** and culet side toward the imaging sensor **904** or digital camera. In such a way, the computer system **940** (also described in FIGS. **19** and **20**) may be in communication with the light **920**, optical filter **924** display to change displays, and digital camera **904** and can control all aspects of the imaging process, including but not limited to light on/off, light intensity **920**, light color **920** light wavelengths **920**, which optical filter is used **924**, when the camera captures an image **904**, how many images are captured by the camera **904**, etc.

(62) The ultimate image captured in this arrangement of FIG. **9** is a table down image **930** but the orientation of the component parts such as the camera **904** and light **920** may be arranged in any way, as long as the order is kept. For example, the left to right orientation of the component parts is for example purposes only and could be up and down or any other orientation. The example orientation in FIG. **9** is not intended to be limiting.

(63) In some examples, alone or in any combination, the pattern of optical filter can be dynamically

and automatically adjusted for a given gemstone. In some examples, such changes are by liquid crystal display which may be changed or edited based on input from a computer system or manual entry of filter type, size, arrangement, spacing, or any other parameter. In some examples, Liquid Crystal Displays (LCD) may be used in conjunction with the light system and/or integrated into the light system in order to provide adaptable and/or dynamic structure to the lighting.

(64) The correlation between the structured, filtered light options and the gemstone physical properties (height, facet dimensions, facet distances, and/or other geometry) may help enhance the contrast and thereby image quality for more accurate matching.

(65) Systems may allow for manual input of these or other physical properties of the gemstone under evaluation, and/or the system may capture an image of the gemstone and thereby determine, based on known distances to camera lens, etc. to model or estimate some or all of the required geometrical measurements to be used. In an automatic arrangement, an image of the gemstone may be captured and analyzed by a back-end computer to determine which best-fit structured light source may be used to capture an enhanced image for comparison.

(66) Once determined, either by manual or automatic determination based on image analysis, the system may direct the light source filter structure to display a particular pre-determined line spacing, thickness, arrangement, setting, pattern, and/or any other kind of arrangement. See FIGS. **5**A and **5**B for examples. The line spacing and thicknesses of any of the filter options shown may be selected, change, and updated for different lighting conditions and image capture to enhance facets, identifiers, and/or other features. Such a change may be implemented by LCD changes on the light and/or any other kind of changing, swapping, or moving of filters into position for the light source to illuminate the gemstone under evaluation.

(67) FIG. **10** shows an example schematic of a transmission mode gemstone imaging system configured to verify a gemstone at girdle view or side-on view. As in FIG. **9** the components may be arranged in any orientation so long as their relative order is maintained as shown in FIG. **10**. The left to right orientation of the light **1020** then filter **1024** then sample **1010** then imaging sensor camera **1004** is not intended to be limiting and could be oriented up and down, right to left, or any other orientation.

(68) In the example, the light source **1020** includes an optical filter **1024** as described herein. The gemstone being imaged **1010** has one side of the girdle toward the light **1020** and the other side of the girdle toward the imaging sensor **1004** or digital camera. In such a way, the computer system **1040** (also described in FIGS. **19** and **20**) may be in communication with the light **1020**, optical filter **1024** display to change displays, and digital camera **1004** and can control all aspects of the imaging process, including but not limited to light on/off, light intensity **1020**, light color **1020** light wavelengths **1020**, which optical filter is used **1024**, when the camera captures an image **1004**, how many images are captured by the camera **1004**, etc. The ultimate image captured in this arrangement of FIG. **10** is a girdle side image **1030**.

(69) FIG. **11** shows an example schematic of a transmission mode gemstone imaging system configured to verify a gemstone **1110** at table-up view toward the camera and culet toward the light source. As in FIGS. **9** and **10**, the components may be arranged in any orientation so long as their relative order is maintained as shown in FIG. **11**. The left to right orientation of the light **1120** then filter **1124** then sample **1110** then imaging sensor camera **1104** is not intended to be limiting and could be oriented up and down, right to left, or any other orientation.

(70) In the example, the light source **1120** includes an optical filter **1124** as described herein. The gemstone being imaged **1110** has the culet side toward the light **1120** and table side toward the imaging sensor **1104** or digital camera. In such a way, the computer system **1140** (also described in FIGS. **19** and **20**) may be in communication with the light **1120**, optical filter **1124** display to change displays, and digital camera **1104** and can control all aspects of the imaging process, including but not limited to light on/off, light intensity **1120**, light color **1120** light wavelengths **1120**, which optical filter is used **1124**, when the camera captures an image **1104**, how many

images are captured by the camera **1104**, etc. The ultimate image captured in this arrangement of FIG. **11** is a table up image **1130**.

Example Hardware Using Reflectance Arrangements

(71) FIG. **12** shows an example schematic of a reflection mode gemstone imaging system configured to verify a gemstone **1210** at table-up view with the culet toward the camera **1204**. Such reflectance examples allow for the light source **1220** and camera **1204** to be placed in different orientations than those described in FIGS. **9**, **10** and/or **11**, so that the light **1220** may pass through and reflect from a dichroic beam splitter **1250** while the imaging camera **1204** may capture images through the dichroic beam splitter **1250**. In such an way, the components such as light source **1220** and camera **1204** may be in different orientations, where those of the FIGS. **9**, **10** and/or **11** are impractical or not desired. One such advantage may be illumination from the same direction as the images are captured, instead of a rear illumination arrangement.

(72) Other advantages to a reflectance arrangement may include that the optical alignment is simple for a user to align the gemstone and/or such an arrangement is also well suited for other imaging modalities such as bright-field and florescent microscopy.

(73) In the example, the light source **1220** includes an optical filter **1224** as described herein. The gemstone being imaged **1210** has the culet side toward the beam splitter **1250** and thereby both the light **1220** and the imaging sensor **1204** or digital camera. In such a way, the computer system **1240** (also described in FIGS. **19** and **20**) may be in communication with the light **1220**, optical filter **1224** display to change displays, and digital camera **1204** and can control all aspects of the imaging process, including but not limited to light on/off, light intensity **1220**, light color **1220** light wavelengths **1220**, which optical filter is used **1224**, when the camera captures an image **1204**, how many images are captured by the camera **1204**, etc. The ultimate image captured in this arrangement of FIG. **12** is a table down image **1230** just like FIG. **9**.

(74) FIG. **13** shows an example schematic of a reflection mode gemstone imaging system configured to verify a gemstone at table-down view. As in Figures. above the components may be arranged in any orientation so long as their relative order is maintained as shown in FIG. **13**. The orientation of the light **1320** then filter **1324** then sample **1310**, imaging sensor camera **1304** is not intended to be limiting and could be oriented up and down, right to left, or any other orientation.

(75) FIG. **13** shows an example schematic of a reflection mode gemstone imaging system configured to verify a gemstone **1310** at table-up view with the table toward the camera **1304**. Such reflectance examples allow for the light source **1320** and camera **1304** to be placed in different orientations than those described in FIGS. **9**, **10** and/or **11**, so that the light **1320** may pass through and reflect from a dichroic beam splitter **1350** while the imaging camera **1304** may capture images through the dichroic beam splitter **1350**. In such an way, the light source **1320** and camera **1304** may be in different orientations, where those of the FIGS. **9**, **10** and/or **11** are impractical or not desired. One such advantage may be illumination from the same direction as the images are captured, instead of a rear illumination arrangement.

(76) Other advantages to a reflectance arrangement may include that the optical alignment is simple to align the gemstone and/or such an arrangement is also well suited for other imaging modalities such as bright-field and florescent microscopy.

(77) In the example, the light source **1320** includes an optical filter **1324** as described herein. The gemstone being imaged **1310** has the table side toward the beam splitter **1350** and thereby both the light **1320** and the imaging sensor **1304** or digital camera. In such a way, the computer system **1340** (also described in FIGS. **19** and **20**) may be in communication with the light **1320**, optical filter **1324** display to change displays, and digital camera **1304** and can control all aspects of the imaging process, including but not limited to light on/off, light intensity **1320**, light color **1320** light wavelengths **1320**, which optical filter is used **1324**, when the camera captures an image **1304**, how many images are captured by the camera **1304**, etc.

(78) The ultimate image captured in this arrangement of FIG. **13** is a table up image **1330** just like

FIG. **10**.

Example Method Steps of Inscribing and Capturing Images

(79) FIG. **14** shows example steps that may be taken to utilize the holders of example FIG. **8** and the setup systems of FIGS. **7**, **9**, **10**, **11**, **12**, and/or **13** alone or in any combination to inscribe a stone and capture a first image of the inscribed stone, for later comparison as described herein.

(80) FIG. **14** explains that to start **1402**, the stone is placed in the holder **1404** (See FIG. **8**) then the stone holder is inserted into the sample chamber **1406**. Next, the stone may be moved to a preset location where the stone girdle can be seen by the imaging system and mapped from the side view (for a girdle inscription) **1408**. Next, the auto focus function may be utilized **1410** to align the girdle top edge with a laser focal plane. Next, center of the girdle position from the top view camera window **1412**. Then, Select or scan the logo or report number on the stone **1414**. The logo or report number label may be placed at the target inscription position **1416** and the inscription may be started **1418**. Once inscribed, the image system may capture an image of the stone and inscription **1420** and stored for future comparison use. Then the sample stage may be returned to an original position for the next inscription **1422** which may revert back to another placement of another stone in the holder **1404** or end **1424**.

Verification Method Examples

(81) FIG. **15** shows method steps to capture images and compare images for matching using the systems and methods described herein.

(82) FIG. **15** shows an example flow chart to illustrate the workflow of gemstone verification methods in conjunction with gemstone imaging systems described here including computer and network systems described. First, in the example, **1502** both reference and test input images are acquired from a gemstone digital imaging system **1504** using the systems and methods described herein. The system may then analyze image quality automatically to filter out any poor quality images **1506**, which may potentially result in verification failure in the following steps. Such a step of filtering poor quality images may include automated image quality assessment software, which is based on both a classical image processing method and an AI model. Some examples may employ any combination of edge detection, noise detection, image comparison to stored examples, and/or image recognition. FIG. **16** shows an example flow chart walking through the example steps the computer systems described herein may take in order to determine whether an image is acceptable or requires another image for comparison. First **1602**, the image is input into the system **1604**. Such an image may be taken from the system described herein, or by any other digital image capture system or method. In some examples, the image is of a gemstone girdle and any associated indicia marked thereon. Next, the computer may extract the gemstone girdle profile from the image **1606**. Next, the computer may create and then analyze a pixel intensity histogram of the digital image within the defined gemstone girdle boundary already determined **1608**. Next, the system may send an image quality threshold **1610**. Such a threshold may be predetermined by the system, loaded manually, or learned over time using AI and/or Machine learning algorithms. Such a threshold may use any number of analysis of the pixels in the image to determine if it is poor or good including but not limited to sharpness of the image, color change between pixels that are next to one another, distance between pixel levels of neighboring pixels, rise distance of pixels next to one another in the image, resolution threshold analysis of pixels in the image, edge detection algorithms for any detected etched or engraved characters, noise detected on image or around detected characters, or any other kind of focus or image sharpness determination. Such corresponding thresholds may be established by a user or the system or artificial intelligence and may be moved, changed, or adjusted. In some examples, the thresholds may be moved depending on history of matches fed back into a model that statistically predicts matches and errors of matches. Next, if the systems and methods determine that the image quality threshold is met or exceeded **1612**, then the image is deemed good quality **1614**, but if not, the image is deemed poor quality **1616**. The systems and methods may then cause display of the determination good or poor

1618 and then store the image and correlated quality assessment result **1620** before ending **1622**.
(83) Systems and methods may also be used to determine image quality assessment using a classical image processing method, alone or in combination as described. In some examples, artificial intelligence systems and methods may be trained and used to determine poor quality images, together with any or none of the following other example tools such as but not limited to edge detection algorithms, noise detection, image comparison, and/or image recognition.
(84) Next, unique gemstone features from any good quality image pairs (reference and test images) in addition to corresponding meta-data for the images can be highlighted **1508** with newly developed gemstone verification method. Highlighting unique features of a gemstone may include but are not limited to color, inscription, facets, inclusion, etc. For example, the systems and methods her may be able to extract them with optical character recognition (OCR) for inscription, AI model for facets and/or color analysis, and/or AI model to relate with other identifiers such as internal inclusions, gemstone cut type, size, weight, etc. alone or in any combination of the above.
(85) In the gemstone verification method, the unique features of each gemstone image may be extracted using an image processing algorithm, which may, in some examples, utilize both image processing methods and artificial intelligence (AI) algorithms. Artificial Intelligence (AI) is a broad term which includes both statistical models (k-means clustering, classification, etc.), neural network-based approaches, and reinforcement learning, and Machine Learning (ML) is a subfield of AI which includes the training of models based on input data from outside sources. These features may then be compared to reference test images **1510**. Additionally, or alternatively, the meta-data corresponding to each image may include information other than gemstone image such as shape, size, color, cut type, girdle condition, wire frame of gemstone, properties, origin, owner, history, natural/synthetic/processed, identification number, alone or in any combination or any other information about the gemstone.
(86) In such examples, the similarity of the paired unique gemstone features can then be measured **1512** automatically by the gemstone verification algorithm.
(87) When the resulting similarity assessed by the above-mentioned methods is relatively high, as compared to a predetermined threshold, the test gemstone can be considered to meet the threshold and deemed or labeled as authentic **1514**. In an example contrary analysis, when the resulting similarity is relatively low (or poor) as compared to a predetermined threshold, the test gemstone can be considered to miss the threshold and deemed or labeled as fake or spurious or any other indicator **1516**. In such examples, those images that do not match the reference gemstone image are deemed to miss the authenticity threshold and thereby labeled as fake. Lastly, the outcome of gemstone verification including authenticity, request date and time, request site, requester's name, or any other data alone or in combination, may be collected and stored **1518** on a designated database for later use, thus ending the example process **1520**.
(88) FIG. **17**A shows an example of gemstone verification as described herein, showing two images of a detail of the girdle of the stones and the inscription, from an identical gemstone. Aspects in the reference image **1702** which is first taken and stored at an earlier time, for example, when the gemstone inscription was made, are compared to a second recent image **1704** of a stone from a remote location, in hopes of verifying the stone in the second instance **1704** to the reference stone images **1702**. The method steps of FIG. **15** may be applied as described. In this example of FIG. **17**A, the outcome from the gemstone verification algorithm is authentic because the similarity of girdle profile and facet junctions are highly similar between two images. For example, the facet junctions **1710** match in distance from the inscriptions **1712**. Further, the lower girdle **1714** and upper girdle **1716** appear in line with the inscriptions **1712** and facet junctions **1710**. By cross comparing all of these different points, the system may deduce or determine whether there is a match or not between the new images **1704** submitted from a remote source, and those stored on the system as the reference image **1702**.
(89) FIG. **17**B shows an example gemstone verification with two images from different gemstones

but the same inscription characters. In this example, aspects in the reference image **1722** stored in the system with the corresponding inscription are compared against a recently taken, new image **1724** possibly from a remote location, and submitted for comparison and verification.

(90) In the example of FIG. **17**B, the outcome from the gemstone verification method as described in FIG. **15** is that the submitted image is fake because the similarity of the submitted image **1724** and the reference image **1722** is not close enough. For example, the girdle profile of the lower girdle **1734** and upper girdle **1736** do not line up with the laser inscription **1732** characters in the same way they do in the reference image **1722**. Further, the facet junctions **1730** in the submitted image **1724** are poorly matched with those in the reference image **1722**. Thus, even though both gemstones **1722** and **1724** are a round brilliant cut, these images show that the details of the variables of facet junctions, laser inscription characters, and girdle profiles do not match.

Artificial Intelligence Examples

(91) Artificial intelligence, machine learning, and other similar methods may be employed to help the image comparison examples described herein, including in FIG. **15**. Briefly, AI is a very broad term, which includes both statistical method (k-means clustering, classification, etc.) neural network-based approaches, and reinforcement learning. Such AI or machine learning may use algorithms that analyze pixelated digital images and determine aspects of the images useful for comparing, while discounting aspects that are not useful for comparing. By so doing, AI algorithms may be able to more accurately match images. For example, images of the same gemstone taken under slightly different lighting conditions may exhibit certain aspects that appear different, but if the AI algorithms are trained to discount such lighting characteristics and instead focus on unchangeable aspects such as shapes, inclusions, facets, colors, and other characteristics, better matches may be made. AI algorithms may be trained using images of the same gemstone and images of different gemstones and identified as such during training.

(92) For example, a common AI system used to extract the unique gemstone features may be but is not limited to, UNET. In such examples, UNET may be trained to extract a targeted feature out of various other features on a given image of a gemstone. Additionally or alternatively, the total training dataset required to make the extraction of targeted features may be reduced significantly by a transfer learning approach.

(93) For example, the similarity of the unique features can be measured by comparing both features geometrically and/or statistically. In some examples, an AI based algorithm can be considered for the similarity assessment because it tends to be robust in performance. In one non-limiting example, Siamese neural network and One-shot learning may be used for face recognition in digital images. One example advantage of these AI models is that it is not necessary to re-train the AI model for any new dataset and its performance can be acceptable. Another non-limiting alternative method in measuring similarity may be using computational data analysis techniques such as k-mean clustering, classification, correlation, and/or regression analysis.

User Interface Examples

(94) FIGS. **18**A, **18**B and **18**C show examples of using the system and methods described here, by an end user with a mobile device. FIG. **18**A shows a back-end database **1802** in communication with a computer system with a processor and memory **1804** that is able to access data in the database **1802** and compare using programmed algorithms as described herein. The service provider gemstone imaging system **1810** is also shown in communication with the computer **1804**. The imaging system for the service provider **1810** may be the same entity that marks the gemstones with an identifier and can verify the specific physical properties of the gemstone and match with the original identifier. This information may be first sent from the original imaging system **1810** to the computer **1804** and stored on the database **1802**. These original images may later be used to compare gemstones at a later time for verification and/or identification purposes.

(95) Also shown is a customer facing imaging system **1822** could be any number of customer facing systems as shown in FIGS. **6**A, **6**B and elsewhere able to illuminate any target gemstone as

described and capture digital images of the gemstone including in some examples, the corresponding identifier as described herein, for example FIG. **1**. It is these later captured images that are compared by the back-end computer **1804** against the previously stored images **1802** for comparison and/or identification. A mobile device smartphone **1820** or other computer with a software application running on it may be used to receive image data from the customer facing imaging system **1822** and send to the back-end computer **1804** for comparison with the images stored in the data storage **1802**. The mobile device **1820** may also receive matching conclusions and results to display to a consumer.

(96) FIG. **18**B shows an example mobile device **1820** with a screen showing the captured image **1824** from the customer facing image system **1822**. In some examples, the mobile device may also include software to capture the image **1826** and send the image capture instruction to the customer facing image capture system **1822**. In such examples, then the mobile device software **1820** may send the captured image to the back-end computer **1804** for comparison.

(97) FIG. **18**C shows examples of the mobile device image capture screen **1830**, and another screen example where the back-end computer system **1804** has indicated an image match **1832**. Not shown may be a screen display indicating when the back-end computer system **1804** detects no match of the captured image and previously stored image. In the example of the image match **1832**, the mobile device software may display any of the stored information that corresponds to the matched images **1836**. For example, a grading report may be displayed for the gemstone that matched the image with the previously stored back-end image data **1802**. Any kind of data could be stored and correlated to an image for matching and then displaying to the mobile device or other screen displays for customers.

Example Network

(98) FIG. **19** shows an example networked diagram of example hardware as described here, that may be used to practice the methods described herein. In such an example, it is possible to place a customer facing digital imaging system **1904** that is customized to the methods described herein to capture images of a sample gemstone for verification/authentication purposes. Such a digital imaging system **1904** may include lights, filters, cameras, and/or any other components to capture images of gemstone that are in need of authenticating from clients or sales staff.

(99) In some examples, the systems described herein may be packaged into a table or desk top arrangement **1904** and placed in a consumer facing off-site location such as a jewelry store or other off-site lab. As described herein, the computer systems such as those in FIGS. **9**, **10**, **11**, **12**, **13** and/or **20** may be in communication with a back-end system **1920** configured to analyze the images, cause storage of the images, compare images, post produce images, and/or any other computer related actions on the images.

(100) After capturing the required number of images using the image capture system **1904**, under the requested filtered lighting environments as described here, the image data may be sent by a network to a computer **1902** and computer storage, such as a server computer or back-end computer system **1920** (see FIG. **20**). In this example, one, two or more input images taken by imaging system **1904**, in some examples in conjunctions with gemstone meta-data, may be uploaded to the computer **1902** or back-end computers **1920** from the imaging system **1904**. The back-end data storage and servers **1920** may store reference images of gemstones taken previously and stored for comparison purposes as described herein. Other data such as but not limited to images and meta-data as a reference information may also be stored locally **1902** and/or on the back end **1920**. In some examples, a gemstone certificate may be generated that includes information on the gemstone and any or all identifying information for it, stored and correlated to the images captured, sent to various customers or vendors, and thereby memorialize any information stored on such certificate.

(101) A display or local computing system **1906** may be in communication with the imaging system **1904** and/or the computing system **1902**. Such an arrangement **1906** may be used to operate

the imaging system **1904**, review and input identifying information about a gemstone under evaluation, send and receive data of the image data from the cameras **1904**, along with any meta data, time/date stamps, geo location information, names, serial numbers, grade report numbers, or any other information which may be used to identify the gemstone under analysis.

(102) In some examples, the computers may be in communication with a network such as the Internet **1910** and thereby to other back-end resources such as computers **1920** and storage through land lines **1944**, cellular **1940** and/or WiFi **1942** type example communication methods.

(103) Upon capture of a gemstone under new analysis by the computing systems **1940**, **1902**, the data may be sent to the back-end servers **1920** for a match, or shared on the local systems **1902** to conduct the matching steps as described herein. In some examples, applications on the local computer **1902** and/or mobile device **1906** may be used to complete the matching, and/or receive information regarding the matching determinations from the back-end servers **1920**.

(104) When all the comparisons are complete, the systems may then verify the authenticity of the gemstone information with the information previously stored by the help of the novel gemstone verification algorithm(s). If the outcome of gemstone verification is authentic, the computer systems can authorize re-issuing the proper gemstone certificate previously stored on the system **1920**, **1902**. In some examples, the systems may store information regarding previous transactions of the gemstone and report such information in a chain-of-title history report. In some examples, a blockchain may be used to store chain-of-title information for a gemstone using the identification information as described herein.

Example Computer Devices

(105) FIG. **20** shows an example computing device **2000** which may be used in the systems and methods described herein. In the example computer **2000** a CPU or processor **2010** is in communication by a bus or other communication **2012** with a user interface **2014**. The user interface includes an example input device such as a keyboard, mouse, touchscreen, button, joystick, or other user input device(s). The user interface **2014** also includes a display device **2018** such as a screen that may display a user interface such as the example of FIG. **13** and an input device **2016** such as touch screen, mouse, keyboard, joystick, or other manual input devices. The computing device **2000** shown in FIG. **20** also includes a network interface **2020** which is in communication with the CPU **2020** and other components. The network interface **2020** may allow the computing device **2000** to communicate with other computers, databases, networks, user devices, or any other computing capable devices. In some examples, alternatively or additionally, the method of communication may be through WiFi, cellular, Bluetooth Low Energy, wired communication, or any other kind of communication. In some examples, alternatively or additionally, the example computing device **2000** includes peripherals **2024** also in communication with the processor **2010**. In some examples, alternatively or additionally, digital camera **2026**. In some examples peripherals **2024** may include lights **2028** and/or filtered lights as disclosed. In some example computing device **2000**, a memory **2022** is in communication with the processor **2010**. In some examples, alternatively or additionally, this memory **2022** may include instructions to execute software such as an operating system **2032**, network communications module **2034**, other instructions **2036**, applications **2038**, applications to digitize images **2040**, applications to process image pixels **2042**, autofocus **2043**, data storage **2058**, data such as data tables **2060**, transaction logs **2062**, sample data **2064**, inscription data **2070** or any other kind of data.

CONCLUSION

(106) As disclosed herein, features consistent with the present embodiments may be implemented via computer-hardware, software and/or firmware. For example, the systems and methods disclosed herein may be embodied in various forms including, for example, a data processor, such as a computer that also includes a database, digital electronic circuitry, firmware, software, computer networks, servers, or in combinations of them. Further, while some of the disclosed implementations describe specific hardware components, systems and methods consistent with the

innovations herein may be implemented with any combination of hardware, software and/or firmware. Moreover, the above-noted features and other aspects and principles of the innovations herein may be implemented in various environments. Such environments and related applications may be specially constructed for performing the various routines, processes and/or operations according to the embodiments or they may include a general-purpose computer or computing platform selectively activated or reconfigured by code to provide the necessary functionality. The processes disclosed herein are not inherently related to any particular computer, network, architecture, environment, or other apparatus, and may be implemented by a suitable combination of hardware, software, and/or firmware. For example, various general-purpose machines may be used with programs written in accordance with teachings of the embodiments, or it may be more convenient to construct a specialized apparatus or system to perform the required methods and techniques.

(107) Aspects of the method and system described herein, such as the logic, may be implemented as functionality programmed into any of a variety of circuitry, including programmable logic devices (PLDs), such as field programmable gate arrays (FPGAs), programmable array logic (PAL) devices, electrically programmable logic and memory devices and standard cell-based devices, as well as application specific integrated circuits. Some other possibilities for implementing aspects include: memory devices, microcontrollers with memory (such as 8PROM), embedded microprocessors, firmware, software, etc. Furthermore, aspects may be embodied in microprocessors having software-based circuit emulation, discrete logic (sequential and combinatorial), custom devices, fuzzy (neural) logic, quantum devices, and hybrids of any of the above device types. The underlying device technologies may be provided in a variety of component types, e.g., metal-oxide semiconductor field-effect transistor (MOSFET) technologies like complementary metal-oxide semiconductor (CMOS), bipolar technologies like emitter-coupled logic (ECL), polymer technologies (e.g., silicon-conjugated polymer and metal-conjugated polymer-metal structures), mixed analog and digital, and so on.

(108) It should also be noted that the various logic and/or functions disclosed herein may be enabled using any number of combinations of hardware, firmware, and/or as data and/or instructions embodied in various machine-readable or computer-readable media, in terms of their behavioral, register transfer, logic component, and/or other characteristics. Computer-readable media in which such formatted data and/or instructions may be embodied include, but are not limited to, non-volatile storage media in various forms (e.g., optical, magnetic or semiconductor storage media) and carrier waves that may be used to transfer such formatted data and/or instructions through wireless, optical, or wired signaling media or any combination thereof. Examples of transfers of such formatted data and/or instructions by carrier waves include, but are not limited to, transfers (uploads, downloads, e-mail, etc.) over the Internet and/or other computer networks via one or more data transfer protocols (e.g., HTTP, FTP, SMTP, and so on).

(109) Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise,” “comprising,” and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in a sense of “including, but not limited to.” Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words “herein,” “hereunder,” “above,” “below,” and words of similar import refer to this application as a whole and not to any particular portions of this application. When the word “or” is used in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

(110) Although certain presently preferred implementations of the descriptions have been specifically described herein, it will be apparent to those skilled in the art to which the descriptions pertains that variations and modifications of the various implementations shown and described herein may be made without departing from the spirit and scope of the embodiments. Accordingly,

it is intended that the embodiments be limited only to the extent required by the applicable rules of law.

(111) The present embodiments can be embodied in the form of methods and apparatus for practicing those methods. The present embodiments can also be embodied in the form of program code embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, or any other machine-readable storage medium, wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the embodiments. The present embodiments can also be in the form of program code, for example, whether stored in a storage medium, loaded into and/or executed by a machine, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the embodiments. When implemented on a general-purpose processor, the program code segments combine with the processor to provide a unique device that operates analogously to specific logic circuits.

(112) The software is stored in a machine readable medium that may take many forms, including but not limited to, a tangible storage medium, a carrier wave medium or physical transmission medium. Non-volatile storage media include, for example, optical or magnetic disks, such as any of the storage devices in any computer(s) or the like. Volatile storage media include dynamic memory, such as main memory of such a computer platform. Tangible transmission media include coaxial cables; copper wire and fiber optics, including the wires that comprise a bus within a computer system. Carrier-wave transmission media can take the form of electric or electromagnetic signals, or acoustic or light waves such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media therefore include for example: disks (e.g., hard, floppy, flexible) or any other magnetic medium, a CD-ROM, DVD or DVD-ROM, any other optical medium, any other physical storage medium, a RAM, a PROM and EPROM, a FLASH-EPROM, any other memory chip, a carrier wave transporting data or instructions, cables or links transporting such a carrier wave, or any other medium from which a computer can read programming code and/or data. Many of these forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to a processor for execution.

(113) The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the embodiments to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the embodiments and its practical applications, to thereby enable others skilled in the art to best utilize the various embodiments with various modifications as are suited to the particular use contemplated.

Claims

1. A method comprising: by a computer with a processor and memory, the computer in communication with a networked comparison server computer, a digital camera and a structured, filtered light source, causing the light source illuminate gemstone in a holder, wherein the gemstone includes an inscription, and wherein the light source includes a structured filter; by the computer, receiving a digital image of the gemstone and at least one identifier for the gemstone; by the computer, retrieving at least one previously stored digital image and its identifier using the received identifier, wherein the previously stored image and its identifiers includes an inscription on a gemstone and its unique features; by the computer, comparing the received digital image of the gemstone and/or identifiers with the at least one previously stored digital image retrieved using the identifier(s), wherein the comparing the received digital image of the gemstone and/or

identifier(s) with the at least one previously stored digital image retrieved using the identifier(s); if the comparison matches, indicating to a user interface, a match; and if the comparison does not match, indicating to the user interface, no match.

2. The method of claim 1 wherein the light source filter is a horizontal filter.

3. The method of claim 1 wherein the light source filter is a vertical filter.

4. The method of claim 1 wherein the light source filter is a grid filter.

5. The method of claim 1 wherein the light source filter is a circular filter.

6. The method of claim 1 wherein the light source filter is a square filter.

7. The method of claim 1 wherein the light source filter is in a particular shape correlated to a geometry of the gemstone.

8. The method of claim 1 wherein the structured, filtered light source includes lines with spacing and size and linewidth that is proportional to at least one of, a distance between the structured, filtered light source to the gemstone, a diameter of the gemstone, a spatial distance between facet junctions of the gemstone, and a height of the gemstone.

9. The method of claim 1 wherein the structured, filtered light source is an optical display/projector/monitor/LEDs.

10. The method of claim 1 wherein the digital camera and the light source are desk top units which are remote from the computer used for comparing with previously stored images.

11. The method of claim 1 wherein the digital camera and the structured, filtered light source are in a same mobile unit which are remote from the computer used for comparing with previously stored images.

12. The method of claim 1 wherein the digital camera and light source are directed along a same axis to the gemstone by a dichroic beam splitter.

13. The method of claim 1 wherein the digital camera and light source are directed at opposite sides of the gemstone to provide a back light image.

14. The method of claim 1 wherein the comparing the received digital image of the gemstone and/or identifier(s) with the at least one previously stored digital image retrieved using the identifier(s), includes comparing gemstone girdle profile in the images.

15. The method of claim 1 wherein the comparing the previously stored digital image of the gemstone and/or identifier(s) can be replaced with a newly acquired digital image of the same gemstone and/or identifier(s).

16. The method of claim 1 wherein the matching server generates a digital certificate/record of gemstone after a successful matching and the resulting digital certificate/record can be provided to a user(s).

17. The method of claim 1 wherein a thickness of lines in the structured, filtered light can be vary from 1 nm to 100 mm and a spacing of lines in the structured, filtered light can be vary from 1 nm to 100 mm.

18. The method of claim 1 wherein lines in the structured, filtered light have a sinusoidal gradation.

19. The method of claim 1 wherein lines in the structured, filtered light are binary without gradation.