(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 July 2025 (10.07.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/147256 A1

(51) International Patent Classification:
G01M 11/02 (2006.01) *G01M 11/04* (2006.01)

(21) International Application Number:
PCT/US2024/010332

(22) International Filing Date:
04 January 2024 (04.01.2024)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV,

(54) Title: OPTICAL PROPERTY MEASUREMENT

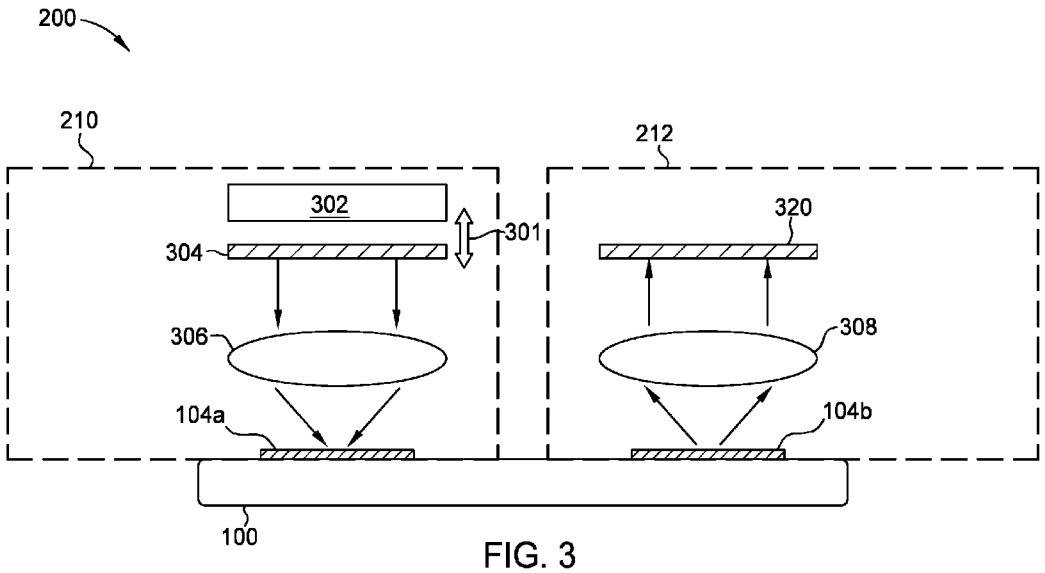


FIG. 3

(57) Abstract: Embodiments herein provide for a measurement system for determining optical properties of an optical device. The measurement system includes a light engine having a light source. The light source is configured to project a light including at least a first wavelength of light, a second wavelength of light, and a third wavelength of light. Reticles are configured to form a pattern from the light projected from the light source. The reticles are configured to be positioned at least in a first position to form a first pattern with the first wavelength of light, a second position to form a second pattern with the second wavelength of light, and a third position to form a third pattern with the third wavelength of light along an axis extending from the light source to a first lens. A detector configured to detect the light from the optical device.

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GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

OPTICAL PROPERTY MEASUREMENT

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to optical devices. More specifically, embodiments described herein provide for a method and apparatus for determining optical properties of an optical device.

Description of the Related Art

[0002] Virtual reality is generally considered to be a computer generated simulated environment in which a user has an apparent physical presence. A virtual reality experience can be generated in 3D and viewed with a head-mounted display (HMD), such as glasses or other wearable display devices that have near-eye display panels as lenses to display a virtual reality environment that replaces an actual environment.

[0003] Augmented reality, however, enables an experience in which a user can still see through the display lenses of the glasses or other HMD device to view the surrounding environment, yet also see images of virtual objects that are generated for display and appear as part of the environment. Augmented reality can include any type of input, such as audio and haptic inputs, as well as virtual images, graphics, and video that enhances or augments the environment that the user experiences. As an emerging technology, there are many challenges and design constraints with augmented reality.

[0004] One such challenge is determining the optical resolution of the optical devices to ensure that image quality standards are met. Current measurement systems for optical devices generally have low sampling rates across a large field of view, low throughput, and fail to properly compensate for imperfections in image quality caused by cameras and image projectors within the measurement systems. Additionally, the measurement systems may be bulky and are susceptible to imperfections associated with the image projectors of the measurement system.

[0005] Accordingly, there is a need for more effective techniques for measuring the optical properties of an optical device.

SUMMARY

[0006] In one embodiment, a measurement system is provided. The measurement system includes a light engine and a detector. The light engine includes a light source configured to project a light. The light comprises at least a first wavelength of light, a second wavelength of light, and a third wavelength of light. One or more reticles are configured to form a pattern from the light projected from the light source. The one or more reticles are configured to be positioned at least in a first position along an axis extending from the light source to a first lens to form a first pattern with the first wavelength of light, a second position along the axis to form a second pattern with the second wavelength of light, and a third position along the axis to form a third pattern with the third wavelength of light. The first lens configured to collimate the light from the light source toward an optical device. The detector configured to detect the light from the optical device.

[0007] In another embodiment, a method is disclosed. The method includes setting one or more reticles of a light engine at a first position along an axis extending from a light source to a first lens. A first wavelength of light is emitted from the light engine toward the one or more reticles. One or more optical properties of an optical device are measured at a detector for the first wavelength of light. The one or more reticles of the light engine are set at a second position along the axis. A second wavelength of light is emitted from the light engine toward the one or more reticles. The one or more optical properties of the optical device are measured at the detector for the second wavelength of light. A function based on the one or more optical properties of the optical device for the first wavelength of light and the second wavelength of light.

[0008] In yet another embodiment, a controller of a measurement system storing instructions that, when executed by a processor, causes the measurement system to measure optical properties of an optical device disposed in the measurement system. The measuring of the optical properties of the optical device includes setting one or more reticles of a light engine at a first position along an axis extending from a light source to a first lens. A first wavelength of light is emitted from the light engine toward the one or more reticles. One or more optical properties of an optical device are measured at a detector for the first wavelength of light. The one or more reticles of the light engine are set at a second position along the axis. A second wavelength of light is emitted from the light engine toward the one or more reticles. The one or more

optical properties of the optical device are measured at the detector for the second wavelength of light. A function based on the one or more optical properties of the optical device for the first wavelength of light and the second wavelength of light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

[0010] Figure 1A is a perspective, frontal view of a substrate, according to embodiments described herein.

[0011] Figure 1B is a perspective, frontal view of an optical device, according to embodiments described herein.

[0012] Figure 2 is a schematic, cross-sectional view of the measurement system, according to embodiments described herein.

[0013] Figure 3 is a schematic illustration of a measurement system for determining optical properties of an optical device, according to embodiments described herein.

[0014] Figure 4 is a flow diagram of a method for determining optical properties of an optical device, according to embodiments described herein.

[0015] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0016] Embodiments of the present disclosure generally relate to optical devices. More specifically, embodiments described herein provide for a method of determining optical properties of an optical device.

[0017] Figure 1A is a perspective, frontal view of a substrate 101 according to embodiments described herein. The substrate 101 includes a plurality of optical

devices 100 disposed on a surface 103 of the substrate 101. The optical devices 100 are waveguide combiners utilized for virtual, augmented, or mixed reality. In some embodiments, which can be combined with other embodiments described herein, the optical devices 100 are flat optical devices, such as metasurfaces.

[0018] The substrate 101 can be either opaque or transparent to a chosen laser wavelength depending on the use of the substrate 101. Additionally, the substrate 101 may be of varying shapes, thicknesses, and diameters. For example, the substrate 101 may have a diameter of about 150 mm to about 300 mm. The substrate 101 may have a circular, rectangular, or square shape. The substrate 101 may have a thickness of between about 300 μm to about 1 mm. Although only nine optical devices 100 are shown on the substrate 101, any number of optical devices 100 may be disposed on the surface 103.

[0019] Figure 1B is a perspective, frontal view of an optical device 100. It is to be understood that the optical devices 100 described herein are exemplary optical devices and the other optical devices may be used with or modified to accomplish aspects of the present disclosure. The optical device 100 includes a plurality of optical device structures 102 disposed on a surface 103 of a substrate 101. The optical device structures 102 may be nanostructures having sub-micron dimensions, e.g., nano-sized dimensions. Regions of the optical device structures 102 correspond to one or more gratings 104, such as a first grating 104a, a second grating 104b, and a third grating 104c. In some embodiments, which can be combined with other embodiments described herein, the optical device 100 includes at least the first grating 104a corresponding to an input coupling grating and the third grating 104c corresponding to an output coupling grating. In some embodiments, which can be combined with other embodiments described herein, the optical device 100 also includes the second grating 104b corresponding to an intermediate grating. The optical device structures 102 may be angled or binary. The optical device structures 102 may have other shapes including, but not limited to, circular, triangular, elliptical, regular polygonal, irregular polygonal, and/or irregular shaped cross-sections.

[0020] In operation, the first grating 104a receives incident beams of light (a virtual image) having an intensity from a light source. The incident beams are split by the optical device structures 102 into T1 beams that have all of the intensity of the incident beams in order to direct the virtual image to the intermediate grating (if utilized) or the third grating 104c. In some embodiments, which can be combined with other

embodiments described herein, the T1 beams undergo total-internal-reflection (TIR) through the optical device 100 until the T1 beams come in contact with the optical device structures 102 of the intermediate grating. The optical device structures 102 of the intermediate grating diffract the T1 beams to T-1 beams that undergo TIR through the optical device 100 to the optical device structures 102 of the third grating 104c. The optical device structures 102 of the third grating 104c outcouple the T-1 beams to the user's eye to modulate the field of view of the virtual image produced from the light source from the user's perspective and further increase the viewing angle from which the user can view the virtual image. In some embodiments, which can be combined with other embodiments described herein, the T1 beams undergo TIR through the optical device 100 until the T1 beams come in contact with the optical device structures 102 of the third grating 104c and are outcoupled to modulate the field of view of the virtual image produced from the light source.

[0021] To ensure that the optical devices 100 meet image quality standards, the optical properties of the optical devices 100 are measured. The optical properties measured may include modulated transfer function (MTF), contrast, brightness, and uniformity, among other optical properties. The MTF is a metric utilized to determine the ability of the optical devices 100 to transfer contrast at a particular resolution from an object to an image. In some embodiments, the optical device MTF provides image quality information related to image resolution and image contrast. Embodiments of the measurement system 200 described herein provide for, among other technical advantages, the ability to obtain the optical device MTF with increased throughput and greater quality control. Additionally, embodiments of the measurement system 200 described herein provide for the ability to obtain the optical properties such that the measured optical properties are not strongly influenced by imperfections of an image projector and/or a camera, such as distortion and astigmatism. Embodiments described herein allow for image quality separation between the optical device 100 and the measurement system 200, which may include imperfections attributable solely to a camera or projector. Further, embodiments described herein enable measurement of optical properties for large field of view (FOV) and RGB channels.

[0022] Figure 2 is a schematic, cross-sectional view of the measurement system 200 according to embodiments described herein. The measurement system 200 includes a body 201 with a first opening 203 and a second opening 205 to allow a stage 207 to move therethrough. The stage 207 is configured to move in an X-

direction, a Y-direction, and a Z-direction in the body 201 of the measurement system 200. The stage 207 includes a tray 209 configured to retain the optical devices 100 (as shown herein) or one or more substrates 101.

[0023] The measurement system 200 is configured to project images such that the optical properties of the optical device 100 can be determined. The stage 207 and the tray 209 may be transparent such that the optical properties obtained utilizing the measurement system 200 is not impacted by the translucence of the stage 207 or the tray 209. The measurement system 200 is in communication with a controller 220 configured to control operation of measurement system 200 and the method 400 described herein.

[0024] The measurement system 200 includes an upper portion 204 oriented toward a top side of the optical devices 100 and a lower portion 206 oriented toward a bottom side of the optical devices 100. The upper portion 204 of the measurement system 200 includes an alignment camera 208, a light engine 210, and a detector 212. The detector 212 detects outcoupled beams projected from the third grating 104c from the top side of the optical devices 100. The detector 212 of measurement system 200 includes a camera 320. The detector 212 of the measurement system 200 includes a lens 308 to focus the outcoupled beams toward the camera 320. By capturing the image of the outcoupled beams at the pupil plane of third grating 104c, the measurement system 200 can image the outcoupled beams before the outcoupled beams experience distortion and dispersion, as the outcoupled beams propagate toward a display.

[0025] A transmission detector 216 detects outcoupled beams projected from the third grating 104c through the bottom side of the optical devices 100. The transmission detector 216 may include a camera (e.g., a near field detector, a far field detector, a wavefront sensor, or combinations thereof). The transmission detector 216 may be configured to measure the optical properties of the optical device 100 using the beams outcoupled from the bottom side of the optical device 100.

[0026] The alignment camera 208 is configured to determine a position of the stage 207 and the optical devices 100. The light engine 210 is configured to illuminate the first grating 104a. In some embodiments, which can be combined with other embodiments described herein, the light engine 210 projects an image of a pattern to the first grating 104a.

[0027] The lower portion 206 of the first subsystem 202 includes a code reader 214 and the transmission detector 216. The code reader 214 is configured to read a code of the optical devices, such as a quick response (QR) code or barcode of an optical device 100. The code read by the code reader 214 may include instructions for obtaining the optical device MTF and other optical properties for various optical devices 100.

[0028] The controller 220 is coupled to the measurement system 200. The controller 220 includes a processor 252, a memory 254, and support circuits 256 that are coupled to one another. The controller 220 is electrically coupled to the measurement system 200 via a wire 258. The wire 258 may also represent, in some embodiments, a wireless connection. The processor 252 may be one of any form of general purpose microprocessor, or a general purpose central processing unit (CPU), each of which can be used in an industrial setting, such as a programmable logic controller (PLC), supervisory control and data acquisition (SCADA) systems, general purpose graphics processing unit (GPU), or other suitable industrial controller. The memory 254 is non-transitory and may be one or more of readily available memory such as random access memory (RAM), read only memory (ROM), or any other form of digital storage, local or remote. The memory 254 contains instructions, that when executed by the processor 252, facilitates execution of the method 400. The instructions in the memory 254 are in the form of a program product such as a program that implements the method of the present disclosure. The program code of the program product may conform to any one of a number of different programming languages. Illustrative computer-readable storage media include, but are not limited to: (i) non-writable storage media (e.g., read-only memory devices within a computer such as CD-ROM disks readable by a CD-ROM drive, flash memory, ROM chips, or any type of solid-state non-volatile semiconductor memory) on which information is permanently stored; and (ii) writable storage media (e.g., floppy disks within a diskette drive or hard-disk drive or any type of solid-state random-access semiconductor memory) on which alterable information is stored. Such computer-readable storage media, when carrying computer-readable instructions that direct the functions of the methods described herein, are examples of the present disclosure.

[0029] Figure 3 is a schematic illustration of measurement system 200. The measurement system 200 may be used for a method 400 of determining an optical device MTF and other optical properties of the optical device 100. The measurement

system 200 includes the light engine 210 and the detector 212. In some embodiments, the measurement system 200 further includes the transmission detector 216 for determining an optical device MTF and other optical properties of the optical device 100 from beams outcoupled from the bottom of the optical device 100. The light engine 210 includes a light source 302, a one or more reticles 304, and a first lens 306. The light engine 210 may further include at least one of a quarter-wave plate or linear polarizer. In some embodiments, which may be combined with other embodiments described herein, the light source 302 is configured to emit at least a first wavelength of light (e.g., red light having a wavelength of about 610 nm – 660 nm), a second wavelength of light (e.g., green light having a wavelength of about 510 nm – 560 nm), and a third wavelength of light (e.g., blue light having a wavelength of about 420 nm – 470 nm). In other embodiments, the light source 302 may emit a broadband light.

[0030] The one or more reticles 304 may include a display. The one or more reticles 304 is configured to move along an axis 301. The axis 301 extends from the light source 302 to the first lens 306. The one or more reticles 304 is further configured to have at least a first position, a second position, and a third position. The first position of the one or more reticles 304 corresponds with the emission of the first wavelength of light from the light source 302. The second position of the one or more reticles 304 corresponds with the emission of the second wavelength of light from the light source 302. The third position of the one or more reticles 304 corresponds with the emission of the third wavelength light from the light source 302. In some embodiments, the one or more reticles 304 may include a first reticle corresponding to the first wavelength of light, a second reticle corresponding to the second wavelength of light, and a third reticle corresponding to the third wavelength of light. The first reticle, second reticle, and third reticle correspond to the first wavelength, second wavelength, and third wavelength, respectively, such that the reticle accounts for how the light at different wavelengths refracts. The positions are configured to optimize the system MTF for the corresponding wavelength.

[0031] In other embodiments, the light source 302 may be capable of emitting a broadband light, including the first wavelength of light, the second wavelength of light, and the third wavelength of light. The one or more reticles 304 is configured to move along the directional axis 301 in order to form a pattern for a particular wavelength of light within the broadband light. For example, in some embodiments, the first position

of the one or more reticles 304 corresponds with the first wavelength of light within the broadband light, the second position of the one or more reticles 304 corresponds with the second wavelength of light within the broadband light, and the third position of the one or more reticles 304 corresponds with the third wavelength of light within the broadband light.

[0032] In one embodiment, as shown in measurement system 200 of Figure 3, the detector 212 includes the camera 320. The camera 320 is configured to detect outcoupled light projected from the third grating 104c though the top side of the optical devices 100 to form an image. A second lens 308 is configured to focus the outcoupled light toward the camera 320.

[0033] The first position, second position, and third position are configured to measure the MTF and other optical properties of the optical device 100 by individually measuring the MTF and optical properties of the optical device 100 when the first wavelength, the second wavelength, and the third wavelength are individually propagated through the optical device 100. By individually measuring the MTF and optical properties of the first wavelength, the second wavelength, and the third wavelength of light, the measurement system 200 is capable of compensating for optical aberrations for increased accuracy in calculating the MTF and other optical properties. Further, the measurement system 200 is capable of measuring the MTF and other optical properties for large field of view and broadband applications on the same measurement system.

[0034] Figure 4 is a flow diagram of a method 400 for measuring the optical properties of an optical device. The method 400 may be configured to be performed in other measurement systems not described herein. The method 400 described herein includes illuminating the first grating 104a of an optical device 100 with the light engine 210, where the incoupled light undergoes TIR until it is outcoupled (e.g., reflected or transmitted) from the third grating 104c as images captured by the detector 212. The images may correspond to a first wavelength, a second wavelength, and a third wavelength (e.g., red, green, and blue light, respectively) emitted from the light engine 210. The images are processed as described in the method 400 to extract the optical properties of the optical device 100.

[0035] At operation 401, a one or more reticles304 of the light engine is set in a first position. At operation 402, a first color of light is emitted from the light engine 210. In some embodiments, the light engine 210 emits a broadband light, and the

one or more reticles 304 at the first position is configured to form a pattern for a particular wavelength of light within the broadband light, e.g., the first position of the reticle 304 corresponds with the first wavelength of light within the broadband light. The first position corresponds with the first color of light, e.g., a first wavelength of light, such as a red light.

[0036] In some embodiments, which can be combined with other embodiments described herein, the light engine 210 is a high resolution image projector with a field of view (FOV) of about 10 degrees to about 120 degrees. The FOV of the light engine 210 is fixed or adjustable. The first pattern is determined by the one or more reticles 304. In some embodiments, the one or more reticles is a first reticle. The one or more reticles 304 may have one of a checkerboard pattern, line pair pattern, or a point matrix pattern. In some embodiments, which can be combined with other embodiments described herein, the one or more reticles 304 is a high-resolution patterned mask. The first pattern of the one or more reticles 304 may be formed via e-beam, ion-beam, or photolithography. In other embodiments, which can be combined with other embodiments described herein, the light engine 210 is one of a LCOS, CLP, micro-light emitting diode (microLED), laser beam scanner, or organic light emitting diode (OLED) microdisplay.

[0037] The first pattern is projected through the first lens 306 to a first grating 104a. The first lens 306 focuses the first pattern toward the first grating 104a. In some embodiments, the first lens 306 may also collimate the light emitted from the light engine 210. The first pattern undergoes TIR through the optical device 100 until the first pattern is outcoupled from a third grating 104c. In some embodiments, which can be combined with other embodiments described herein, the optical device 100 may include a surface relief grating based waveguide combiner, a volume hologram based waveguide combiner, a birdbath waveguide combiner, a partial reflective mirror array combiner, or a freeform optics combiner.

[0038] At operation 403, the optical properties of the optical device are measured with respect to the first color of light. An image of the first pattern is captured at a detector 212 to measure the optical properties. The image is of the first pattern formed by the first one or more reticles 304. The optical properties may include MTF, contract, brightness, and uniformity.

[0039] At operation 404, the one or more reticles of the light engine is set in a second position. At operation 405, a second color of light is emitted from the light

engine 210. The second position corresponds with the second color of light, e.g., a second wavelength of light, such as a green light. The second color of light is projected by the light engine 210 of the measurement system 200 toward the optical device 100. The second color of light propagates through the one or more reticles 304 at the second position to form a second pattern. In embodiments in which the light engine 210 emits a broadband light, the one or more reticles 304 at the second position is configured to form a pattern for the second wavelength of light within the broadband light.

[0040] In some embodiments, the one or more reticles 304 is a second reticle. The second pattern is determined by the second reticle. The second pattern of the second reticle may be the same as the first pattern from the first reticle, or may be different from the first pattern of the first reticle.

[0041] The second pattern is projected through the first lens 306 to a first grating 104a. The first lens 306 focuses the second pattern toward the first grating 104a. The second pattern undergoes TIR through the optical device 100 until the second pattern is outcoupled from a third grating 104c.

[0042] At operation 406, the optical properties of the optical device are measured with respect to the second color of light. An image of the second pattern is captured at a detector 212 to measure the optical properties. The image is of the second pattern formed by the second reticle.

[0043] At operation 407, a function is determined for the optical device based on the one or more optical properties for the first wavelength of light and the second wavelength of light. Optical properties such as brightness and efficiency are determined using a weighted sum of the first wavelength of light and the second wavelength of light. For optical properties related to color metrics, a conversion algorithm in color space is used to calculate the optical properties from the measurements. A calibrated spectrum of the light engine 210 and a measured response curve of the detector 212 are utilized in the algorithm to develop the image at the detector 212. The optical property measurements of the first color of light, the second color of light, and the third color of light are analyzed. A controller 220 may be configured to analyze the optical property measurements of the first color of light, the second color of light, and/or the third color of light. In some embodiments, which can be combined with other embodiments described herein, the measurements are analyzed to locate a plurality of points on the images. Each of the plurality of points

may correspond to a different FOV across the image. For example, each of the plurality of points may correspond to an edge of adjacent squares in a checkerboard pattern. The plurality of points are converted into a function depending on the pattern formed. For example, the function may be a point spread function, a line spread function, or an edge spread function.

[0044] The controller 220 may be configured to obtain the function of the optical properties. To properly obtain the MTF corresponding to the baseline image, the light intensity variation across the images of the first color of light, the second color of light, and the third color of light needs to be minimized. The light intensity variation across the images can be reduced by adjusting the exposure time of the image. The exposure time can be adjusted for each of the plurality of points of the function.

[0045] The optical properties of the optical device may be obtained by a controller 220. By correlating the images of the first color of light, the second color of light, and the third color of light using the plurality of points and the function, a MTF performance can be measured and a failure can be detected. Further, the pupil function degradation along the propagation in the third grating 104c can be detected. Thus, the cause of the MTF failure may also be detected. The optical device MTF and other optical properties obtained with the method 400 is less prone to be affected to imperfections of the light engine 210.

[0046] In summation, a method and apparatus for determining a MTF and other optical properties of an optical device is described herein. The apparatus includes a measurement system including a stage configured to retain an optical device or an optical device substrate having at least one optical device disposed thereon. A light engine is disposed above the stage. The light engine includes a light source configured to project a light to the optical device at a range of wavelengths. One or more reticles is configured to form a pattern from the light projected from the light source. A detector is configured to detect the light from the optical device or optical device substrate at the pupil plane of the optical device. The images of the light detected detector are compared to determine the MTF and other optical properties of the optical device. By individually measuring the MTF and optical properties of the optical device by color of light, the measurement system is capable of compensating for optical aberrations for increased accuracy in calculating the MTF and other optical properties. Further, the measurement system is capable of measuring the MTF and other optical properties for large field of view and broadband applications on the same

measurement system. The cause of a MTF failure can further be detected by the measurement system.

[0047] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A measurement system, comprising:
a light engine, comprising:
a light source, the light source configured to project a light, the light comprising at least:
a first wavelength of light;
a second wavelength of light; and
a third wavelength of light;
one or more reticles configured to form a pattern from the light projected from the light source, wherein the one or more reticles are configured to be positioned at least in:
a first position along an axis extending from the light source to a first lens to form a first pattern with the first wavelength of light;
a second position along the axis to form a second pattern with the second wavelength of light; and
a third position along the axis to form a third pattern with the third wavelength of light; and
the first lens configured to collimate the light from the light source toward an optical device; and
a detector configured to detect the light from the optical device.

2. The measurement system of claim 1, wherein the detector includes a camera and a second lens, wherein the second lens if configured to focus the light towards the camera.

3. The measurement system of claim 1, wherein the first position corresponds to the first wavelength of light, the second position corresponds to the second wavelength of light, and the third position corresponds to the third wavelength of light.

4. The measurement system of claim 1, further comprising a controller, wherein the controller is configured to analyze the light detected at the detector.

5. The measurement system of claim 1, wherein the one or more reticles comprises:

a first reticle corresponding to the first wavelength of light;

a second reticle corresponding to the second wavelength of light; and

a third reticle corresponding to the third wavelength of light.

6. The measurement system of claim 1, wherein:

the light source comprises a broadband light source;

the one or more reticles at the first position is configured to form a first pattern with the first wavelength of light within the broadband light;

the one or more reticles at the second position is configured to form a second pattern with the second wavelength of light within the broadband light; and

the one or more reticles at the third position is configured to form a third pattern with the third wavelength of light within the broadband light.

7. A method, comprising:

setting one or more reticles of a light engine at a first position along an axis extending from a light source to a first lens;

emitting a first wavelength of light from the light engine toward the one or more reticles;

measuring one or more optical properties of an optical device at a detector for the first wavelength of light;

setting the one or more reticles of the light engine at a second position along the axis;

emitting a second wavelength of light from the light engine toward the one or more reticles;

measuring the one or more optical properties of the optical device at the detector for the second wavelength of light; and

determining a function based on the one or more optical properties of the optical device for the first wavelength of light and the second wavelength of light.

8. The method of claim 7, wherein:

the first wavelength of light propagates through the one or more reticles at the first position to form a first pattern; and

the second wavelength of light propagates through the one or more reticles at the second position to form a second pattern.

9. The method of claim 8, the one or more reticles further comprising:

a first reticle corresponding to the first wavelength of light at the first position; and

a second reticle corresponding to the second wavelength of light at the second position, wherein the second reticle is different from the first reticle.

10. The method of claim 8, further comprising:

focusing the first pattern toward the optical device using a first lens prior to measuring the one or more optical properties of the optical device using the first wavelength of light; and

focusing the second pattern toward the optical device using the first lens prior to measuring the one or more optical properties of the optical device using the second wavelength of light.

11. The method of claim 8, further comprising:

focusing the first pattern toward a camera of the detector using a second lens of the detector prior to measuring the one or more optical properties of the optical device using the first wavelength of light; and

focusing the second pattern toward the camera using the second lens prior to measuring the one or more optical properties of the optical device using the second wavelength of light.

12. The method of claim 7, wherein:

the light source is a broadband light source;

the one or more reticles at the first position is configured to form a first pattern for the first wavelength of light within the broadband light; and

the one or more reticles at the second position is configured to form a second pattern for the second wavelength of light within the broadband light.

13. A controller of a measurement system storing instructions that, when executed by a processor, causes the measurement system to measure optical properties of an

optical device disposed in the measurement system, wherein measuring the optical properties of the optical device comprises:

setting one or more reticles of a light engine at a first position along an axis extending from a light source to a first lens;

emitting a first wavelength of light from the light engine toward the one or more reticles;

measuring one or more optical properties of an optical device at a detector for the first wavelength of light;

setting the one or more reticles of a light engine at a second position along the axis;

emitting a second wavelength of light from the light engine toward the one or more reticles; and

measuring one or more optical properties of an optical device at the detector for the second wavelength of light,

wherein a function is determined based on the one or more optical properties of the optical device for the first wavelength of light and the second wavelength of light.

14. The controller of claim 13, wherein:

the first wavelength of light propagates through the one or more reticles at the first position to form a first pattern; and

the second wavelength of light propagates through the reticle at the second position to form a second pattern.

15. The controller of claim 14, the reticle further comprising:

a first reticle corresponding to the first wavelength of light at the first position; and

a second reticle corresponding to the second wavelength of light at the second position, wherein the second reticle is different from the first reticle.

16. The controller of claim 14, further comprising:

focusing the first pattern toward the optical device using a first lens prior to measuring the one or more optical properties of the optical device using the first wavelength of light; and

focusing the second pattern toward the optical device using the first lens prior to measuring the one or more optical properties of the optical device using the second wavelength of light.

17. The controller of claim 14, further comprising:

focusing the first pattern toward a camera of the detector using a second lens of the detector prior to measuring the one or more optical properties of the optical device using the first wavelength of light; and

focusing the second pattern toward the camera using the second lens prior to measuring the one or more optical properties of the optical device using the second wavelength of light.

18. The controller of claim 13, wherein analyzing the optical properties of the optical device is performed by the controller.

19. The controller of claim 13, wherein the light source is a broadband light source.

20. The controller of claim 19, wherein:

the one or more reticles at the first position is configured to form a first pattern for the first wavelength of light within the broadband light; and

the one or more reticles at the second position is configured to form a second pattern for the second wavelength of light within the broadband light.

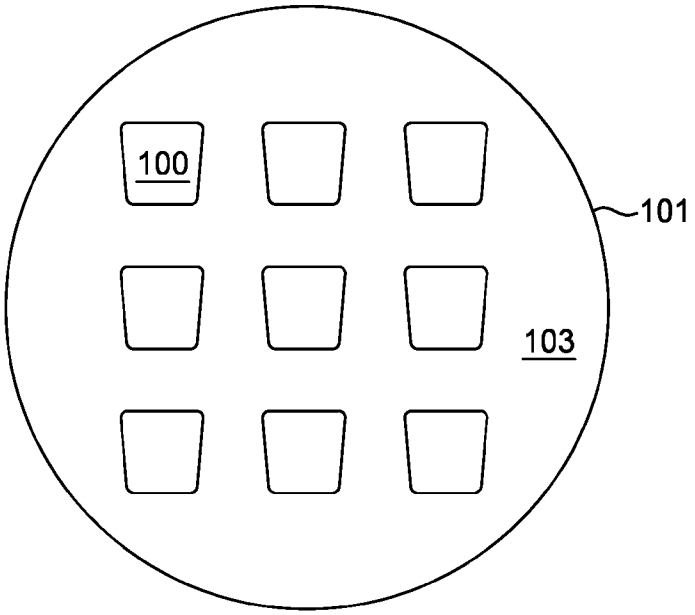


FIG. 1A

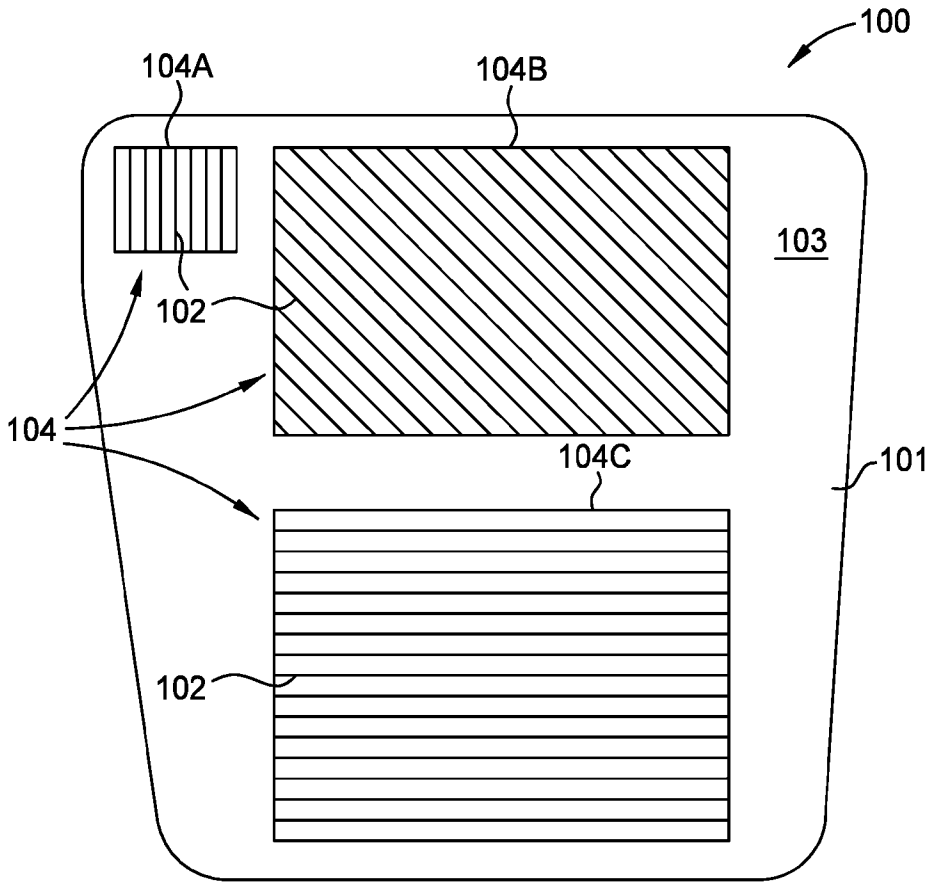


FIG. 1B

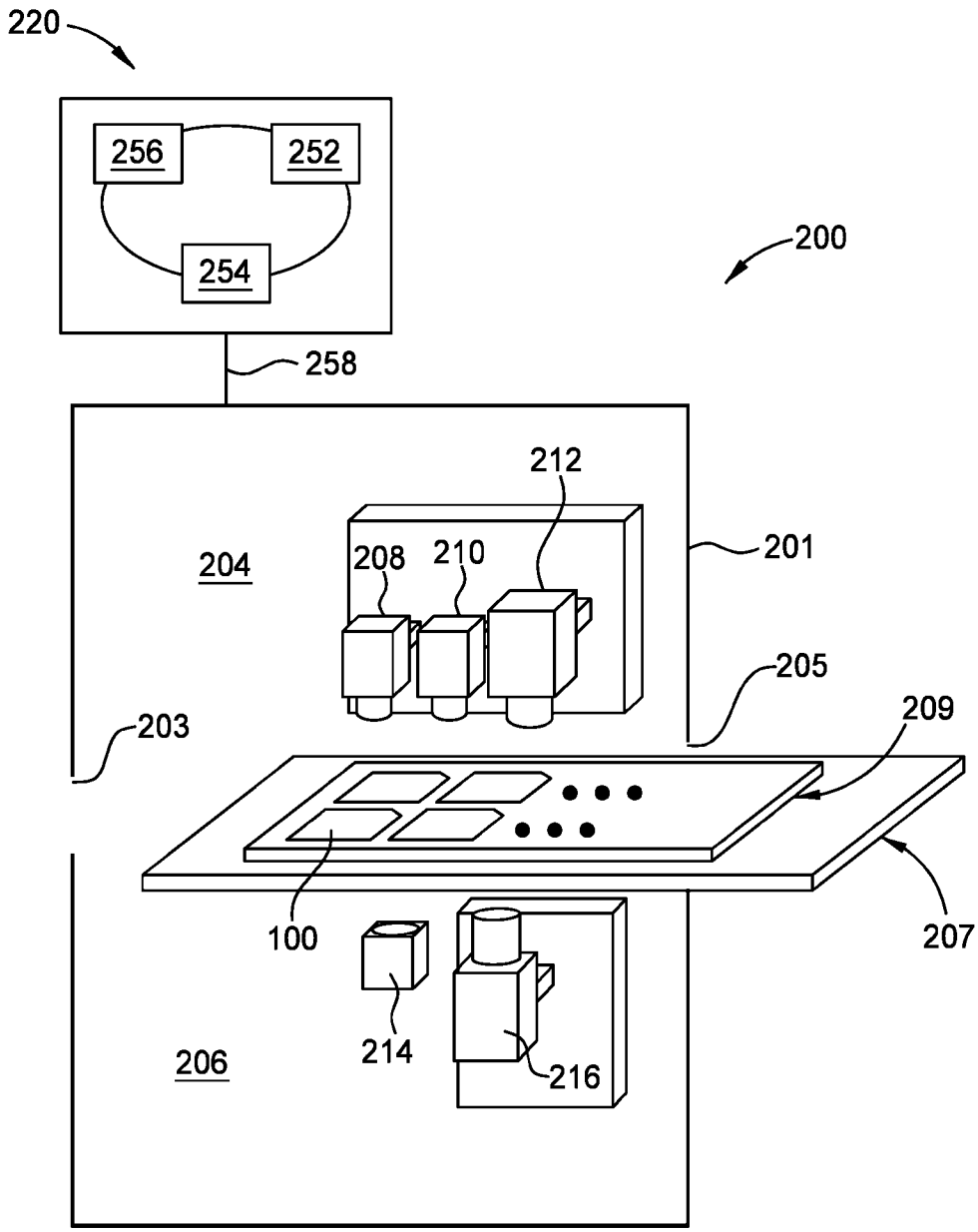

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FIG. 2

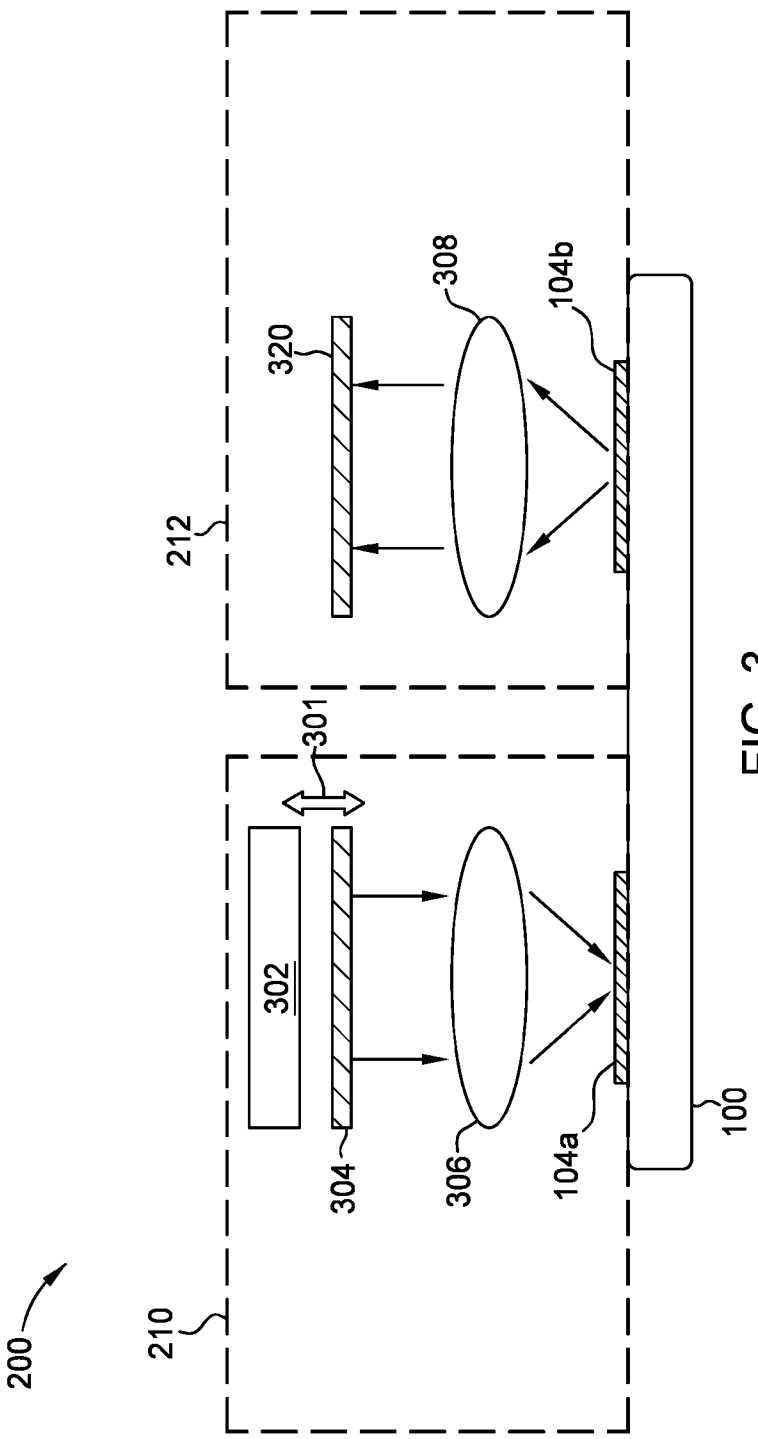


FIG. 3

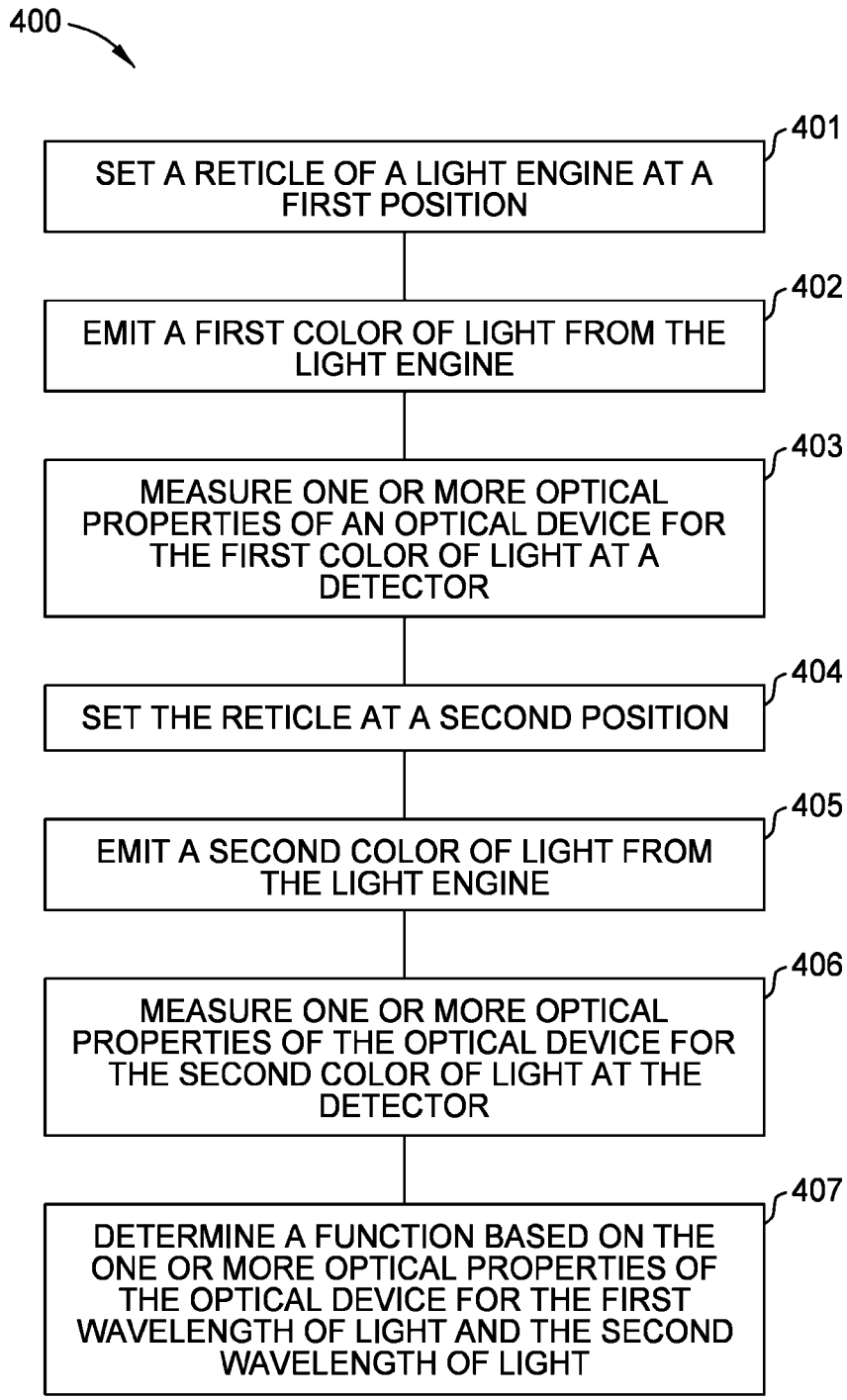

400
401
SET A RETICLE OF A LIGHT ENGINE AT A FIRST POSITION
402
EMIT A FIRST COLOR OF LIGHT FROM THE LIGHT ENGINE
403
MEASURE ONE OR MORE OPTICAL PROPERTIES OF AN OPTICAL DEVICE FOR THE FIRST COLOR OF LIGHT AT A DETECTOR
404
SET THE RETICLE AT A SECOND POSITION
405
EMIT A SECOND COLOR OF LIGHT FROM THE LIGHT ENGINE
406
MEASURE ONE OR MORE OPTICAL PROPERTIES OF THE OPTICAL DEVICE FOR THE SECOND COLOR OF LIGHT AT THE DETECTOR
407
DETERMINE A FUNCTION BASED ON THE ONE OR MORE OPTICAL PROPERTIES OF THE OPTICAL DEVICE FOR THE FIRST WAVELENGTH OF LIGHT AND THE SECOND WAVELENGTH OF LIGHT

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/010332

A. CLASSIFICATION OF SUBJECT MATTER

G01M 11/02(2006.01)i; **G01M 11/04**(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)

G01M 11/02(2006.01); G02B 27/30(2006.01); G02B 27/34(2006.01); G03F 7/20(2006.01); G06T 1/00(2006.01); G06T 7/521(2017.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: reticle, wavelength, pattern, function, and measurement

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2022-0163423 A1 (APPLIED MATERIALS, INC.) 26 May 2022 (2022-05-26) paragraphs [0023]-[0050] and figures 2-5	1-20
Y	US 2022-0137425 A1 (KONRAD GMBH) 05 May 2022 (2022-05-05) paragraphs [0024], [0046]-[0049] and figure	1-20
A	US 2022-0164972 A1 (APPLIED MATERIALS, INC.) 26 May 2022 (2022-05-26) paragraphs [0017]-[0038] and figures 1A-4	1-20
A	CN 114839843 A (SHANGHAI CHUANXIN SEMICONDUCTOR CO., LTD.) 02 August 2022 (2022-08-02) paragraphs [0039]-[0074] and figures 1-6	1-20
A	US 5747221 A (KIM, CHONG-HOE et al.) 05 May 1998 (1998-05-05) column 3, line 8 - column 6, line 40 and figures 2-7	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2024	**27 September 2024**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**PARK, Tae Wook**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/010332

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