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COLORIMETER WITH GRAY SCALE CAMERA

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TECHNOLOGICAL FIELD

[0001] Exemplary embodiments of this disclosure relate generally to methods and systems for providing image quality testing using a colorimeter.

BACKGROUND

[0002] Many conventional display devices (e.g., TV, monitor, cellphone, extended reality (XR) devices, etc.) may provide a user with an image of varying colors and resolutions. It may be beneficial for such display devices to provide an image with an image quality that would provide a clear and concise image to the user. Image quality may refer to the level of accuracy with which the imaging system may capture, process, store, compress, transmit and display the signals that form an image. The weighted combination of all the visually significant attributes of an image, such as the attributes mentioned above as well as contrast, lighting, etc., may aid in making an image pleasant to a user. Determining the level of accuracy of an image may be determined via image quality testing (IQT). IQT may be a key testing process for conventional display devices (e.g., TV, monitor, cellphone, XR devices, etc.). Conventionally, image colorimeters may be used to perform IQT during the manufacturing (benchmarking) process. Image colorimeters used in testing may provide measurement of display visual performance that matches human perception of brightness (luminance), color, spatial relationships, etc.

[0003] Conventionally, to improve measurement accuracy a spectrometer may be integrated into the colorimeter system for testing for IQT. Conventionally, the addition of spectrometers may compensate for the spectral offset between the calibration source and the device under test (DUT) and increase accuracy in IQT. However, the system stability relies heavily on the coupling of the spectrometer and camera. With the coupling of the spectrometer and camera, error may be introduced due to the spectrometer/fiber (or switchable mirror) instability, restricting the testing processes that may be completed by the system. The addition of spectrometers may slow down the process of IQT resulting in prolonged exposure time for certain color filters used in conventional colorimeter systems, which may be harmful for the display being tested. Costs for IQT may also be greatly affected by the addition of spectrometers. Image colorimeters may already be expensive due to the high cost for color filters, adding a high-quality spectrometer and a system to couple the spectrometer with the colorimeter may greatly increase costs for accurate IQT. Lastly, the addition of a spectrometer may limit the use case of colorimeters and certain standard testing (ANSI contrast) may not be done.

[0004] In view of the foregoing drawbacks, it may be beneficial to provide a colorimeter system to facilitate image quality testing that may be cost efficient and accurate for manufacturing purposes.

BRIEF SUMMARY

[0005] Methods and systems for image quality testing (IQT) via a colorimeter system for display devices are disclosed. The use of the colorimeter disclosed may maintain system accuracy and reduce costs.

[0006] In an exemplary embodiment the colorimeter system may include a lens, a monochrome camera, and an external spectrometer coupled to the monochrome camera. The spectrometer having an optical channel, a slit, and a spectroscopic resolving element, with light being directed to the spectrometer system through the optical channel. The spectrometer may measure the spectrum, calculate chromaticity, and identify the spectral shape (e.g., peak wavelength, full width at half maximum (FWHM)) for monochrome camera correction selection. The monochrome camera may be configured to capture a raw grayscale image, where the raw grayscale image may be converted to a luminance map to apply correction decided by the spectrometer. In one alternative embodiment, the colorimeter system may further include a controller configured to correct the color image from the monochrome camera system using the signal captured from the spectrometer.

[0007] Additional features and advantages will be set forth in the detailed description Still other objects of the present disclosure will become readily apparent to those skilled in the art from that description, simply by way of illustration of the best modes suited to carry out the invention. It is to be understood that both the foregoing description and the following detailed description are merely exemplary and are intended to provide an overview or framework to understand the nature and character of the claims. The invention described herein, is capable of other different embodiments and its several details are capable of modifications in various obvious aspects all without departing from the scope of the invention. Accordingly, the drawing and descriptions will be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 illustrates a conventional colorimeter system used for image quality testing.

[0009] FIG. 2 illustrates exemplary hardware or software architecture in accordance with an exemplary embodiment.

[0010] FIG. 3 illustrates a colorimeter system associated with image quality testing in accordance with an exemplary embodiment.

[0011] FIG. 4 illustrates an exemplary method associated with a colorimeter system in accordance with an exemplary embodiment.

[0012] The figures depict various embodiments for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles described herein.

DETAILED DESCRIPTION

[0013] Some embodiments of the present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, various embodiments of the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Like reference numerals refer to like elements throughout.

[0014] As defined herein, an extended reality (XR) device may refer to any device that uses virtual reality, augmented reality, mixed reality, hybrid reality, Metaverse reality or some combination or derivative thereof.

[0015] As defined herein a “computer-readable storage medium,” which refers to a non-transitory, physical or tangible storage medium (e.g., volatile or non-volatile memory device), may be differentiated from a “computer-readable transmission medium,” which refers to an electromagnetic signal.

[0016] As referred to herein, a Metaverse may denote an immersive extended reality world in which XR devices may be utilized in a network (e.g., a Metaverse network) in which there may, but need not, be one or more social connections among users in the network. The Metaverse network may be associated with three-dimensional (3D) virtual worlds, online games (e.g., video games), one or more content items such as, for example, non-fungible tokens (NFTs) and in which the content items may, for example, be purchased with digital currencies (e.g., cryptocurrencies) and other suitable currencies.

[0017] It is to be understood that the methods and systems described herein are not limited to specific methods, specific components, or to particular implementations. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

[0018] Many conventional display devices (e.g., TV, monitor, cellphone, XR devices, etc.) may provide a user with an image of varying colors and resolutions. It may be beneficial for such display devices to provide an image with an image quality that would provide a clear and concise image to the user. Image quality testing (IQT) may be used to determine the level of accuracy of an image presented on a display device. Conventionally, image colorimeters may be used to perform IQT during the manufacturing (benchmarking) process, such systems may include a lens, a monochrome camera, and three to four color filters. The monochrome camera may be a charge coupled device (CCD), complementary metal oxide semiconductor (CMOS) camera, or any monochrome camera. The transmission of light through color filters used in conventional colorimeters may be used for image color matching functions.

[0019] Colorimeters may be imaging devices that behave like a camera. In some embodiments, image colorimeters may include a time-sequential configuration. In some embodiments the time-sequential configuration separates the measurement objective color in a time sequential manner by spinning a color wheel comprised of color filters. At any particular moment, the measurement objective photons with a selected color transmit through the filter and hit the embedded CCD or CMOS sensor inside the camera of the colorimeter system. Accordingly, the overall display color information and imaging is reconstructed after at least one cycle of the color wheel spinning, where one image is taken at a time. Conventionally, the images taken may need to be combined to form a final output or image. For example, some color wheels may have 3 to 4 filters therefore 3 to 4 images may be taken with each cycle or revolution of the color wheel. The 3 to 4 images associated with each filter will then need to be combined to form a final output or image for use in IQT.

[0020] In some embodiments the colorimeter system used for display testing may further include a controller that may adjust monochrome camera accuracy to match the spectrometer accuracy. Adjusting the camera accuracy may include building a characterization model using a color correction matrix. Conventionally, the color correction matrix transforms the camera color space to spectrometer color space. Accordingly, the color correction matrix is a transformation between RGB values (e.g., a first 3-dimensional vector) and XYZ values (e.g., a second 3-dimensional vector). Since the spectrometer and the monochrome camera are coupled or integrated, conventionally, in the colorimeter system, the color correction may be generated in real time. Thus, a continuous and fluid imaging pipeline may be established for display testing.

[0021] Imaging colorimeters may provide measurement of display visual performance that matches human perception of brightness (e.g., luminance), color, spatial relationships, etc. To improve the measurement accuracy of image colorimeter systems, conventionally, a spectrometer may be integrated in the colorimeter system. With the addition of spectrometers to colorimeter systems may come with many drawbacks, such as increased error, testing limitations, slow testing times, and increased costs for testing.

[0022] The drawbacks associated with the addition of spectrometers to colorimeter systems used in benchmarking IQT may have a negative impact on image quality and cost of devices containing a display. For example, Dynamic Uniformity Correction (DUC) in augmented reality devices. In DUC the colorimeter may need to collect images with luminance or chromaticity information at different angles, and due the high cost and low speed of conventional colorimeters the throughput is extremely low. Low throughput in such devices may have a significant impact on XR production efficiency, and costs related including devices and methods to increase throughput.

[0023] The present disclosure is generally directed to systems and methods for a colorimeter system for display devices that may have increased accuracy, decreased costs for use or manufacture, and/or faster processing time, in view of conventional colorimeter systems for display devices. Examples in the present disclosure may include head-mounted displays (e.g., or other extended reality devices) or any device with a display that may need to undergo image quality testing.

[0024] FIG. 1 illustrates a conventional colorimeter system 100 used for image quality testing. Colorimeter system 100 may be a sophisticated color instrument that performs a color measurement based on light passing through the system, which may simulate the way the human eye is sensitive to light. The colorimeter system 100 may include a spectrometer 104, large field of view (FOV) lens 106, a camera system 101, and a coupling system 112. The camera system 101 may include a color filter wheel 103 containing a number of color filters, and a CCD camera 102 (e.g., monochrome camera). The camera system 101 may be coupled to the spectrometer 104 via the coupling system 112. The coupling system 112 may include a beam splitter 113 (or mirror on a flipper) configured to direct or split light (e.g., light 110) passing through large FOV lens 106 to both the spectrometer 104 and the camera system 101. Also shown in FIG. 1 is a target 108. Target 108 provides an optical target so that the camera system 101 may form a 2-dimensional (2D) image on a CCD sensor in an image plane of a CCD camera 102. In some embodiments target 108 may be an emissive target of a reflective target. Target 308 may be a light emitting diode (LED) display, a liquid crystal display (LCD) or any other type of display used in a TV, computer, cellphone, laptop, tablet, XR devices, etc.

[0025] Light 110 from target 108 may be captured via large FOV lens 106 and directed to the camera system 101 and spectrometer 104, via the splitting or mirroring of light 110 via beam splitter 113 (or mirror on a flipper). A portion of the coupling system 112 associated with spectrometer 114 may be referred to as an optical channel. In some embodiments, light (e.g., light 110) may be directed to the spectrometer via an optical channel, where the optical channel may comprise lenses and mirrors. In some embodiments, the optical channel may focus light (e.g., light 110) through a slit into the spectrometer 104. The spectrometer 104 may include a collimating mirror, a spectroscopic resolving element, a focusing mirror, and a detector array. In some embodiments, spectroscopic resolving element may be a diffraction grating or a prism. In conventional systems, the spectrometer 104 may be configured to capture light 101 and determine or identify many spectral characteristics of light 110 i.e., spectral shape, color information, etc. Light may be directed via large FOV lens 106 towards camera system 101, where the Large FOV lens 106 may be any mirror, lens, prism, or any combination thereof. Camera system 101 may be configured to spin color filter wheel 103 and capture an image for each filter of the color wheel 103. The camera system 101 may combine the images captured for each filter to form a resultant image and provide color values at which the colorimeter system 100 may test for image quality.

[0026] FIG. 2 illustrates exemplary hardware or software architecture in accordance with an exemplary embodiment. The processing system 200 of FIG. 2 may implement operations in accordance with an exemplary embodiment. The processing system is only one example of a suitable processing system with a device (e.g., camera, spectrometer, etc.) and is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the methodology described herein. The components of processing system 200 may include processor 202, memory 204, storage 206, input/output (I/O) interface 208, communication interface 212, and bus 210. Although the present disclosure describes and illustrates a particular processing system having a particular number of particular components in a particular arrangement, this disclosure contemplates any suitable processing system having any suitable number of any suitable components in any suitable arrangement.

[0027] In exemplary embodiments, processor 302 includes hardware for executing instructions, such as those making up a device capable of capturing images or assessing characteristics of light. As an example and not by way of limitation, to execute instructions, processor 202 may retrieve (or fetch) the instructions from an internal register, an internal cache, memory 204, or storage 206; decode and execute them; and then write one or more results to an internal register, an internal cache, memory 204, or storage 206. In particular embodiments, processor 202 may include one or more internal caches for data, instructions, or addresses. This disclosure contemplates processor 202 including any suitable number of any suitable internal caches, where appropriate. As an example and not by way of limitation, processor 202 may include one or more instruction caches, one or more data caches, and one or more translation lookaside buffers (TLBs). Instructions in the instruction caches may be copies of instructions in memory 204 or storage 206, and the instruction caches may speed up retrieval of those instructions by processor 202. Data in the data caches may be copies of data in memory 204 or storage 206 for instructions executing at processor 202 to operate on; the results of previous instructions executed at processor 202 for access by subsequent instructions executing at processor 202 or for writing to memory 204 or storage 206; or other suitable data. The data caches may speed up read or write operations by processor 202. This disclosure contemplates processor 202 including any suitable number of any suitable internal registers, where appropriate. Where appropriate, processor 202 may include one or more arithmetic logic units (ALUs); be a multi-core processor; or include one or more processors 202. Although this disclosure describes and illustrates a particular processor, this disclosure contemplates any suitable processor.

[0028] In exemplary embodiments, memory 204 includes main memory for storing instructions for processor 202 to execute or data for processor 202 to operate on. As an example and not by way of limitation, processing system 200 may load instructions from storage 206 or another source (such as, for example, another processing system 200) to memory 204. Processor 202 may then load the instructions from memory 204 to an internal register or internal cache. To execute the instructions, processor 202 may retrieve the instructions from the internal register or internal cache and decode them. During or after execution of the instructions, processor 202 may write one or more results (which may be intermediate or final results) to the internal register or internal cache. Processor 202 may then write one or more of those results to memory 204. In particular embodiments, processor 202 executes only instructions in one or more internal registers or internal caches or in memory 204 (as opposed to storage 206 or elsewhere) and operates only on data in one or more internal registers or internal caches or in memory 204 (as opposed to storage 206 or elsewhere). One or more memory buses (which may each include an address bus and a data bus) may couple processor 202 to memory 204. Bus 210 may include one or more memory buses, as described below. In exemplary embodiments, one or more memory management units (MMUs) reside between processor 202 and memory 204 and facilitate accesses to memory 204 requested by processor 202. In particular embodiments, memory 204 includes random access memory (RAM). This RAM may be volatile memory, where appropriate. Where appropriate, this RAM may be dynamic RAM (DRAM) or static RAM (SRAM). Moreover, where appropriate, this RAM may be single-ported or multi-ported RAM. This disclosure contemplates any suitable RAM. Memory 204 may include one or more memories 204, where appropriate. Although this disclosure describes and illustrates particular memory, this disclosure contemplates any suitable memory.

[0029] In exemplary embodiments, storage 206 includes mass storage for data or instructions. As an example, and not by way of limitation, storage 206 may include a hard disk drive (HDD), flash memory, random access memory (RAM), read only memory (ROM), non-volatile read only memory (NVROM) or a Universal Serial Bus (USB) drive or a combination of two or more of these. Storage 206 may include removable or non-removable (or fixed) media, where appropriate. Storage 206 may be internal or external to processing system 200, where appropriate. In exemplary embodiments, storage 206 is non-volatile, solid-state memory. In particular embodiments, storage 206 includes read-only memory (ROM). This disclosure contemplates mass storage 206 taking any suitable physical form. Storage 206 may include one or more storage control units facilitating communication between processor 202 and storage 206, where appropriate. Where appropriate, storage 206 may include one or more storages 206. Although this disclosure describes and illustrates particular storage, this disclosure contemplates any suitable storage.

[0030] In exemplary embodiments, I/O interface 208 includes hardware, software, or both, providing one or more interfaces for communication between processing system 200 and one or more I/O devices. Processing system 200 may include one or more of these I/O devices, where appropriate. One or more of these I/O devices may enable communication between a user and processing system 200. As an example and not by way of limitation, a I/O device may include a keyboard, keypad, microphone, monitor, mouse, printer, scanner, speaker, still camera, stylus, tablet, touch screen, video camera, another suitable I/O device or a combination of two or more of these. An I/O device may include one or more sensors. This disclosure contemplates any suitable I/O devices and any suitable I/O interfaces 208 for them. Where appropriate, I/O interface 208 may include one or more device or software drivers enabling processor 202 to drive one or more of these I/O devices. I/O interface 208 may include one or more I/O interfaces 208, where appropriate. I/O interface 208 may be housed on a separate system or any I/O system suitable for communication between processing system 200 and a user. Although this disclosure describes and illustrates a particular I/O interface, this disclosure contemplates any suitable I/O interface.

[0031] In exemplary embodiments, communication interface 312 includes hardware, software, or both providing one or more interfaces for communication (such as, for example, packet-based communication) between processing system 200 and one or more other processing systems 200 or one or more networks. As an example and not by way of limitation, communication interface 212 may include a network interface controller (NIC) or network adapter for communicating with an Ethernet or other wire-based network or a wireless NIC (WNIC) or wireless adapter for communicating with a wireless network, such as a WI-FI network. This disclosure contemplates any suitable network and any suitable communication interface 212 for it. As an example and not by way of limitation, processing system 200 may communicate with an ad hoc network, a personal area network (PAN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), or one or more portions of the Internet or a combination of two or more of these. One or more portions of one or more of these networks may be wired or wireless. As an example, processing system 200 may communicate with a wireless PAN (WPAN) (such as, for example, a BLUETOOTH WPAN), a WI-FI network, a WI-MAX network, a cellular telephone network (such as, for example, a Global System for Mobile Communications (GSM) network), or other suitable wireless network or a combination of two or more of these. Processing system 200 may include any suitable communication interface 212 for any of these networks, where appropriate. Communication interface 212 may include one or more communication interfaces 212, where appropriate. Although this disclosure describes and illustrates a particular communication interface, this disclosure contemplates any suitable communication interface.

[0032] In particular embodiments, bus 210 includes hardware, software, or both coupling components of processing system 200 to each other. As an example and not by way of limitation, bus 210 may include an Accelerated Graphics Port (AGP) or other graphics bus, an Enhanced Industry Standard Architecture (EISA) bus, a front-side bus (FSB), a HYPERTRANSPORT (HT) interconnect, an Industry Standard Architecture (ISA) bus, an INFINIBAND interconnect, a low-pin-count (LPC) bus, a memory bus, a Micro Channel Architecture (MCA) bus, a Peripheral Component Interconnect (PCI) bus, a PCI-Express (PCIe) bus, a serial advanced technology attachment (SATA) bus, a Video Electronics Standards Association local (VLB) bus, or another suitable bus or a combination of two or more of these. Bus 210 may include one or more buses 210, where appropriate. Although this disclosure describes and illustrates a particular bus, this disclosure contemplates any suitable bus or interconnection.

[0033] Herein, a computer-readable non-transitory storage medium or media may include one or more semiconductor-based or other integrated circuits (ICs) (such, as for example, field-programmable gate arrays (FPGAs) or application-specific ICs (ASICs)), hard disk drives (HDDs), hybrid hard drives (HHDs), optical discs, optical disc drives (ODDs), magneto-optical discs, magneto-optical drives, floppy diskettes, floppy disk drives (FDDs), magnetic tapes, solid-state drives (SSDs), RAM-drives, SECURE DIGITAL cards or drives, any other suitable computer-readable non-transitory storage media, or any suitable combination of two or more of these, where appropriate. A computer-readable non-transitory storage medium may be volatile, non-volatile, or a combination of volatile and non-volatile, where appropriate.

[0034] FIG. 3 illustrates a colorimeter system 300 associated with image quality testing in accordance with an exemplary embodiment. Colorimeter system 300 may be a sophisticated color instrument that performs a color measurement based on light passing through the system, which may simulate the way the human eye is sensitive to light. The colorimeter system 300 may include a spectrometer system 302 and a camera system 306. The spectrometer system may further include a spectrometer 301 coupled with a lens 303, and the camera system may include a monochrome camera 305 and a large field of view (FOV) lens 307 attached to the monochrome camera 305 to direct light into the camera system 306. Monochrome camera 305 may be configured to capture grayscale images or monochrome camera 305 may be a monochrome camera and thus may eliminate the need for color filters that may be used in conventional colorimeter systems. The monochrome camera 305 may be a charged coupled device (CCD) camera, complementary metal oxide system (CMOS) camera or any camera configured to capture a grayscale or monochrome image. Also shown in FIG.3 is a target 308. Target 308 provides an optical target so that the camera system 306 may form a 2-dimensional (2D) image on a sensor in an image plane of a monochrome camera 305. In some embodiments target 308 may be an emissive target of a reflective target. Target 308 may be a light emitting diode (LED) display, a liquid crystal display (LCD) or any other type of display used in a TV, computer, cellphone, laptop, tablet, XR devices, etc.

[0035] Colorimeter system 300 may be able to acquire a grayscale image and form an imaging pipeline simultaneously. Accordingly, the spectral measurement and the imaging may share the measurement lighting area at similar times. Light 310 from target 308 may be captured via large FOV lens 307 and lens 303 and directed to the monochrome camera 305 and spectrometer 301 respectively.

[0036] A portion of light 310 may be directed to the spectrometer system 302 via lens 303. Lens 303 may be referred to as an optical channel. In some embodiments, light may be directed to the spectrometer 301 via an optical channel in the spectrometer system 302, where the optical channel may comprise lenses and mirrors. In some embodiments, lens 303 may focus light through a slit into the spectrometer 301. The spectrometer 301 may include a collimating mirror, a spectroscopic resolving element, a focusing mirror, and a detector array. In some embodiments, spectroscopic resolving element may be a diffraction grating or a prism. Spectrometer 301 may be a compact low-cost spectrometer, or any spectrometer configured to capture spectrum shape of light. Spectrometer 301 may include a processor 202 and a memory 204 as shown in FIG. 2. The memory 204 may store commands when executed by processor 202 and may cause spectrometer 301 to perform many different operations in accordance with an exemplary embodiment such as identifying a spectrum shape. For example, the processor 202 may establish communication with a controller (e.g., communication interface 212), and provide data or commands to camera system 306. Processor 202 may also be configured to execute commands provided by a controller. In some embodiments, processor 202 may provide color coordinate (e.g., chromaticity) to a controller. Accordingly, the color coordinate may include highly resolved spectral information from target 308 provided by spectrometer system 302 to a controller.

[0037] A portion of light 310 may be directed via large FOV lens 307 towards the camera system 306. Large FOV lens 307 may be any mirror, lens, prism, or any combination thereof. Camera system 306 may include a processor (e.g., processor 202) and a memory (e.g., memory 204). The memory may store commands when executed by the processor may cause the camera system 306 to perform many different operations associated with an exemplary embodiment, such as capture a grayscale image of target 308. For example, processor 202 may establish communication with a controller, and provide data and commands to camera system 306. Processor 202 may also be configured to execute commands provided by a controller. Also, in some embodiments processor 202 may provide grayscale values measured by camera system 306 to controller.

[0038] FIG. 4 illustrates an exemplary method 400 associated with a colorimeter system in accordance with an exemplary embodiment. Steps in the method 400 may be applied in a manufacturing or production environment for display devices. In some embodiments, steps in method 400 may be performed more frequently, such as for every display being tested. Steps in method 400 may be performed for each one of a number of images test on each display. Steps in method 400 may be performed by a communication interface 212 (e.g., a controller) using data provided by a camera system (e.g., camera system 306) or a spectrometer system (e.g., spectrometer system 302). The data provided to the communication interface 212 may be stored in a memory (e.g., memory 204) and processed by a processor (e.g., processor 202) in the camera system, or a memory (e.g., memory 204) and processed by a processor (e.g., processor 202) in the spectrometer system.

[0039] Step 410 may include providing a target (e.g., target 308). In some embodiments, step 410 may include selecting a number of screen displays having standardized characteristics. For example, the number of screen displays may include a set of screens, each having a single, pre-determined color. In some embodiments selecting a number of screen displays may include selecting screen displays having spatial uniformity. For example, step 410 may include selecting a plurality of screen displays having a uniform intensity.

[0040] Step 420 may include measuring spectrum of light and calculating chromaticity data of target 308 from spectrometer system 302. Step 430 may include identifying monochrome camera response correction matrix from data captured via spectrometer system 302. The spectrum data and calculated chromaticity data received in step 420 may include determination of light characteristics, such as peak wavelengths or full width half maximum (FWHM) of light to determine a response correction matrix determined by spectral analysis of light 310.

[0041] Step 440 may include providing a response correction matrix to camera system 306, where grayscale image of target 308 may be converted to a luminance map to apply response correction determined by spectrometer system 302. Response correction may be performed by a change to camera system imaging settings.

[0042] Methods and systems for a quick, accurate, and cost-effective colorimeter for image quality testing (IQT) have been disclosed. In conventional systems images need to be taken of the target image (e.g., target 308) for every filter used in the system. In many conventional systems, there are 3 to 4 color filters resulting in 3 to 4 images being taken during a cycle or revolution of the color wheel, which in turn may need to be combined to form one final output image for IQT. In the present disclosure, no color filter wheel is needed to capture a grayscale image of the target image (e.g., target 308) thus greatly reducing time needed to test image quality and shortens exposure time for color filters that may be harmful for displays. For example, to capture an image conventionally with 3 filters it may take 2 seconds to capture an image and due to the number of filters and the limitation of having to combine the captured 3 images associated with each filter it may take 6 seconds to capture a full image. Conversely, with the colorimeter system of the present disclosure no color filters may be needed thus allowing for the image needed for IQT to be captured in 2 seconds, and 3 times faster than conventional systems. Since many conventional systems may have 3 to 4 color filters that each need to capture a image of the target and combine the 3 to 4 images to one final image for IQT, the present disclosure provides a system where capture of the final image may be 3 to 4 times faster. Thus, image quality testing speeds may be increased.

[0043] Conventionally, accuracy in colorimeters may be affected by the addition of spectrometers (e.g., added component of error) to the system and the amount of information needed from the spectrometer to determine image quality. Conversely, with the use of grayscale images only spectrum shape data is needed from the spectrometer thus reducing the error introduced from spectrometers, whereas conventionally 3 or more sets of data may have been traversed between the spectrometer system and camera system introducing 3 instances of error to the colorimeter system. Thus, reducing the instances of error between the camera system (e.g., camera system 306) and spectrometer system (e.g., spectrometer 302) may improve the accuracy of image quality testing.

[0044] Conventionally, color filters (e.g., color wheel), spectrometer coupling system, or a specialized spectrometer may need to be used in colorimeter systems to measure IQT. For colorimeter system of the present disclosure (e.g., colorimeter system 300), with the use of grayscale images and only needing a spectrum shape from the spectrometer there may be no need for color filters, a spectrometer coupling system nor a specialized spectrometer. Thus, the present disclosure may reduce manufacturing costs for IQT, and may increase testing speeds and improve accuracy of IQT.

[0045] The foregoing description of the embodiments has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the patent rights to the precise forms disclosed. Persons skilled in the relevant art may appreciate that many modifications and variations are possible in light of the above disclosure.

[0046] Some portions of this description describe the embodiments in terms of algorithms and symbolic representations of operations on information. These algorithmic descriptions and representations are commonly used by those skilled in the data processing arts to convey the substance of their work effectively to others skilled in the art. These operations, while described functionally, computationally, or logically, are understood to be implemented by computer programs or equivalent electrical circuits, microcode, or the like. Furthermore, it has also proven convenient at times, to refer to these arrangements of operations as modules, without loss of generality. The described operations and their associated modules may be embodied in software, firmware, hardware, or any combinations thereof.

[0047] Any of the steps, operations, or processes described herein may be performed or implemented with one or more hardware or software modules, alone or in combination with other devices. In one embodiment, a software module is implemented with a computer program product comprising a computer-readable medium containing computer program code, which may be executed by a computer processor for performing any or all of the steps, operations, or processes described.

[0048] Embodiments also may relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a computing device selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a non-transitory, tangible computer readable storage medium, or any type of media suitable for storing electronic instructions, which may be coupled to a computer system bus. Furthermore, any computing systems referred to in the specification may include a single processor or may be architectures employing multiple processor designs for increased computing capability.

[0049] Embodiments also may relate to a product that is produced by a computing process described herein. Such a product may comprise information resulting from a computing process, where the information is stored on a non-transitory, tangible computer readable storage medium and may include any embodiment of a computer program product or other data combination described herein.

[0050] The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the patent rights be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the patent rights, which is set forth in the following claims.

WHAT IS CLAIMED:

1. A system comprising:

an optical target that emits a light to a spectrometer system and a camera system, wherein:

the spectrometer system comprises a spectrometer, an optical channel, a slit, and a spectroscopic resolving element, wherein the light is directed to the spectrometer via the optical channel, wherein;

the spectrometer determines a spectral shape associated with the light,

the spectrometer calculates a chromaticity associated with the light, and

the spectrometer provides a response correction matrix based on the spectral shape to the camera system, and

the camera system comprises a camera and a lens, wherein:

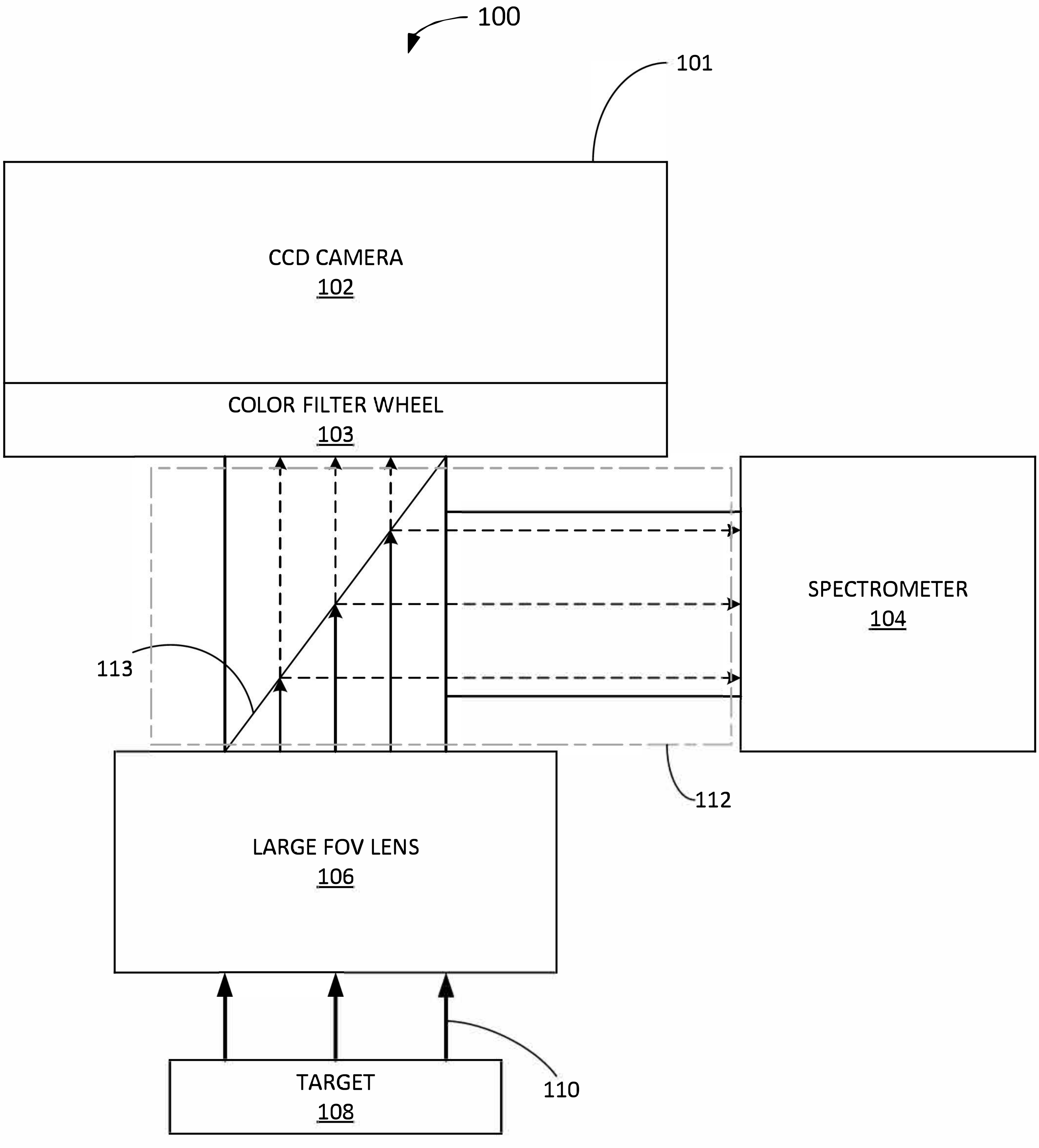
the camera system provides a grayscale image of the light,

the camera system converts the grayscale image to a luminance map, and

the camera system receives the response correction matrix, via the spectrometer system, wherein based on settings of the camera system the response correction matrix is adjusted.

ABSTRACT OF THE DISCLOSURE

Methods and systems for using a monochrome camera in colorimeter systems to perform image quality testing are provided during the manufacturing (e.g., benchmarking) process. The system may include a target image displayed on a device for directing light to the system. The system (e.g., colorimeter system) may include a spectrometer system and a camera system. The spectrometer system may receive light from the target image and may perform functions such as determining the spectrum, calculating the chromaticity, and identifying the spectral shape associated with the light from the display being tested. The camera system may receive the light from the display being tested in gray scale, create a luminance map to represent the colors on the display, and based on the data determined, via the spectrometer system, apply corrections to the display.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CCD CAMERA
102
COLOR FILTER WHEEL
103
SPECTROMETER
104
113
112
LARGE FOV LENS
106
TARGET
108
110

FIG. 1

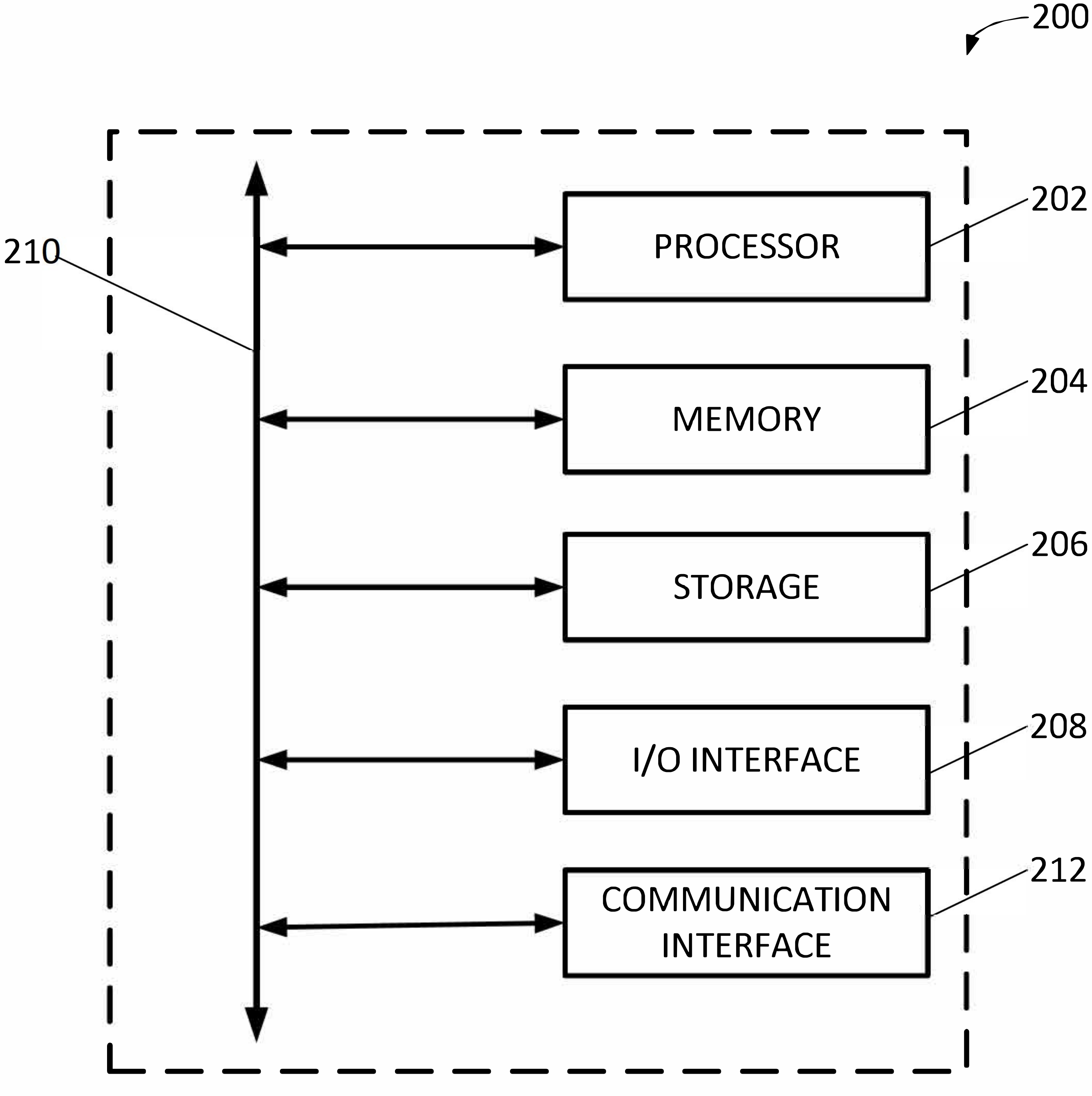
200
202
PROCESSOR
210
204
MEMORY
206
STORAGE
208
I/O INTERFACE
212
COMMUNICATION INTERFACE

FIG. 2

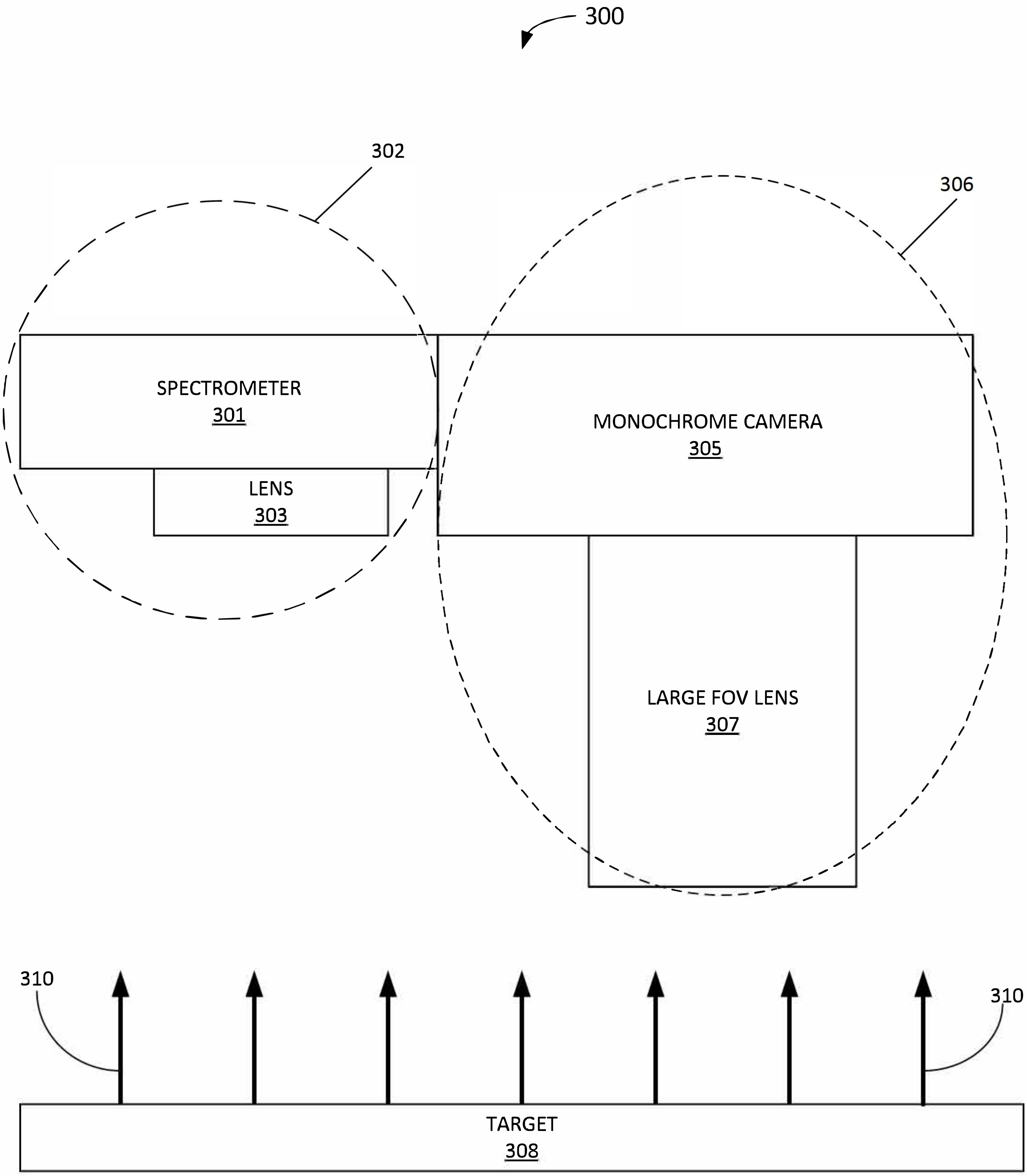
300
302
306
SPECTROMETER
301
LENS
303
MONOCHROME CAMERA
305
LARGE FOV LENS
307
310
310
TARGET
308

FIG. 3

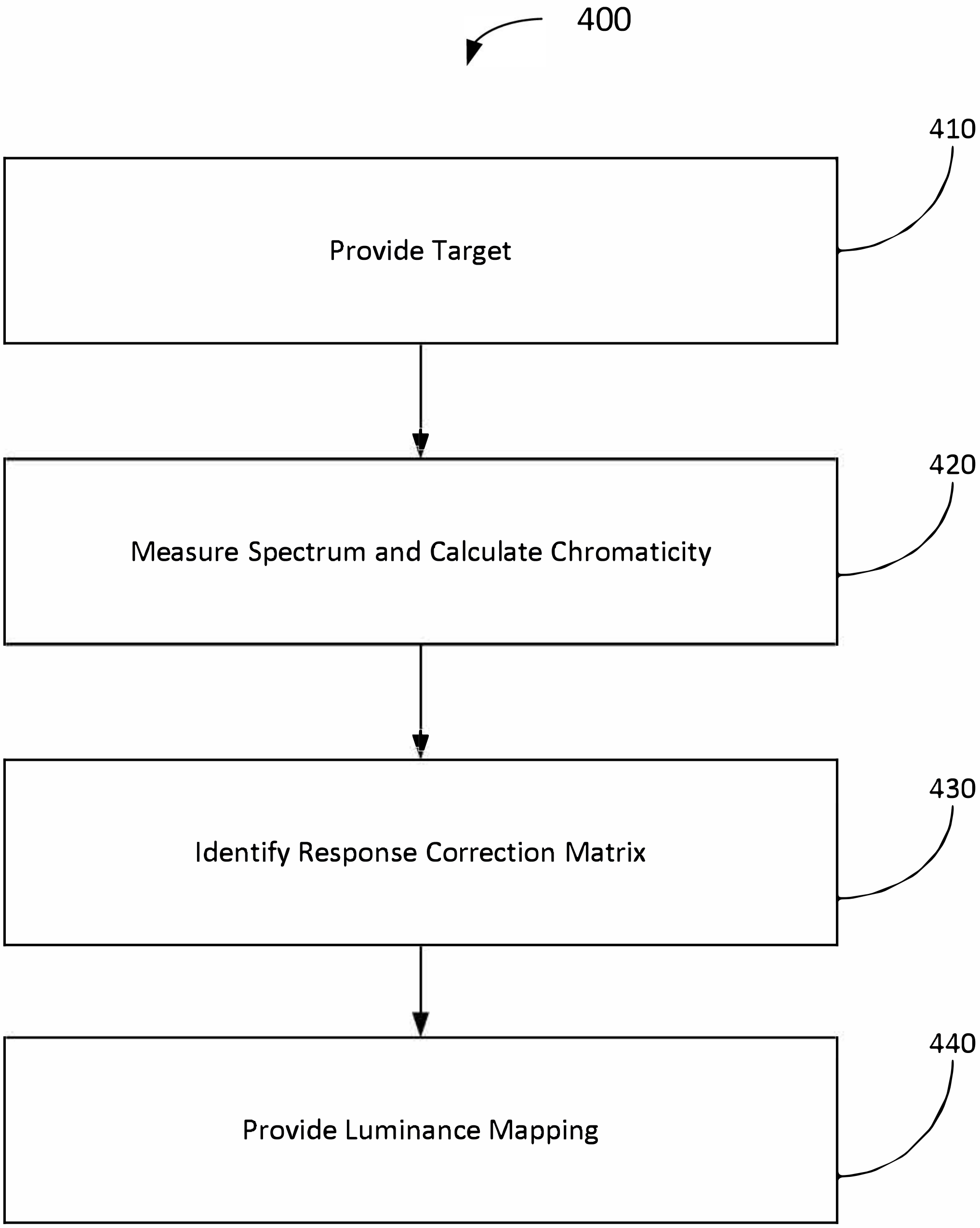
400
410
Provide Target
420
Measure Spectrum and Calculate Chromaticity
430
Identify Response Correction Matrix
440
Provide Luminance Mapping

FIG. 4