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[Continued on next page]

(54) Title: DISPLAY PROJECTOR

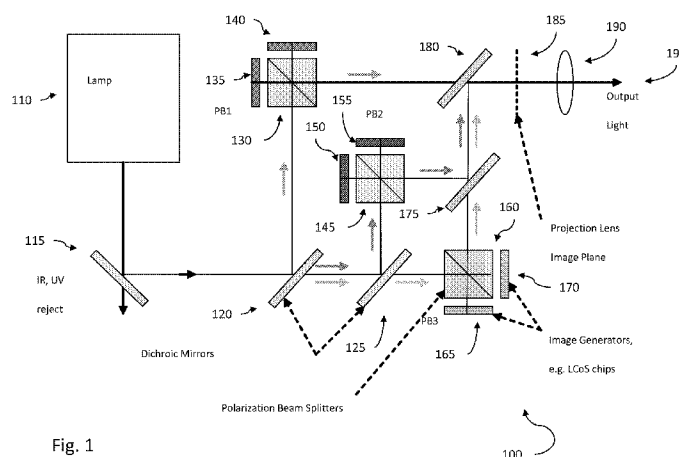


Fig. 1

(57) Abstract: A system, method and apparatus is provided for a display projector. The display projector and components thereof provide a variety of systems, methods and apparatuses which can be combined in various ways. In some embodiments, a display projector is provided which is highly efficient based on the use of an RGB LCoS system. In some embodiments, laser diodes are used as a light source and in other embodiments, LEDs (light emitting diodes) are used as a light source. In some embodiments, a projected overlay is used. In some embodiments, an alignment system and method is provided. In some embodiments, an integrated optical polarization combining prism is used. In some embodiments, dynamic range is increased through adjustment of the projected image. In some embodiments, a single set of projection optics are used to project three different colors in an alternating fashion. Each of the features mentioned with regard to some embodiments may be combined with the other features mentioned in various embodiments of systems, methods and apparatuses.



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Display Projector

CLAIM OF PRIORITY

[0001] This application claims priority to United States patent application serial no. 12/015,500, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/015,502, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/015,503, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/015,505, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/015,506, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/033,003, which is hereby incorporated herein by reference. This application claims priority to United States patent application serial no. 12/033,002, which is hereby incorporated herein by reference. This application claims priority to United States provisional patent application serial no. 61/011,509, which is hereby incorporated herein by reference. This application claims priority to United States provisional patent application serial no. 61/029,590, which is hereby incorporated herein by reference.

BACKGROUND

[0002] Projection of motion pictures in theatres is still primarily done based on film and projection technology little changed since the dawn of motion pictures. However, compared to film, digital media allows for much easier storage of representations of an image. In order to move beyond film-based projection, it would be useful to provide a digital projector which fits general theater requirements.

[0003] Furthermore, a consortium of studios has set forth a standard for future digital projection systems. While this standard is by no means final, it provides a rough guide as to what a system must do – what specifications must be met. Thus, it may be useful to provide a digital projection system which meets the standards of the studio consortium.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The present invention is illustrated by way of example in the accompanying drawings. The drawings should be understood as illustrative rather than limiting.

[0005] Figure 1 illustrates an embodiment of an LCoS image projector.

[0006] Figure 2 illustrates transmission characteristics of dichroic mirrors.

[0007] Figure 3 illustrates alignment aspects of the embodiment of Figure 1.

[0008] Figure 4 illustrates cooling assemblies associated with the embodiment of Figure 1.

[0009] Figure 5 illustrates another embodiment of an LCoS image projector.

- [0010] Figure 6 illustrates an embodiment of an LCoS chip assembly with a TEC mounted thereto.
- [0011] Figure 7 illustrates cooling in embodiments such as those of Figures 1 and 5.
- [0012] Figure 8 illustrates an embodiment of a computer which may be used with the projectors of Figures 1 and 5, for example.
- [0013] Figure 9 illustrates an embodiment of a system using a computer and a projector.
- [0014] Figure 10 illustrates an embodiment of a network which may be used with various embodiments of the projectors and associated computers.
- [0015] Figures 11 and 12 illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiment of Figure 5, for example.
- [0016] Figure 13 illustrates an embodiment of a display system.
- [0017] Figure 14 illustrates an embodiment of a process of cycling colors and polarization states.
- [0018] Figure 15A illustrates an alternate embodiment of a display system.
- [0019] Figure 15B further illustrates an embodiment of a complex polarization beam splitter of Figure 15A.
- [0020] Figure 16 illustrates another alternate embodiment of a display system.
- [0021] Figure 17 illustrates an embodiment of a process of projecting an image.
- [0022] Figure 18 illustrates an alternate embodiment of a process of projecting an image.
- [0023] Figure 19 illustrates an embodiment of a system using a computer and a projector.
- [0024] Figure 20 illustrates an embodiment of a computer which may be used with the projectors of Figures 13, 15 and 16, for example.
- [0025] Figure 21 illustrates yet another embodiment of a system using a computer and a projector.
- [0026] Figure 22 illustrates an embodiment of multiple position filter wheels which may be used with a projector.
- [0027] Figure 23 illustrates a timeline of operation of an embodiment of a projector with increased dynamic range provided through use of a multiple position filter.
- [0028] Figure 24 illustrates an embodiment of an LCoS image projector.
- [0029] Figure 25 illustrates an embodiment of a PLZT ceramic filter.
- [0030] Figure 26 illustrates an embodiment of an optical subsystem using two PLZT filters in parallel.
- [0031] Figure 27 illustrates an embodiment of a process of projecting images through use of a filter for increased dynamic range.
- [0032] Figure 28 illustrates an embodiment of a system using a computer and a projector.
- [0033] Figure 29 illustrates an embodiment of a computer which may be used with the projectors of Figure 24 (and 28), for example.
- [0034] Figure 30 illustrates an embodiment of a display system.

[0035] Figure 31 illustrates another embodiment of a display system.

[0036] Figure 32 illustrates an embodiment of a process of displaying images.

[0037] Figure 33 illustrates an embodiment of displayed images.

[0038] Figure 34 illustrates yet another embodiment of a display system.

[0039] Figure 35 illustrates another embodiment of a process of displaying images.

[0040] Figure 36 illustrates an embodiment of a system using a computer and a projector.

[0041] Figure 37 illustrates an embodiment of a computer which may be used with the projectors of Figures 30, 31 and 34, for example.

[0042] Figures 38A and 38B illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiment of Figure 34, for example.

[0043] Figure 39 illustrates an embodiment of an array of light sources which may be used with a projector.

[0044] Figure 40 illustrates another embodiment of an array of light sources which may be used with a projector.

[0045] Figure 41 illustrates an embodiment of an array of light sources fabricated on a substrate.

[0046] Figure 42 illustrates another embodiment of an array of light sources fabricated on a substrate.

[0047] Figure 43 illustrates an embodiment of a process of installing an array of light sources.

[0048] Figure 44 illustrates an embodiment of a process of operating an array of light sources.

[0049] Figure 45 illustrates an embodiment of a system using a computer and a projector.

[0050] Figure 46 illustrates an embodiment of a computer which may be used with the system of Figure 45, for example.

[0051] Figure 47 illustrates an embodiment of a projector which may be used with the various embodiments described herein.

[0052] Figure 48 illustrates an embodiment of a calibration system.

[0053] Figure 49 illustrates an embodiment of an alignment system for a projector.

[0054] Figure 50 illustrates an embodiment of a graph of image intensity in an alignment or calibration system.

[0055] Figure 51 illustrates another embodiment of a calibration system as part of a projector.

[0056] Figure 52 illustrates an embodiment of a process of aligning a projector.

[0057] Figure 53 illustrates an embodiment of a process of projecting an image.

[0058] Figure 54 illustrates an embodiment of a system using a computer and a projector.

[0059] Figure 55 illustrates an embodiment of a computer which may be used with the projectors of Figure 51, for example.

[0060] Figure 56 illustrates yet another embodiment of a system using a computer and a projector.

[0061] Figure 57 illustrates an embodiment of a network which may be used with various embodiments of the projectors and associated computers.

[0062] Figure 58 illustrates an embodiment of an LCoS image projector.

[0063] Figure 59 illustrates another embodiment of an LCoS image projector.

[0064] Figure 60 illustrates yet another embodiment of an LCoS image projector.

[0065] Figures 61A, 61B and 61C illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiments of Figures 59 and 60, for example.

[0066] Figure 61D illustrates an embodiment of a process of optically processing light through a polarizing beamsplitter such as the embodiment of Figures 61A-61C.

[0067] Figure 62 illustrates an alternative embodiment of an LCoS image projector based on the embodiment of Figure 60.

[0068] Figure 63 illustrates an embodiment of a PLZT ceramic filter.

[0069] Figure 64 illustrates cooling in embodiments such as those of Figures 58, 59, 60 and 62, for example.

[0070] Figure 65 illustrates an embodiment of a computer which may be used with the projectors of Figures 58, 59 and 60, for example.

[0071] Figure 66 illustrates an embodiment of a system using a computer and a projector.

DETAILED DESCRIPTION

[0072] A system, method and apparatus is provided for a display projector. The specific embodiments described in this document represent examples or instances of the present invention, and are illustrative in nature rather than restrictive.

[0073] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the invention can be practiced without these specific details. In other instances, structures and devices are shown in block diagram form in order to avoid obscuring the invention.

[0074] Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments.

[0075] The following description is divided into a number of sections devoted to various features which may be implemented in a variety of circumstances. However, the various features of different embodiments may be combined with features of other embodiments to ultimately achieve a desired embodiment.

For example, a projector may use the basic design of Figure 1 with thermoelectric coolers, added infrared capabilities, additional components for enhancing the dynamic range of brightness available, and a light source based on laser diodes or LEDs, for example. Other combinations of the various features will likewise be understood, even though such combinations are not immediately illustrated in the drawings or explicitly spelled out in the text.

High Brightness Large Screen Projected Displays using LCoS Image Generators

[0076] A high efficiency optical design for three color RGB (red, green, blue) image projectors is shown in Figure 1 that uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A randomly polarized white light source (110) is stripped of IR and UV components by an IR/UV rejection filter (115) input to a first dichroic mirror (DM1 – 120) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 130). The remainder of the spectrum passes through the dichroic mirror (120) to a second dichroic mirror (DM2 – 125), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 145). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 160).

[0077] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 135, 140, 150, 155, 165 and 170). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (130, 145 and 160), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (175 and 180) to form a white image (at projection lens image plane 185) which is focused on a remote screen using a projection lens (190) to provide output light 195.

[0078] Application of a voltage to an LCoS chip pixel that is insufficient for 90 degree rotation of the optical polarization results in a smaller rotation of the plane of polarization for a beam reflected from an LCoS chip. On passing back (of the beam) through the polarizing beam splitter the rotated beam is split into two orthogonal polarized components of different intensities that exit the beam splitter in different directions. Thus the intensity of the output beam is reduced in proportion to the degree of polarization rotation (i.e. voltage on the pixel), and the unrotated portion is returned along its entrance path back toward the source.

[0079] Although many optical projection systems have been designed, multicolor displays using reflective LCoS image generation chips, one design the inventor is aware of is not well suited to large high brightness displays. The LCoS image generation devices employ a liquid crystal layer sandwiched between a transparent optical surface and a silicon electronic chip which applies a voltage to the liquid crystal layer on a pixel by pixel basis, causing spatially localized polarization rotation of light and thereby enabling an image to be

imparted to light input through the transparent surface and reflecting back from the chip surface. The LCoS devices are universally employed in a reflective mode where the reflected light contains the image information.

[0080] The above referenced design uses four beam splitting cubes and several color absorption filters. It suffers from a low light efficiency as the input light is first split into two polarizations, each of which is then passed through color filters. This implementation causes half of the polarized light to be absorbed in the color filters. The absorbed light significantly heats the filters, trapping the heat between the polarizing cubes. Consequently this design, although compact, is only compatible with low intensity light, perhaps small fractions of a watt. A large screen multi-media display must be capable of transmitting several hundred watts of light, with potentially tens of watts absorbed in the image generating chips.

[0081] In contrast the proposed optical design implementation first separates the input light on a spectral basis, blue, red, then green light, using color separating dichroic mirrors, and each color is then input to its own polarizing beam splitter which directs polarized light to two LCoS image planes, one for each light polarization state. The light is thus spread over six separate LCoS chips. The reflected output images from the three beam splitters each contain both optical polarizations for their respective color, and the colored images are then re-combined using dichroic mirrors. By this means no light is absorbed in color filters and the system is capable of much higher optical power throughput as the dichroic mirrors absorb comparatively little light, and each color path is very efficient with minimal light loss at the LCoS planes. The LCoS image chips are accessible from the rear (the non-image side) and active chip cooling may therefore be employed to maintain each chip within a preferable operating temperature range.

[0082] In one embodiment, the blue light is first separated using a blue reflecting, red and green transmitting dichroic mirror. Blue light is separated first as, for a maximum brightness display, it can least tolerate optical power losses, and some red and green light is lost at the blue reflecting dichroic mirror. Next the red light is separated as this is less tolerant to loss than the green portion of the spectrum. Reflection spectra of typical dichroic mirrors are shown in Figure 2, with Figure 2A showing a blue reflecting dichroic mirror and Figure 2B showing a red reflecting dichroic mirror.

[0083] After passing through their respective LCoS image planes each color is recombined using dichroic mirrors similar to those used in the initial color separation process. It is noted the two re-combining dichroic mirrors are very angle sensitive as rotations will move the image planes out of registration. In an embodiment, the optical path lengths from the optical source to each LCoS image plane is essentially the same to enable essentially the same illumination fill factor and pattern to be obtained for each image plane. Similarly the three output colored images from the LCoS are all essentially equidistant from the projection lens, thereby enabling all images to be projected in focus.

[0084] The three images are typically combined in the image plane of the projection lens enabling existing projection lenses to be used. The images from the LCoS image generation chips are relayed to the

projection lens image plane using standard relay lens techniques to maximize light throughput. The optical paths are arranged so that a single set of relay optics relays the image from each LCoS chip to the projector lens image plane. The relay optics is configured so the magnification from the LCoS image chips to the output image plane matches the output image plane format.

[0085] The basic optical system of Figure 1 lies in a plane in some embodiments, which minimizes the number of optical elements, thereby minimizing scattered light and maintaining maximum image contrast. Each beam splitting cube is mounted on the same surface and all optical paths are co-planar. This facilitates fabrication and optical alignment. The co-planar layout also facilitates thermal control of the LCoS image generators as 'through the support-plate' airflow in a direction perpendicular to the plane of the optical system is easily configured and keeps the cooling air away from the optical path, reducing the possibility of optical artifacts created by air turbulence.

[0086] The LCoS image projector may use existing projection display components such as lamp hoses and associated power supplies, and available projection lenses. Both lamp houses and projection lenses are typically close to the image plane in film projectors. The light output from the lamp house is therefore relayed to the LCoS image chips by illumination relay optics with a magnification that matches the lamp output area to the image chip area.

[0087] In some embodiments, the two LCoS image chips for each beam splitter may be aligned during initial assembly into a module which includes the dichroic mirrors, and locates each chip on axis, precision aligned in rotation about that axis, and optically equidistant from the output face of the beam splitter as shown by the dotted lines in Figure 3. With all three modules in nominal position, the green module is focused to the output image plane, followed by focusing the red and then blue modules by translating the modules parallel to the input/output optical axes.

[0088] Thus, Figure 3 illustrates the various modules which may be translated together for alignment/focusing purposes. A focusing optic 310 may be provided as needed. Module 330 includes dichroic mirror 120, beam splitter 130, and LCoS chip assemblies 135 and 140. Module 350 includes dichroic mirror 125, beam splitter 145, and LCoS chip assemblies 150 and 155. Note that the chip assemblies are shown with thermoelectric coolers and air plenums in this illustration.

[0089] Beam splitter 160 and associated components may be positioned as needed for focus/transmission purposes. Then, module 1 (330) may be translated to align beam splitter 130 (and corresponding optics) with dichroic mirror 180. Similarly, module 2 (350) may then be translated to align beam splitter 145 with dichroic mirror 175.

[0090] For high brightness displays it is desirable to pass as much optical energy through the system as possible. The limiting factor may well be the ability of the LCoS image generators to absorb heat as they are typically limited to an operating temperature range of 40 -75C. Each LCoS chip consumes several hundred

milliwatts of electrical power. It is therefore potentially beneficial to add temperature control to each LCoS image chip as this will allow greater light power input and also eliminate any issue with differential expansion of the different image planes and provide cooling for the LCoS driver chip. In one embodiment, each LCoS chip is mounted on a Thermo-Electric Cooler (TEC) as in Figure 4, with the cooling airflow directed into the page.

[0091] Thus, Figure 4 illustrates cooling assemblies associated with the embodiment of Figure 1. Assembly 410 includes a beam splitter 420, windows 430, liquid crystal 440, LCoS drive chips 450, TE coolers 460 and air cooling fins 470. The stack of window 430, liquid crystal 440, LCoS drive chip 450, TE cooler 460 and air cooling fins 470 provide a cooled LCoS assembly. Along with beam splitter 420, input light 415 is then transformed by this assembly into output light 475.

[0092] The TEC generates a temperature differential between two opposite faces and requires the TEC hot side be cooled by a flow of air or liquid. The air cooled configuration in Figure 3 shows two LCoS chips per color and provides the ability to modulate the two different polarizations of an un-polarized colored beam. The ability to put images on a screen with two orthogonal optical polarizations facilitates simple implementation of 3D imagery, although viewers need to wear polarization discriminating eyewear.

[0093] In an embodiment using polarization combining optics to reduce the number of LCoS image chips to three as shown in Figure 5, one may provide a projection system with fewer LCoS chips.

[0094] Thus, Figure 5 provides an illustration of another embodiment of an LCoS image projector. A randomly polarized white light source (510) is stripped of IR and UV components by an IR/UV rejection filter (515) input to a first dichroic mirror (515) which reflects the blue portion of the spectrum to a prism 540 that converts the entire beam to the same polarization by means of a half-wave plate and passes it to a polarizing beam splitter (530). The remainder of the spectrum passes through the dichroic mirror (515) to a second dichroic mirror (520), which reflects the red portion of the spectrum to a second polarization combining prism 555 and polarizing beam splitter (545). The remaining spectrum passes to a third polarization combining prism 570 and polarizing beam splitter (560).

[0095] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, one of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 535, 550 and 565). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (530, 545 and 560), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (575 and 580) to form a white image (at projection lens image plane 585) which is focused on a remote screen using a projection optics (590) to provide output light 595. Focusing to plane 585 may involve additional optics 583.

Furthermore, each of LCoS chips 535, 550 and 565 are provided with a TEC (537, 552 and 567 respectively) and associated air plenum (539, 554 and 568 respectively) to provide cooling.

[0096] The optical design as in Figure 1 lends itself to fabrication in a plane so multiple projectors are easily mounted side by side in close proximity. In such embodiments, cooling air flow to each LCoS is perpendicular to the plane of the optics, e.g. into the page, and does not pass through the optical path.

[0097] The TE cooler/LCoS chip assembly is mounted to the optical plate by bonding it into a ceramic holder with adhesive, so the ceramic thermally isolates the assembly from the main structure as in Figure 6. The polarizing optics which passes light to and from the LCoS image chip is also mounted on the ceramic holder to minimize any thermal drift between it and the LCoS chip. The ceramic holder is mounted to the optical base structure via machined bosses in three locations which define a plane, and rotation and translation in the plane are prevented by a pair of stainless steel pins.

[0098] Thus, Figure 6 illustrates an embodiment of an LCoS chip assembly with a TEC mounted thereto. Input light 610 passes through polarizing beam splitter 620 to LCoS chip 630. TEC 635 is mounted thereto to provide cooling. Heat sink fins 640 allow heat to be radiated into airflow 660. TEC635 and associated heat sink fins 640 are mounted to side walls 655 and 650 using foamed plastic spacers 645. LCoS chip 630 is mounted to ceramic mount 625, which is connected or coupled to wall 655 using machined bosses 631, fasteners 627 and pin 629.

[0099] In an embodiment, the optical system is configured vertically with the TECs and heat sinks well apart from the optical path. The optics are located between two vertical plates in a dust free enclosure with the cooling air that passes over the finned heat sink passing between the plates in a confined region as shown in Figure 7B. To maintain the maximum projected image resolution on the screen it is preferable to minimize vibration of the optical system so the cooling air is passed into the air plenum via a flexible connecting hose, as is further illustrated in Figure 7A. The cooling air for the projection lamp is similarly passed into the lamp-house through a flexible hose for the same reason.

[00100] Thus, Figure 7 illustrates cooling in embodiments such as those of Figures 1 and 5. Figure 7A illustrates a side view of the cooling system, and Figure 7B illustrates a perspective view of the cooling system in embodiments such as those of Figures 1 and 5. System 700 includes external housing walls 725 and 730, forming a housing with (cooling) air input and output openings. Internal walls 730 support the optics of the system. Mounted to internal walls 730 are three sets of an LCoS chip 735, TEC 737 and air fins 740. Fan 710 provides air input to the system to cool the air fins 740, and thus the TECs 737 and LCoS chips 735. The perspective view of Figure 7B shows that apertures 755 provide for cooling air flow through support walls 730 to the air fins 740. These apertures 755 may be formed such that they do not cross the optical paths of the corresponding LCoS chips, thereby reducing artifacts from thermal variations in the air of the projector.

[00101] Figure 8 illustrates an embodiment of a computer which may be used with the projectors of Figures 1 and 5, for example. The following description of Figure 8 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00102] Figure 8 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 800 interfaces to external systems through the modem or network interface 820. It will be appreciated that the modem or network interface 820 can be considered to be part of the computer system 800. This interface 820 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00103] The computer system 800 includes a processor 810, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 840 is coupled to the processor 810 by a bus 870. Memory 840 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 870 couples the processor 810 to the memory 840, also to non-volatile storage 850, to display controller 830, and to the input/output (I/O) controller 860.

[00104] The display controller 830 controls in the conventional manner a display on a display device 835 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 830 can, in some embodiments, also control a projector such as those illustrated in Figures 1 and 5, for example. The input/output devices 855 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 1 and 5, which may be addressed as an output device, rather than as a display. The display controller 830 and the I/O controller 860 can be implemented with conventional well known technology. A digital image input device 865 can be a digital camera which is coupled to an i/o controller 860 in order to allow images from the digital camera to be input into the computer system 800. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00105] The non-volatile storage 850 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into

memory 840 during execution of software in the computer system 800. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 810 and also encompasses a carrier wave that encodes a data signal.

[00106] The computer system 800 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 810 and the memory 840 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00107] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 840 for execution by the processor 810. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 8, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00108] In addition, the computer system 800 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 850 and causes the processor 810 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 850.

[00109] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00110] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00111] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00112] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00113] Figure 9A illustrates an embodiment of a system using a computer and a projector. System 910 includes a conventional computer 920 coupled to a digital projector 930. Thus, computer 920 can control projector 930, providing essentially instantaneous image data from memory in computer 920 to projector 930. Projector 930 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 920 may monitor conditions of projector 930, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 930.

[00114] Figure 9B illustrates another embodiment of a system using a computer and projector. System 950 includes computer subsystem 960 and optical subsystem 980 as an integrated system. Computer 960 is essentially a conventional computer with a processor 965, memory 970, an external communications interface 973 and a projector communications interface 976.

[00115] The external communications interface 973 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 976

provides for communication with projector subsystem 980, allowing for control of LCoS chips (not shown) included in projector subsystem 980, for example. Thus, projector communications interface 976 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 960, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 950. System 950 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00116] It may be useful to provide network services for a projection system. Figure 10 shows an embodiment of several computer systems that are coupled together through a network 1005, such as the internet. The term "internet" as used herein refers to a network of networks which uses certain protocols, such as the tcp/ip protocol, and possibly other protocols such as the hypertext transfer protocol (HTTP) for hypertext markup language (HTML) documents that make up the world wide web (web). The physical connections of the internet and the protocols and communication procedures of the internet are well known to those of skill in the art.

[00117] Access to the internet 1005 is typically provided by internet service providers (ISP), such as the ISPs 1010 and 1015. Users on client systems, such as client computer systems 1030, 1040, 1050, and 1060 obtain access to the internet through the internet service providers, such as ISPs 1010 and 1015. Access to the internet allows users of the client computer systems to exchange information, receive and send e-mails, and view documents, such as documents which have been prepared in the HTML format. These documents are often provided by web servers, such as web server 1020 which is considered to be "on" the internet. Often these web servers are provided by the ISPs, such as ISP 1010, although a computer system can be set up and connected to the internet without that system also being an ISP.

[00118] The web server 1020 is typically at least one computer system which operates as a server computer system and is configured to operate with the protocols of the world wide web and is coupled to the internet. Optionally, the web server 1020 can be part of an ISP which provides access to the internet for client systems. The web server 1020 is shown coupled to the server computer system 1025 which itself is coupled to web content 1095, which can be considered a form of a media database. While two computer systems 1020 and 1025 are shown in Fig. 10, the web server system 1020 and the server computer system 1025 can be one computer system having different software components providing the web server functionality and the server functionality provided by the server computer system 1025 which will be described further below.

[00119] Client computer systems 1030, 1040, 1050, and 1060 can each, with the appropriate web browsing software, view HTML pages provided by the web server 1020. The ISP 1010 provides internet connectivity to the client computer system 1030 through the modem interface 1035 which can be considered part of the client computer system 1030. The client computer system can be a personal computer system, a network computer, a web tv system, or other such computer system.

[00120] Similarly, the ISP 1015 provides internet connectivity for client systems 1040, 1050, and 1060, although as shown in Fig. 10, the connections are not the same for these three computer systems. Client computer system 1040 is coupled through a modem interface 1045 while client computer systems 1050 and 1060 are part of a LAN. While Fig. 10 shows the interfaces 1035 and 1045 as generically as a "modem," each of these interfaces can be an analog modem, isdn modem, cable modem, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems.

[00121] Client computer systems 1050 and 1060 are coupled to a LAN 1070 through network interfaces 1055 and 1065, which can be ethernet network or other network interfaces. The LAN 1070 is also coupled to a gateway computer system 1075 which can provide firewall and other internet related services for the local area network. This gateway computer system 1075 is coupled to the ISP 1015 to provide internet connectivity to the client computer systems 1050 and 1060. The gateway computer system 1075 can be a conventional server computer system. Also, the web server system 1020 can be a conventional server computer system.

[00122] Alternatively, a server computer system 1080 can be directly coupled to the LAN 1070 through a network interface 1085 to provide files 1090 and other services to the clients 1050, 1060, without the need to connect to the internet through the gateway system 1075.

[00123] At least one of the optical elements discussed previously bears further discussion. Figures 11 and 12 illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiment of Figure 5, for example. Various display systems using various light sources can be configured using a single image generation chip (LCoS) with maximum light efficiency if both polarizations from the light sources can be directed to the same image chip. This can be accomplished by means of a polarization combining prism which separates an input beam into two polarizations, and rotates one to be oriented similarly to the other. The two halves of the input beam illuminate the two halves of an image generating chip (or other reflective optical component) as shown in Figure 11. A single polarization beam splitter would suffice if half the light from the light source were not used, but this allows for greater efficiency.

[00124] Using a light source similar to that of Fig. 1, one can interpose a more complex polarization beam splitter between the light source and an LCoS chip 1160 in display system 1100, resulting in creation of two output beams with the same polarization. Beam splitter 1150 splits a beam into two beams with the same polarization state. By including a half-wave plate 1140 at an interface within the beam splitter 1150, one of the beams (the beam passing through the half-wave plate) is polarization rotated to the same state as the other (the beam passing through the mirror and around the half-wave plate) so each beam illuminates a different half of the LCoS chip with the same polarization. Note that the half-wave plate 1140 extends only through half of the interface with beam splitter 1150 – thus it only interacts with one of the beams and has no effect on the other beam. The result is two beams directed at the LCoS chip 1160 with the same polarization. The resulting output beams 1180 are then directed at a screen, potentially through further projection optics. Note that LCoS chip 1160

may need to have twice the width of the LCoS chips 160 of Fig. 1, to accommodate the two beams from beam splitter 1150. Alternatively, a lower resolution image can be produced using half of one LCoS chip 160 for each beam.

[00125] Figure 12 further illustrates the complex polarization beam splitter 1150. Prism 1155 receives light from a light source, and splits it into two light beams having orthogonal polarization states. Mirror 1165 reflects one beam with a first polarization state upward (in this perspective). Half wave plate 1140 rotates the polarization state of the other beam from a second polarization state to the first polarization state. As a result, two beams are transmitted through prism 1175 to a reflective optical component, such as LCoS 1160, with each having the same polarization state. Note that whether the first or second polarization state is chosen is not material. The reflective component then reflects light back (potentially modulated for an image) through prism 1175, which reflects the light from the reflective optical component 1160 as output light 1180.

[00126] Further consideration of various embodiments may also be illustrative. In an embodiment, a system is provided. The system includes a housing. The system further includes a first LCoS assembly coupled to the housing. The system also includes a second LCoS assembly coupled to the housing. The system further includes a third LCoS assembly coupled to the housing. Additionally, the system includes a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter is arranged to split incoming light between the first LCoS assembly and the second beam splitter. The second beam splitter is arranged to split incoming light between the second LCoS assembly and the third LCoS assembly. The system also includes a first beam recombiner and a second beam recombiner both coupled to the housing. The first beam recombiner is arranged to receive light from the first LCoS assembly and the second LCoS assembly. The second beam recombiner is arranged to receive light from the first beam recombiner and from the third LCoS assembly. The system also includes a first light source to provide incoming light to the first beam splitter. The system further includes an output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source.

[00127] In some embodiments, the first LCoS assembly, the second LCoS assembly and the third LCoS assembly each include a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization.

[00128] In some embodiments, the first beam splitter is mounted with the first LCoS assembly on a first mounting component which, when translated along an axis, causes the first LCoS assembly and the first beam splitter to translate along the axis therewith. In such embodiments, the second beam splitter may be mounted with the second LCoS assembly on a second mounting component which, when translated along an axis, causes the second LCoS assembly and the second beam splitter to translate along the axis therewith.

[00129] In some embodiments, each of the first, second and third LCoS assemblies further include a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. Moreover, in some embodiments, an IR/UV rejection optical component disposed between the light source and the first beam splitter. Additionally, in some embodiments, a fan is coupled to the housing. Moreover, in some embodiments, a coolant circulation system coupled to the housing and coupled to the heat sinks of the first, second and third LCoS assemblies. Also, in some embodiments, the fan is arranged in the housing to circulate air in a path distinct from an optical path of the first, second and third LCoS assemblies.

[00130] Additionally, in some embodiments, the system includes a processor and a memory coupled to the processor. Moreover, the system may include a bus coupled to the memory and the processor. Also, the system may include a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies. Likewise, the system may include an interface coupled to the processor, the interface to receive data from a source external to the system.

[00131] The system, in various embodiments, may use a variety of light sources. In some embodiments, the first light source is a lamp. In some embodiments, the first light source is a plurality of LEDs. In some embodiments, the first light source is a plurality of laser diodes. Moreover, in some embodiments, the first beam recombiner is a dichroic mirror and the second beam recombiner is a dichroic mirror.

[00132] In another embodiment, a system is provided. The system includes a housing. The system also includes a first LCoS assembly coupled to the housing. The first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip.

[00133] The system may further include a second LCoS assembly coupled to the housing. The second LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. The system may also include a third LCoS assembly coupled to the housing. The third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

[00134] The system may also include a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter is arranged to split incoming light between the first LCoS assembly and the

second beam splitter. The second beam splitter is arranged to split incoming light between the second LCoS assembly and the third LCoS assembly. A first dichroic mirror and a second dichroic mirror both are also coupled to the housing in some embodiments. The first dichroic mirror is arranged to receive light from the first LCoS assembly and the second LCoS assembly, and the second dichroic mirror is arranged to receive light from the first beam recombiner and from the third LCoS assembly. The system may further include a first light source to provide incoming light to the first beam splitter. The system may also include an output optics element coupled to the housing and arranged to receive light from the second dichroic mirror and to focus an output light source.

[00135] The system further includes a processor and a memory coupled to the processor. The system also includes a bus coupled to the memory and the processor. The system further includes a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies.

[00136] The system may further include a user interface coupled to the processor. The system may also include an IR/UV rejection optical component disposed between the light source and the first beam splitter. The system may further include a coolant circulation system coupled to the housing and coupled to the heat sinks of the first, second and third LCoS assemblies. The system may also include an interface coupled to the processor, the interface to receive data from a source external to the system.

Projector with Three Dimensional Simulation and Extended Dynamic Range

[00137] A moderate sized (e.g. 2x3m) image of modest brightness can be projected onto a surface by three Light Emitting Diodes (LEDs), or Laser Diodes (LDs), each of a different color, e.g. red, green, blue, or yellow, cyan, magenta, repetitively pulsed in rapid sequence so as to simultaneously illuminate two LCoS image generation chips with the same color light pulse, but with complimentary optical polarization as determined by the light pulse passing through a broadband polarizing beam splitter cube as shown in Figure 13. Each LED/LD beam exits the cube after reflection from an LCoS image chip having been polarization modulated on a pixel by pixel basis by a digital image electronically written to the LCoS chip. The two oppositely linear polarized, three color, image beams returning through the polarizing beam splitter combine to produce a 3-color image, video or static. When viewed through polarizing glasses and with appropriate images input to the two LCoS chips, the images can produce a simulated 3D image.

[00138] Turning to the specific components of Fig. 13, a projection system 1300 is displayed. Light sources 1305, 1315 and 1325 each provide one of green, red and blue light, respectively. Each light source is tuned through optics 1310, 1320, and 1330, which may be used to focus the light or otherwise transform the light output of lights sources 1305, 1315 and 1325, respectively. Dichroic mirrors 1340 are used to combine the multiple sources of light into a single light source entering polarizing beam splitter 1350.

[00139] Polarizing beam splitter 1350 splits the light into two orthogonally polarized light beams, with each polarized light beam bouncing off of an LCoS image chip 1360. LCoS image chips 1360 modulate the light based on data supplied from an outside source, to create two images (one for each polarized beam). Polarizing

beam splitter 1350 combines the beams coming from LCoS image chips 1360, providing an output beam that passes through output optics 1370 and creates an output beam 1380 which may be projected on a screen.

[00140] Another option for producing a 3D image simulation is to pass the output images through a single Liquid Crystal phase plate which converts the two linearly polarized output beams of each color sequence into opposed circularly polarized beams, eliminating image degradation by rotation of the viewer's head as occurs with linearly polarized 3D viewing systems.. The wave plate voltage may be optimized for each color in turn and sequenced in synchronization with the illuminating LEDs/LDs.

[00141] The optical projection system shown in Figure 13 provides a relatively limited size image due to the moderately low power of presently available LEDs. The three output beams, e.g. red, green, and blue, are combined with dichroic mirrors when LEDs are employed as light sources but if LDs are used each source can be coupled to an output fiber optic and the three fibers bundled so their outputs are in close proximity, eliminating the need for separate beam collimating lenses and beam combining dichroic mirrors. Advances in LED power potentially will eliminate or reduce restrictions on the size of the image or corresponding power of the beam.

[00142] When a dark scene is projected the image dynamic range of the projected display may be extended by reducing the output power of the light sources and simultaneously increasing the image chip transmission to precisely compensate for the reduced LED/LD outputs. For digitally generated masters, the scene brightness can be coded directly to the three light sources if desired, eliminating the need to pre-scan the image and build a file of source intensity values synchronized with image chip modulation states.

[00143] The LEDs/LDs can also be replaced by a white light source and a rotating colored filter wheel with each color filter appropriately synchronized with the image chip signals. Moreover, the three color display can be extended to include the use of near infra red images if desired for simulation and training purposes. This would involve extending the light sequence to four or more pulses with a corresponding increase in the pulse repetition rate for any given frame rate. Combining a fourth light source (or fourth filter for a white light source) can be accomplished based on the design shown in Fig. 13, for example.

[00144] An alternative is the use of a single image chip illuminated with laser diodes whose outputs, unlike LEDs, are optically polarized. This allows both images of a 3D display to be generated from the same image chip with full optical efficiency but requires the color sequence be cycled at twice the rate, 144 Hertz for a 24 frames per second display, and an electrically driven wave plate be positioned at the output to switch the polarization state prior to each color sequence, i.e. at a 48 Hertz rate. In this configuration the optics is the same as in Figure 13 but with only one image generation LCoS chip. Full optical efficiency is obtained without a faster color sequence cycle rate or a wave plate if 3D effects are not required. The two polarizations, P1, P2, three color RGB sequence for 3D images is shown in Figure 14. The different colors can be pulsed and the polarizations controlled to allow for the repeating sequence, and synchronization with data provided to the LCoS chip results in the desired projected images.

[00145] A similar display system using sequentially pulsed LEDs can be configured using a single image generation chip (LCoS) with maximum light efficiency if both polarizations from the light sources can be directed to the same image chip. This can be accomplished by means of a polarization combining prism which separates an input beam into two polarizations, and rotates one to be oriented similarly to the other. The two halves of the input beam illuminate the two halves of an image generating chip as shown in Figure 15A. A single polarization beam splitter would suffice if half the light from the LEDs were not used.

[00146] Using a light source similar to that of Fig. 13, one can interpose a more complex polarization beam splitter between the light source and an LCoS chip 1360 in display system 1500, resulting in creation of two output beams with the same polarization. Beam splitter 1550 splits a beam into two beams with the same polarization state. By including a half-wave plate 1540 at an interface within the beam splitter 1550, one of the beams (the beam passing through the half-wave plate) is polarization rotated to the same state as the other (the beam passing through the mirror and around the half-wave plate) so each beam illuminates a different half of the LCoS chip with the same polarization. Note that the half-wave plate 1540 extends only through half of the interface with beam splitter 1550 – thus it only interacts with one of the beams and has no effect on the other beam. The result is two beams directed at the LCoS chip 1360 with the same polarization. The resulting output beams 1580 are then directed at a screen, potentially through further projection optics. Note that LCoS chip 1360 may need to have twice the width of the LCoS chips 1360 of Fig. 13, to accommodate the two beams from beam splitter 1550. Alternatively, a lower resolution image can be produced using half of one LCoS chip 1360 for each beam.

[00147] Figure 15B further illustrates the complex polarization beam splitter 1550. Prism 1555 receives light from a light source, and splits it into two light beams having orthogonal polarization states. Mirror 1565 reflects one beam with a first polarization state upward (in this perspective). Half wave plate 1540 rotates the polarization state of the other beam from a second polarization state to the first polarization state. As a result, two beams are transmitted through prism 1575 to a reflective optical component, such as LCoS 1360, with each having the same polarization state. Note that whether the first or second polarization state is chosen is not material. The reflective component then reflects light back (potentially modulated for an image) through prism 1575, which reflects the light from the reflective optical component 1360 as output light 1580.

[00148] The eye sensitivity to frame rates flicker increases with display brightness, requiring faster frame rates for comfortable viewing. The display frame rate is limited by the time to refresh the LCoS imaging chip and the duration of the light pulse for the refreshed image. One means of maximizing the frame rate is to alternately refresh the two polarization states and illuminate the chip not being refreshed, i.e. one chip is being refreshed while the other is being illuminated. This is accomplished by a slightly modified laser diode illumination system where a polarization switch (e.g. a liquid crystal wave plate), is used to alternate the light pulses between two image chips as in Figure 16. This also allows the laser diode illumination of each image chip

for 50% of the time, or 16.66% for each of three colors. The same technique can be used with LEDs if the input (LED output) to the switch is first polarized.

[00149] In the circumstance where the image is projected onto a screen which does not preserve the polarization of the projected light the viewer will not perceive a 3D effect even with polarized glasses. If the 3D images are projected sequentially the 3D effect will be perceived if viewed through active light blocking glasses, operating synchronously with projection of the image. The two sets of images which provide 3D information are seen by the viewer with the glasses alternately blocking and passing the appropriate image sequence to each eye. In such an embodiment, this requires the projected images and the transmission of the glasses be synchronized so the appropriate image is seen. The alternate sides of the glasses are blocked/opened so a different image sequence passes through each side of the viewers glasses. The synchronization of the projected image and the viewer's glasses is achieved by a signal transmitted by the projector and received by the viewer's glasses. One option for achieving this is by a very low power radio frequency signal.

[00150] Turning to Fig. 16, system 1600 uses polarization switch 1345 to produce two differently polarized states of light entering beam splitter 1350. The resulting output light is transmitted through projection optics 1670 to provide output beam 1680, which may be projected on a screen. Polarization switch 1345, as mentioned with regard to Fig. 14, can be used to impart circular polarization, such as clockwise and anti-clockwise polarization, for example.

[00151] The process of some of these embodiments can be further illustrated with reference to Fig. 17. Process 1700 includes programming data for blue light, illuminating blue light, programming data for red light, illuminating red light, programming data for green light and illuminating green light. This round robin process can be repeated for each frame resulting in the projection of an image through the embodiment of Fig. 13, for example. Process 1700 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 1700 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00152] Process 1700 initiates with programming of an LCoS chip with data for display of a blue image at module 1710. At module 1720, a blue light source is illuminated (or a color wheel is turned to blue). This, through use of appropriate optics, results in display of the blue image as modulated by the LCoS chip. At module 1730, the LCoS chip is programmed for display of a red image. Likewise, at module 1740, a red light source is illuminated (or a color wheel is turned to red), and the corresponding red image as modulated by the LCoS chip is displayed. At module 1750, the LCoS chip is programmed for display of a green image. Likewise, at module 1760, a green light source is illuminated (or a color wheel is turned to green), and the corresponding green image as modulated by the LCoS chip is displayed. This process can then be repeated for each frame (or multiple times

for each frame) as needed. Moreover, the process can be expanded for other colors or light sources (e.g. infrared) or changed for a different set of colors (e.g. cyan, magenta, yellow).

[00153] Process 1800 of Fig. 18 illustrates an alternative process for display of an image. Process 1800 includes programming a half-wave plate for a first orientation, programming data and illuminating a light source for each of blue, red and green light, programming the half-wave plate for a second orientation, and then programming data and illuminating a light source for each of blue, red and green light. Thus, process 1800 allows for display of two different polarizations of each of three different light sources (or three types of light). The first and second orientations may be two different (potentially orthogonal) linear polarizations, or two different time-varying polarizations (e.g. circular), for example.

[00154] Process 1800 initiates with programming of a half-wave plate for a first polarization at module 1810. Thus may involve a time-varying polarization or a constant polarization, and thus may involve production of a biasing voltage. At module 1820, an LCoS chip is programmed with data for display of a blue image. At module 1825, a blue light source is illuminated (or a color wheel is turned to blue). Through use of appropriate optics, the blue image as modulated by the LCoS chip is displayed. At module 1830, the LCoS chip is programmed for display of a red image. At module 1835, a red light source is illuminated (or a color wheel is turned to red), and the corresponding red image as modulated by the LCoS chip is displayed. At module 1840, the LCoS chip is programmed for display of a green image. Likewise, at module 1845, a green light source is illuminated (or a color wheel is turned to green), and the corresponding green image as modulated by the LCoS chip is displayed.

[00155] Process 1800 continues with programming of a half-wave plate for a second polarization at module 1850. The process then proceeds to programming an LCoS chip with data for display of a blue image at module 1860. At module 1865, a blue light source is illuminated (or a color wheel is turned to blue), and the blue image as modulated is displayed. The LCoS chip is programmed for display of a red image at module 1870. At module 1875, a red light source is illuminated (or a color wheel is turned to red), and the corresponding red image as modulated by the LCoS chip is displayed. At module 1880, the LCoS chip is programmed for display of a green image. Likewise, at module 1885, a green light source is illuminated (or a color wheel is turned to green), and the corresponding green image as modulated by the LCoS chip is displayed. This process can then be repeated for each frame (or multiple times for each frame) as needed, and can be expanded or changed for other light sources.

[00156] Figure 19A illustrates an embodiment of a system using a computer and a projector. System 1910 includes a conventional computer 1920 coupled to a digital projector 1930. Thus, computer 1920 can control projector 1930, providing essentially instantaneous image data from memory in computer 1920 to projector 1930. Projector 1930 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 1920 may monitor conditions of projector

1930, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 1930.

[00157] Figure 19B illustrates another embodiment of a system using a computer and projector. System 1950 includes computer subsystem 1960 and optical subsystem 1980 as an integrated system. Computer 1960 is essentially a conventional computer with a processor 1965, memory 1970, an external communications interface 1973 and a projector communications interface 1976.

[00158] The external communications interface 1973 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 1976 provides for communication with projector subsystem 1980, allowing for control of LCoS chips (not shown) included in projector subsystem 1980, for example. Thus, projector communications interface 1976 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 1960, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 1950. System 1950 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00159] Figure 21 illustrates yet another embodiment of a computer and projector system. Added to the embodiment of Figure 19B are two optional eyeglass interface components. Eyeglass interface 2190 allows for control of eyeglasses through use of a processor 1965 controlling the projector 1980. Alternatively, eyeglass interface 2195 allows for direct communication between the projector 1980 and eyeglass interface 2195 – thereby allowing for a standalone design, for example. Each of eyeglass interface 2190 and 2195 may be expected to send out signals to control polarized glasses such as those discussed above.

[00160] Figure 20 illustrates an embodiment of a computer which may be used with the projectors of Figures 13, 15 and 16, for example. The following description of Figure 20 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00161] Figure 20 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 2000 interfaces to external systems through the modem or network interface 2020. It will be appreciated that the modem or network interface 2020 can be considered to be part of the computer system 2000. This interface 2020 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00162] The computer system 2000 includes a processor 2010, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 2040 is coupled to the processor 2010 by a bus 2070. Memory 2040 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 2070 couples the processor 2010 to the memory 2040, also to non-volatile storage 2050, to display controller 2030, and to the input/output (I/O) controller 2060.

[00163] The display controller 2030 controls in the conventional manner a display on a display device 2035 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 2030 can, in some embodiments, also control a projector such as those illustrated in Figures 13 and 17, for example. The input/output devices 2055 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 13 and 17, which may be addressed as an output device, rather than as a display. The display controller 2030 and the I/O controller 2060 can be implemented with conventional well known technology. A digital image input device 2065 can be a digital camera which is coupled to an i/o controller 2060 in order to allow images from the digital camera to be input into the computer system 2000. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00164] The non-volatile storage 2050 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory 2040 during execution of software in the computer system 2000. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 2010 and also encompasses a carrier wave that encodes a data signal.

[00165] The computer system 2000 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 2010 and the memory 2040 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00166] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 2040 for execution by the processor 2010. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 20, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00167] In addition, the computer system 2000 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 2050 and causes the processor 2010 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 2050.

[00168] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00169] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00170] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00171] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00172] Further consideration of various embodiments may provide additional insights. In one embodiment, an apparatus is provided. The apparatus includes a first polarizing beam splitter to receive light from an input source and provide a first output with a first polarization and a second output with a second polarization. The apparatus further includes a half-wave plate arranged to receive the first output of the first polarizing beam splitter and provide a half-wave plate output having the second polarization. The apparatus also includes a mirror arranged to receive the second output beam of the first polarizing beam splitter and provide a mirror output having the second polarization. The apparatus may further include a second polarizing beam splitter to receive the half-wave plate output and the mirror output and transmit the half-wave plate output and the mirror output to an external reflective component. The second polarizing beam splitter is further to receive reflected light from the reflective component and to transmit the light from the reflective component as an external output beam. The apparatus may use a reflective component which is an image modulation component.

[00173] In another embodiment, a system is provided. The system includes a housing. The system further includes a first light source coupled to the housing, the first light source providing red light. The system also includes a second light source coupled to the housing, the second light source providing green light. The system further includes a third light source coupled to the housing, the third light source providing blue light. The system also includes a first beam combining optical element and a second beam combining optical element both coupled to the housing. The first beam combining optical element is arranged to receive light from the first light source and the second light source. The second beam combining optical element is arranged to receive light from the first beam combining optical element and from the third light source.

[00174] The system further includes an LCoS assembly coupled to the housing and arranged to receive light from the second beam recombining element. The LCoS assembly includes a polarization beam splitter

arranged to receive light from the second beam combining element. The polarization beam splitter includes a first polarizing beam splitter to receive light from the second beam combining element and provide a first output with a first polarization and a second output with a second polarization. The polarization beam splitter further includes a half-wave plate arranged to receive the first output of the first polarizing beam splitter and provide a half-wave plate output having the second polarization. The polarization beam splitter further includes a mirror arranged to receive the second output beam of the first polarizing beam splitter and provide a mirror output having the second polarization. The polarization beam splitter also includes a second polarizing beam splitter to receive the half-wave plate output and the mirror output and transmit the half-wave plate output and the mirror output to an external reflective component. The second polarizing beam splitter receives reflected light from the reflective component and transmits the light from the reflective component as an external output beam.

[00175] The LCoS assembly further includes a first LCoS chip coupled to receive light from the polarization beam splitter and to reflect modulated light to the polarization beam splitter. The LCoS assembly also includes a second LCoS chip coupled to receive light from the polarization beam splitter and to reflect modulated light to the polarization beam splitter. The LCoS assembly may alternatively include a single LCoS chip coupled to receive light from the polarization beam splitter of both the half-wave plate output and the mirror output and to reflect modulated light to the polarization beam splitter.

[00176] The system may further include a first focusing optical element interposed between the first light source and the first beam recombining optical element to focus light from the first light source on the first beam recombining element. The system may also include a second focusing optical element interposed between the second light source and the first beam recombining optical element to focus light from the second light source on the first beam recombining element. The system may further include a third focusing optical element interposed between the third light source and the second beam recombining optical element to focus light from the third light source on the second beam recombining element. The system may also include output focusing optics coupled to the housing and arranged to focus an output beam of the polarization beam splitter of the LCoS array. In some embodiments, the first beam recombining optical element is a dichroic mirror; and the second beam recombining optical element is a dichroic mirror.

[00177] The system may further include a controller coupled to the first light source, the second light source and the third light source. The controller may also be coupled to control light output of the first light source, the second light source and the third light source. The system may also include a polarization switch coupled to the controller and disposed between the second beam recombining optical element and the LCoS assembly. The polarization switch may be controlled by the controller. The system may also include an eyeglass interface coupled to the controller, the controller to determine signals output by the eyeglass interface. In some embodiments, the first light source is an LED, the second light source is an LED and the third light source is an

LED. In other embodiments, the first light source is a laser diode, the second light source is a laser diode and the third light source is a laser diode. Furthermore, in some embodiments, the polarization switch is a PLZT switch.

[00178] The system may include a processor and a memory coupled to the processor. The system may also include a bus coupled to the memory and the processor. The system may further include a communications path between the processor and each of the first and second LCoS chips. The system may also include an interface coupled to the processor, the interface to receive data from a source external to the system. In some embodiments, the processor provides the controller.

[00179] In another embodiment, a system is presented. The system includes a housing. The system also includes a first light source coupled to the housing, the first light source providing red light. The system further includes a second light source coupled to the housing, the second light source providing green light. The system also includes a third light source coupled to the housing, the third light source providing blue light. Moreover, the system includes a first beam combining optical element and a second beam combining optical element both coupled to the housing. The first beam combining optical element is arranged to receive light from the first light source and the second light source. The second beam combining optical element is arranged to receive light from the first beam combining optical element and from the third light source. The system further includes an LCoS assembly coupled to the housing and arranged to receive light from the second beam recombining element.

[00180] In some embodiments, the LCoS assembly includes a polarization beam splitter arranged to receive light from the second beam combining element. The LCoS assembly further includes a first LCoS chip coupled to receive light of a first polarization from the polarization beam splitter and to reflect modulated light to the polarization beam splitter. The LCoS assembly also includes a second LCoS chip coupled to receive light of a second polarization from the polarization beam splitter and to reflect modulated light to the polarization beam splitter.

[00181] In some embodiments, the system further includes a first focusing optical element interposed between the first light source and the first beam recombining optical element to focus light from the first light source on the first beam recombining element. The system may further include a second focusing optical element interposed between the second light source and the first beam recombining optical element to focus light from the second light source on the first beam recombining element. The system may also further include a third focusing optical element interposed between the third light source and the second beam recombining optical element to focus light from the third light source on the second beam recombining element.

[00182] In some embodiments, the first beam recombining optical element is a dichroic mirror and the second beam recombining optical element is a dichroic mirror. In some embodiments, the system may further include output focusing optics coupled to the housing and arranged to focus an output beam of the polarization beam splitter of the LCoS array. Additionally, in some embodiments, the system further includes a controller

coupled to the first light source, the second light source and the third light source. The controller is coupled to control light output of the first light source, the second light source and the third light source. Moreover, in some embodiments, the controller is to sequence the first light source, the second light source and the third light source.

[00183] The system may further include a polarization switch coupled to the controller and disposed between the second beam recombining optical element and the LCoS assembly, the polarization switch controlled by the controller. The system may also include an eyeglass interface coupled to the controller. The controller is to determine signals output by the eyeglass interface. The system may use a first light source, a second light source and a third light source that are LEDs. Alternatively, the system may use a first light source, a second light source and a third light source that are laser diodes. In some embodiments, the polarization switch is a PLZT switch.

[00184] Some embodiments of such systems may further include a processor and a memory coupled to the processor. Such embodiments may also include a bus coupled to the memory and the processor. Likewise, such embodiments may also include a communications path between the processor and each of the first and second LCoS chips. Additionally, such embodiments may include an interface coupled to the processor, the interface to receive data from a source external to the system.

[00185] In another embodiment, a method is provided. The method includes programming a light modulator with a blue image. The method also includes illuminating a blue light source. The method further includes programming a light modulator with a red image. The method also includes illuminating a red light source. The method further includes programming a light modulator with a green image. The method also includes illuminating a green light source.

[00186] The method may also include programming a half-wave plate to pass light of a first polarization. The method may further include performing the programming of the blue, red and green images and the illuminating of the blue, red and green light sources. The method may likewise include programming a half-wave plate to pass light of a second polarization. The method may further include performing the programming of the blue, red and green images and the illuminating of the blue, red and green light sources. Additionally, the method may include focusing light output from the image modulator as an output beam. Moreover, the method may include controlling sequencing of the illuminating of the red, blue and green light sources.

[00187] In yet another embodiment, a system is provided. The system includes a housing. The system also includes a first light source coupled to the housing, the first light source providing red light. The system further includes a second light source coupled to the housing, the second light source providing green light. The system also includes a third light source coupled to the housing, the third light source providing blue light. The system also includes a first dichroic mirror and a second dichroic mirror both coupled to the housing. The first dichroic mirror is arranged to receive light from the first light source and the second light source, and the second dichroic mirror is arranged to receive light from the first dichroic mirror and from the third light source.

[00188] The system further includes a first focusing optical element interposed between the first light source and the first dichroic mirror to focus light from the first light source on the first beam combining element. The system also includes a second focusing optical element interposed between the second light source and the first dichroic mirror to focus light from the second light source on the first beam combining element. The system further includes a third focusing optical element interposed between the third light source and the second dichroic mirror to focus light from the third light source on the second beam combining element.

[00189] The system also includes a polarization beam splitter arranged to receive light from the second beam combining element. The system further includes a first LCoS chip coupled to receive light of a first polarization from the polarization beam splitter and to reflect modulated light to the polarization beam splitter. The system also includes a second LCoS chip coupled to receive light of a second polarization from the polarization beam splitter and to reflect modulated light to the polarization beam splitter. The system further includes Output focusing optics coupled to the housing and arranged to focus an output beam of the polarization beam splitter of the LCoS array.

[00190] The system also includes a controller coupled to the first light source, the second light source and the third light source. The controller is coupled to control light output of the first light source, the second light source and the third light source. The controller is to sequence the first light source, the second light source and the third light source. The system further includes a processor and a memory coupled to the processor. The system also includes a bus coupled to the memory and the processor. The system further includes a communications path between the processor and each of the first and second LCoS chips and the controller.

Intra-Scene Dynamic Range Increase by Use of Programmed Multi-Step Filter

[00191] In most optical projectors the dynamic range of the projected image is limited by two light levels, one is the brightest level achievable and the other is the lowest level achievable. While the highest level is usually set by the projection lamp power and system transmission, the lowest level is set by several factors, each of which adds light to the dark screen. When a dark screen is projected one contribution is the ambient light level in the theater which is not related to the projector performance. Another is the amount of light placed on the screen by the projector from two sources, the first being the light transmitted as part of the image and the second is the light scattered by the projection optics into the projection lens.

[00192] Both of these are determined as set factors of the light intensity input to the system. For example if the darkest elements of the image generator produce a contrast of 1000:1, (or 30db, 3.0 density), and the scattered light level is also 1 part per thousand, the darkest part of the projected image will be at 2 parts per thousand, or a contrast of 500:1 in a totally dark cinema, i.e. no ambient light. In normal operation theater safety consideration require some ambient lighting, which will further reduce the image contrast seen by the viewer.

[00193] To achieve a large range of brightness on the projected image one may consider that the viewer is not specifically interested in the brightness level, but only the ability to discern scene details at all levels of

brightness. Thus when a dark scene is shown, say 100 times less bright than full light, if the contrast dynamic range is only 500:1 the projected image can have no more contrast than 5:1, causing a low contrast image of 'washed out' appearance, regardless of the higher contrast in the scene at the image generator.

[00194] Hence the dynamic range of the visual experience can be greatly enhanced in a digital projector if the lamp brightness can be reduced when less bright scenes are shown, without causing a reduction in projected image contrast. However it is not necessary to maintain the full dynamic range in lower light level scenes as the human eye performs less well under these circumstances. It is desirable that when a prolonged dark scene is projected that the effective projector lamp brightness be reduced and the digital image be brightened to partially compensate. For example, in the above circumstance where a projected image of 500:1 contrast was reduced to 5:1, had the lamp level been reduced by 10:1 and the transmission at the image generation chip been increased by 10:1, the same screen brightness would be achieved but the contrast would increase to 50:1. Similarly a 50:1 reduction in lamp brightness and corresponding increase in image transmission would give the same screen brightness but an image contrast of 250:1.

[00195] It is therefore advantageous to provide a mechanism to effectively reduce the lamp brightness on demand without it being necessary to turn down the lamp power, which can cause instabilities and offers only a limited range of brightness. One means of doing this is to install a rotary filter wheel in the optical path near the input to the projector and which contains sections of different transmission. A filter wheel with different transmission zones, one being an open aperture, can be quickly rotated into any of several positions to effectively reduce the lamp power and increase the system optical dynamic range.

[00196] In a digitally driven display it is easy to preview the memory and determine which scenes do not exceed certain brightness levels and for how long this condition persists. For example if no area of a scene reaches to within a factor of eight (3 bits) of the maximum brightness for a period exceeding, for example, 1 second and extending for 45 seconds, then a filter reducing the light throughput can be rotated into the optical path for this duration and the display transmission increased by 3 bits on every pixel during the 45 second interval. During the time in question, each frame is displayed with brightness multiplied by a factor of 8 (3 bits) to compensate for the filter, thus maintaining the level of contrast of the projected image.

[00197] This effectively increases the projected scene contrast by the factor of eight (3 bits). A filter having several zones of, for example, 0 (open), 4 and 8 bits will effectively increase the projected inter scene contrast by up to 8 bits or 256, so that a projector with an inter scene dynamic range of say 10 bits (1,024:1) could project scenes over a brightness range of 256x1,000, i.e. 256,000:1 or 18 bits, with a minimum contrast of 1,000 in every scene. In effect the image generator inter scene dynamic range of 1000:1 can be moved down scale by a factor of 256 for different scenes without losing any contrast. The lower usable light level on the display screen is set not by the projected image contrast but the contrast on the screen set by the ambient light level in the theater.

[00198] Pre-selection of filter wheel positions for each reduced brightness scene can be programmed into the projector digital controls so the filter position- scene registration is automatic. Only a few filter steps are necessary in many embodiments. Three filter positions are sufficient in some embodiments, and redundancy can be built into the filter locations, e.g. two positions of each step in a wheel as in Figure 22. The wheel should step to a selected filter location in a bi-directional manner so sudden transition to very dark scenes or transition to bright scenes can quickly be accommodated, i.e. in less than one standard frame time of about 42 milliseconds.

[00199] In further reference to Figure 22, two embodiments of potential filter wheels are illustrated, each of which may be used in various embodiments. Wheel 2200 includes three distinct filters. Filter 2210 is a relatively opaque filter, designed to transmit approximately 1/256th of incident light. Filter 2220 is a partially transmissive filter in this situation, designed to transmit approximately 1/8th of incident light. Filter 2230 is a fully transmissive filter in this situation, designed to transmit all incident light. In some embodiments, filter 2230 may be provided by leaving the hole for the filter open.

[00200] An alternative six position wheel is presented as wheel 2250. Each of filters 2210, 2220 and 2230 is provided twice. Keeping the corresponding filters diametrically opposed in this instance allows for any position of the wheel to provide for an immediate change (one-position rotation) to either of the other two available filter settings. Additionally, unlike wheel 2200, wheel 2250 allows for a reduced step-size (60 degrees, rather than 2220 degrees) when the wheel 2250 is rotated.

[00201] The filter configurations in Figure 22 provide a single step response between any two optical transmission states. Bright flashes in the projected images are avoided by moving the wheel to the desired reduced transmission state immediately after the image moves to a darker state, and the image moved to a darker state immediately before the wheel moves to a higher transmission state. This timing sequence, with filter insertion at A and removal at B, is shown in Figure 23.

[00202] The timing sequence of Figure 23 allows for filter transitions at scene transitions, relying on quick mechanical and electrical transitions in the system. Initially, a bright scene is shown, with full transmission of light. When a transition to a dark scene occurs, the image chip for projection is darkened (adjusting to the new scene), the filter is switched, and the image chip is brightened (to account for the new filter in place). Projection with the filter in place can occur with the full dynamic range of the chip, and thus greater contrast on the screen. When the scene transitions to bright frames again, the filter is switched, and then the image chip is darkened, accounting for the return to greater light in the projector. Without the filter in place, the dynamic range on a dark scene is much lower, whereas with the filter in place, the dynamic range is expanded to allow for more variation.

[00203] The rotary stepping transmission filter can be located in the optical path near the UV-IR reject filter, either just ahead or just behind as desired, depending on the filter material survivability under intense radiation. Figure 24 shows a stepping filter wheel located in the optical path just after the UV-IR reject filter. Note that the filter wheel may be rotated out of plane relative to the other reflective surfaces as long as the excess

light is removed from the optical path. Sideways deflection of the excess light to a dark absorber cooled by an external air flow is potentially desirable, though not specifically illustrated to avoid added complexity in the drawings. This will also provide the shortest increase in the optical path. This option for dynamic range extension is applicable to all digital images and can be invoked at the projected display level without any additional requirement being placed on the original image capture.

[00204] Various projectors may be used with such a filter system. A high efficiency optical design for three color RGB (red, green, blue) image projectors is shown in Figure 24 that uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A randomly polarized white light source (2410) is stripped of IR and UV components by an IR/UV rejection filter (2415) and adjusted for contrast (light level) by filter wheel (2413) to provide input to a first dichroic mirror (DM1 – 2420) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 2430). The remainder of the spectrum passes through the dichroic mirror (2420) to a second dichroic mirror (DM2 – 2425), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 2445). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 2460).

[00205] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 2435, 2440, 2450, 2455, 2465 and 2470). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (2430, 2445 and 2460), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (2475 and 2480) to form a white image (at projection lens image plane 2485) which is focused on a remote screen using a projection lens (2490) to provide output light 2495.

[00206] Application of a voltage to an LCoS chip pixel that is insufficient for 90 degree rotation of the optical polarization results in a smaller rotation of the plane of polarization for a beam reflected from an LCoS chip. The partially rotated beam, on passing back through the polarizing beam splitter is split into two orthogonal polarized components of different intensities that exit the beam splitter in different directions. Thus the intensity of the output beam is reduced in proportion to the degree of polarization rotation (i.e. voltage on the pixel), and the unrotated portion is returned along its entrance path back toward the source.

[00207] The LCoS image generation devices employ a liquid crystal layer sandwiched between a transparent optical surface and a silicon electronic chip which applies a voltage to the liquid crystal layer on a pixel by pixel basis, causing spatially localized polarization rotation of light and thereby enabling an image to be imparted to light input through the transparent surface and reflecting back from the chip surface. The LCoS devices are universally employed in a reflective mode where the reflected light contains the image information.

[00208] Although many optical projection systems have been designed as multicolor displays using reflective LCoS image generation chips, one design the inventor is aware of is not well suited to large high brightness displays. The above referenced design uses four beam splitting cubes and several color absorption filters. It suffers from a low light efficiency as the input light is first split into two polarizations, each of which is then passed through color filters. This implementation causes half of the polarized light to be absorbed in the color filters. The absorbed light significantly heats the filters, trapping the heat between the polarizing cubes. Consequently this design, although compact, is only compatible with low intensity light, perhaps small fractions of a watt. A large screen multi-media display must be capable of transmitting several hundred watts of light, with potentially tens of watts absorbed in the image generating chips.

[00209] In contrast the proposed optical design implementation first separates the input light on a spectral basis, blue, red, then green light, using color separating dichroic mirrors, and each color is then input to its own polarizing beam splitter which directs polarized light to two LCoS image planes, one for each light polarization state. The light is thus spread over six separate LCoS chips. The reflected output images from the three beam splitters each contain both optical polarizations for their respective color, and the colored images are then re-combined using dichroic mirrors. By this means no light is absorbed in color filters and the system is capable of much higher optical power throughput as the dichroic mirrors absorb comparatively little light, and each color path is very efficient with minimal light loss at the LCoS planes. The LCoS image chips are accessible from the rear (the non-image side) and active chip cooling may therefore be employed to maintain each chip within a preferable operating temperature range.

[00210] In one embodiment, the blue light is first separated using a blue reflecting, red and green transmitting dichroic mirror. Blue light is separated first as, for a maximum brightness display, it can least tolerate optical power losses, and some red and green light is lost at the blue reflecting dichroic mirror. Next the red light is separated as this is less tolerant to loss than the green portion of the spectrum.

[00211] After passing through their respective LCoS image planes each color is recombined using dichroic mirrors similar to those used in the initial color separation process. It is noted the two re-combining dichroic mirrors are very angle sensitive as rotations will move the image planes out of registration. In an embodiment, the optical path lengths from the optical source to each LCoS image plane is essentially the same to enable essentially the same illumination fill factor and pattern to be obtained for each image plane. Similarly the three output colored images from the LCoS are all essentially equidistant from the projection lens, thereby enabling all images to be projected in focus.

[00212] The three images are typically combined in the image plane of the projection lens enabling existing projection lenses to be used. The images from the LCoS image generation chips are relayed to the projection lens image plane using standard relay lens techniques to maximize light throughput. The optical paths are arranged so that a single set of relay optics relays the image from each LCoS chip to the projector lens image

plane. The relay optics is configured so the magnification from the LCoS image chips to the output image plane matches the output image plane format.

[00213] The basic optical system of Figure 24 lies in a plane in some embodiments, which minimizes the number of optical elements, thereby minimizing scattered light and maintaining maximum image contrast. Each beam splitting cube is mounted on the same surface and all optical paths are co-planar. This facilitates fabrication and optical alignment. The co-planar layout also facilitates thermal control of the LCoS image generators as 'through the support-plate' airflow in a direction perpendicular to the plane of the optical system is easily configured and keeps the cooling air away from the optical path, reducing the possibility of optical artifacts created by air turbulence.

[00214] The LCoS image projector may use existing projection display components such as lamp hoses and associated power supplies, and available projection lenses. Both lamp houses and projection lenses are typically close to the image plane in film projectors. The light output from the lamp house is therefore relayed to the LCoS image chips by illumination relay optics with a magnification that matches the lamp output area to the image chip area.

[00215] Generally it is desirable to minimize the number of moving parts in any system. One option for doing this in a projector is to replace the filter wheel with an electrically programmable filter that can withstand the high optical energy flux near the lamp source. This can be achieved by a filter made from PLZT ceramic, an electro-optic material that effectively rotates the plane of polarization of an optical beam to a degree set by an applied voltage. The PLZT ceramic wafer is coated with inter-digitated electrodes as shown in Figure 25. The PLZT can have similar electrode patterns on both sides as the polarizing field propagates only a small distance into the material. A typical electrode material is a transparent layer of Tin Oxide, and the electrodes on the two sides are offset to provide relatively uniform transmission. Typical drive voltages are a few hundred volts and the response is limited by the device capacitance and is often about one millisecond.

[00216] With further reference to Figure 25, one may further understand the structure and function of the PLZT. PLZT wafer system 2500 is illustrated with PLZT wafer 2510 having two electrodes 2520 and 2530, and an external voltage source 2540. The electrodes 2520 and 2530 may constitute first and second electrodes, and each may be placed on opposite sides (first and second sides) of wafer 2510. With a reasonable thickness of wafer 2510, the electric field between electrodes 2520 and 2530 will sufficiently penetrate wafer 2510 to change its transmission characteristics. For a material such as tin oxide, the interdigitated electrodes shown will generally suffice to provide a change in transmission characteristics throughout the wafer 2510. The typical effect is a polarization rotation which in conjunction with a linear polarizer produces the effect of a filter with electrically controllable transmission. Edge effects can be avoided by over-sizing the wafer somewhat relative to the optical path for projection.

[00217] For maximum throughput light efficiency the lamp output must first be separated into two polarized components, each of which passes through a PLZT filter of settable transmission before the two components are recombined as in Figure 26. The filter may be configured so the light transmitted is at a maximum, or minimum, or in the mid range, with no applied voltage, depending on the orientation of the electrodes relative to the beam splitters.

[00218] Further reference to Figure 26 may illustrate the use of two parallel PLZT filters. System 2600 provides an optical subsystem which may be used in a projector, for example. Input light 2620 is first split by polarization beam splitter 2630, resulting in two beams with orthogonal polarization. One such beam passes to mirror 2640 and through PLZT filter 2650. The other such beam passes through PLZT filter 2655 and to mirror 2645. Both beams are then recombined at polarization beam splitter 2660 (undergoing a reverse transmission relative to the transmission through beam splitter 2630). This results in output beam 2660, which provides both polarizations of light at a reduced (potentially) intensity.

[00219] An overall process for use of a filter and projector to increase dynamic range in a projector is provided in Figure 27. The process 2700 includes scanning the image data for brightness levels (and storing such information), projecting a frame, adjusting brightness for the next frame, and then projecting the next frame. Process 2700 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 2700 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00220] Process 2700 initiates with a scan of available image data at module 2710. The image data is scanned for brightness levels, and the levels are recorded, along with areas where a different brightness setting (e.g. a different filter or filter setting) may be used. In the case of differing filter voltages, this represents a voltage transition. In the case of different filter elements, this represents a filter transition (e.g. rotating in the proper filter). At module 2720, the first image is projected. At module 2730, a determination is made as to whether the filter needs to change for the next frame (based on the scan of digital data). The transition occurs as necessary. At module 2740, the next frame is displayed. The process may then repeat modules 2730 and 2740 until the scanned data is completely projected, for example.

[00221] The overall system used with various implementations (of the methods and apparatuses described above) may also be instructive. Figure 28A illustrates an embodiment of a system using a computer and a projector. System 2810 includes a conventional computer 2820 coupled to a digital projector 2830. Thus, computer 2820 can control projector 2830, providing essentially instantaneous image data from memory in computer 2820 to projector 2830. Projector 2830 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 2820 may monitor conditions

of projector 2830, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 2830.

[00222] Figure 28B illustrates another embodiment of a system using a computer and projector. System 2850 includes computer subsystem 2860 and optical subsystem 2880 as an integrated system. Computer 2860 is essentially a conventional computer with a processor 2865, memory 2870, an external communications interface 2873 and a projector communications interface 2876.

[00223] The external communications interface 2873 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 2876 provides for communication with projector subsystem 2880, allowing for control of LCoS chips (not shown) included in projector subsystem 2880, for example. Thus, projector communications interface 2876 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 2860, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 2850. System 2850 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00224] Figure 29 illustrates an embodiment of a computer which may be used with the projectors of Figure 24 (such as in the combinations of Figure 28), for example. The following description of Figure 29 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00225] Figure 29 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 2900 interfaces to external systems through the modem or network interface 2920. It will be appreciated that the modem or network interface 2920 can be considered to be part of the computer system 2900. This interface 2920 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00226] The computer system 2900 includes a processor 2910, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 2940 is coupled to the processor 2910 by a bus 2970. Memory 2940 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 2970 couples the processor 2910 to the memory 2940, also to non-volatile storage 2950, to display controller 2930, and to the input/output (I/O) controller 2960.

[00227] The display controller 2930 controls in the conventional manner a display on a display device 2935 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 2930 can, in some embodiments, also control a projector such as those illustrated in Figures 22 and 26, for example. The input/output devices 2955 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 22 and 26, which may be addressed as an output device, rather than as a display. The display controller 2930 and the I/O controller 2960 can be implemented with conventional well known technology. A digital image input device 2965 can be a digital camera which is coupled to an i/o controller 2960 in order to allow images from the digital camera to be input into the computer system 2900. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00228] The non-volatile storage 2950 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory 2940 during execution of software in the computer system 2900. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 2910 and also encompasses a carrier wave that encodes a data signal.

[00229] The computer system 2900 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 2910 and the memory 2940 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00230] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 2940 for execution by the processor 2910. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 29, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00231] In addition, the computer system 2900 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 2950 and causes the processor 2910 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 2950.

[00232] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00233] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00234] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00235] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00236] A further discussion of some potential embodiments may be useful. In one embodiment, a system is provided. The system includes a housing. The system also includes a light source coupled to the housing. The system further includes a light transmission modulating element coupled to the housing and arranged to receive light from the light source. The system also includes an image modulating subsystem arranged to receive light from the light transmission modulating element and coupled to the housing. The system further includes Output focusing optics arranged to receive light from the image modulating subsystem and coupled to the housing.

[00237] The light transmission modulating element may be a filter wheel having a plurality of positions of varying transmissivity. In one embodiment, the filter wheel is a six position filter wheel having three transmissivity levels, with each transmissivity level occupying two positions diametrically opposite a center of the filter wheel. In another embodiment, the filter wheel is a three position filter wheel having three transmissivity levels, one transmissivity level associated with each position. In yet another embodiment, the light transmission modulating element is a PLZT filter.

[00238] In some embodiments, the light transmission modulating element includes a first polarization beam splitter coupled to the housing and arranged to receive light from the light source. The light transmission modulating element also includes a first PLZT filter coupled to the housing and arranged to receive light of a first polarization from the first polarization beam splitter. The light transmission modulating element further includes a second PLZT filter coupled to the housing and arranged to receive light of a second polarization from the first polarization beam splitter. The light transmission modulating element also includes a second polarization beam splitter coupled to the housing and arranged to receive and combine light from the first PLZT filter and the second PLZT filter.

[00239] In yet another embodiment, the image modulating subsystem includes a first LCoS assembly coupled to the housing. The first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. Such an embodiment may further involve the image modulating subsystem further including a second LCoS assembly coupled to the housing. The second LCoS assembly includes a polarization beam splitter coupled

optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. Similarly, the image modulating subsystem may further include a third LCoS assembly coupled to the housing. The third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip.

[00240] In some embodiments, the system further includes an IR/UV rejection optical component disposed between the light source and the light transmission modulating element. In some embodiment, the system may also include a processor and a memory coupled to the processor. Likewise, the system may further include a bus coupled to the memory and the processor. Moreover, the system may further include a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies.

[00241] In another embodiment, a method is provided. The method includes observing a light level of an image of a projector. The method also includes shifting a light transmissivity level of the projector. The method further includes projecting the image based on the light transmissivity level of the projector.

[00242] The method may further include observing a change in light level of the image of the projector. The method may also include shifting the light transmissivity level of the projector again. The method may additionally include projecting the image based on the light transmissivity level of the projector.

[00243] In some embodiments, observing the light level occurs as the image is projected. In some embodiments, observing the light level includes reviewing image data to be projected and recording light transmissivity level settings based on reviewing the image data to be projected. Observing the light level also includes determining a current light transmissivity level setting based on image data associated with the image of the projector. Shifting a light transmissivity level of the projector in such embodiments includes shifting the light transmissivity level of the projector to the current light transmissivity level setting.

[00244] In some embodiments, observing the light level includes determining a current light transmissivity level setting based on image data associated with the image of the projector. Shifting a light transmissivity level of the projector includes shifting the light transmissivity level of the projector to the current light transmissivity level setting. In some embodiments, the light transmissivity level may be set to one of three discrete settings associated with a mechanical component. In other embodiments, the light transmissivity level may be set with an electrical signal based on an electrical response associated with an electronically alterable optical component.

[00245] In yet another embodiment, a method is provided. The method includes reviewing image data to be projected. The method further includes recording light transmissivity level settings based on reviewing the image data to be projected. The method also includes determining a current light transmissivity level setting based on image data associated with an image of a projector. The method further includes shifting the light transmissivity level of the projector to the current light transmissivity level setting. The method also includes projecting the image based on the light transmissivity level of the projector. In some embodiments, the light transmissivity level may be set to a nearly continuously variable magnitude with an electrical signal based on an electrical response associated with an electronically alterable optical component. In other embodiments, the light transmissivity level may be set to one of a plurality of discrete settings associated with a mechanical component.

Projected Overlay for Copy Degradation

[00246] The availability of small hand held video cameras has enabled unauthorized copying of movies in public theater environments and resulted in illegal DVD's appearing for sale. One approach to reduce the incentive for this activity is to degrade the recorded video such that the DVD later offered for sale is of such poor quality as to substantially reduce or eliminate the sale of illicit DVDs. A possible means of degrading the illegally recorded image is to add an overlay image onto the projected movie image that is invisible to the viewer in the theater, but is recorded by hand held video cameras.

[00247] Video cameras separate the image into the blue, green, and red portions of the spectrum for recording and generally use optical pass band filters for this purpose. These filters do not generally have a high level of blocking for portions of the spectrum outside of the visible region. For some cameras a near infra red (IR), image projected onto the screen will be recorded along with the red image, but will be invisible to the unaided human eye. Projected intensities in the infra-red will be sufficiently low at the screen as to hold no risk of eye damage to the theater viewer, but will degrade the image recorded by video cameras. Once recorded along with the red portions of the movie on the 'red' image sensor in the video camera, the IR overlay will not be separable and when the captured video is replayed it will appear as a red image superposed on the original movie. The effectiveness of the image degradation technique will vary with the video camera used to capture the illicit image as color separation filters and detectors differ with camera type.

[00248] Turning to the specific components of Fig. 30, a high efficiency optical design for three color RGB (red, green, blue) image projectors is shown. This embodiment uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A randomly polarized white light source (3010) is stripped of IR and UV components by an IR/UV rejection filter (3015) input to a first dichroic mirror (DM1 – 3020) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 3030). The remainder of the spectrum passes through the dichroic mirror (3020) to a second dichroic mirror (DM2 – 3025), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 3045). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 3060).

[00249] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 3035, 3040, 3050, 3055, 3065 and 3070). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (3030, 3045 and 3060), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (3075 and 3080) to form a white image (at projection lens image plane 3085) which is focused on a remote screen using a projection lens (3090) to provide output light 3095.

[00250] Two possible approaches exist in regard to an IR overlay image: one where the false 'red' IR image is precisely aligned with the real image, and one where it is not. The first approach is discussed further below. In the second approach the IR image is not accurately registered to the movie image but is simply a low resolution image independently aimed at the movie screen.

[00251] The IR light source for this can be either the same broadband lamp source used in the projector, or a separate lamp. The IR may also be obtained from Light Emitting Diodes (LEDs), or laser diode (LD) sources. Use of a separate IR source would enable IR image projection without the need for customized projectors and would enable use with existing equipment, including standard film projectors. Figure 31 shows a typical RGB digital projector using LCoS image chips where the IR for the overlay is obtained from the projection lamp. As suggested in the figure, the IR source illuminating the slide can be pulsed at an annoying flicker rate by use of a chopper wheel to interrupt the IR image on the screen.

[00252] Turning to Fig. 31, the embodiment illustrated is provided by adding components to the embodiment of Fig. 30. Similar modifications may be made to other projectors to achieve a similar type of functionality. System 3100 includes an IR reflector 3115, chopper wheel 3125, focusing optics 3135, IR slide 3145, projection optics 3155, all of which produce an IR output beam 3165. IR reflector 3115 reflects IR radiation rejected by rejection optics (filter) 3015 through a chopper wheel 3125 and into focusing optics 3135. Chopper wheel 3125 may selectively block or transmit radiation (light), allowing for pulsing of an image without pulsing a light source. Radiation focused by optics 3135 is then transmitted through IR slide 3145, to form an image – IR slide 3145 has a pre-defined image which is imposed on the IR radiation. Projection optics 3155 then focus the resulting image for projection on a screen, resulting in projection beam 3165, which can be projected on a screen.

[00253] A process of operating a projector such as that of Fig. 31 can be found in Fig. 32. Process 3200 includes receiving image data, programming the image data, projecting using the image data, and projecting an infra-red image. Process 3200 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules

designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 3200 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00254] Process 3200 begins a cycle at module 3210 with receipt of image data for a frame. At module 3220, the image data is programmed into the appropriate display device, such as through programming of an LCoS chip (or set of chips), for example. At module 3230, projection of an image (using red, green and blue light, for example) occurs using the image data. At module 3240, an infra-red image (independent of the image data) is also projected. Thus, modules 3230 and 3240 may operate simultaneously, for example. Additionally, one may expect process 3200 to repeat, such as on a frame-by-frame basis.

[00255] Static or pulsed IR images intended to degrade copied video can be obtained by using a lamp, LED, or laser diode (LD) source that projects a fixed image of a slide to the screen. Images such as a 'skull and cross bones', a snake, scorpion, or some similar widely recognized symbol or legend are easily projected. More complex legends could include the identification of the cinema from which the image was taken and perhaps the time and date of recording.

[00256] An example of an original image and a degraded image can be found in Fig. 33. Fig. 33A illustrates an image which may be projected on a screen. Fig. 33B illustrates another image, in which red bars are superimposed on the image of Fig. 33A. In such an image, the red bars may be projected at infra-red (IR) images. When the projected image is recorded by a video-recorder that does not filter out near-IR, the IR image will likely be recorded as red, and thus will play back as red rather than IR. Thus, the recorded image will appear to be that of Fig. 33B, even though the image visible on the screen to most viewers was that of Fig. 33A at the time of the recording.

[00257] For both dynamic and static IR overlays using LED or LD sources the degree of image degradation can be enhanced by pulsing the IR image at the eye response rate, at about 8-10 Hertz. This would cause the illicit image to flicker at an annoying rate when replayed. Additionally, to maximize the IR intensity on the screen for a given laser diode source an image could be projected using a hologram, or computer generated hologram (CGH). Alternately, a group of IR LEDs could be imaged onto the projection screen and moved around by prisms or mirrors to produce a similar effect. Switching the LEDs randomly on and off would produce the effect of a swarm of fireflies on the screen.

[00258] In an embodiment using polarization combining optics to reduce the number of LCoS image chips to three as shown in Figure 34, one may provide a projection system with fewer LCoS chips. Thus, Figure 34 provides an illustration of another embodiment of an LCoS image projector. A randomly polarized white light source (3410) is stripped of IR and UV components by an IR/UV rejection filter (3415) input to a first dichroic mirror (3415) which reflects the blue portion of the spectrum to a half-wave plate 3440 and a polarizing beam splitter (3430). The remainder of the spectrum passes through the dichroic mirror (3415) to a second dichroic

mirror (3420), which reflects the red portion of the spectrum to a second half wave plate 3455 and polarizing beam splitter (3445). The remaining spectrum passes to a third half wave plate 3470 and polarizing beam splitter (3460).

[00259] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, one of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 3435, 3450 and 3465). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. The half wave plates 3440, 3455 and 3470 may be electronically controlled to determine whether light (polarization) is rotated or not, allowing for output of both polarizations on a sequential basis.

[00260] Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (3430, 3445 and 3460), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (3475 and 3480) to form a white image (at projection lens image plane 3485) which is focused on a remote screen using a projection optics (3490) to provide output light 3495. Focusing to plane 3485 may involve additional optics 3483. Furthermore, each of LCoS chips 3435, 3450 and 3465 are provided with a TEC (3437, 3452 and 3467 respectively) and associated air plenum (3439, 3454 and 3468 respectively) to provide cooling.

[00261] One may add a fourth set of optics and LCoS chips to the embodiment of Fig. 34 in order to provide IR projection capabilities. Similarly, one may add a fourth set of optics and LCoS chips to the embodiment of Fig. 30 to implement IR projection, too. A process of operating such a device is provided in the illustration of Fig. 35.

[00262] Fig. 35 provides an illustration of an embodiment of a process of operating a projector with IR capabilities. Process 3500 includes receiving image data, programming the image data, and projecting based on the image data. Process 3500 begins its cycle at module 3510 with receipt of image data. This image data is then programmed into a modulation component, such as an LCoS chip or set of chips in a display at module 3520. At module 3530, the projector displays an image based on the programmed image data. In the case of a projector with IR capabilities, image data may be expected to arrive with four components, for red (R), green (G), blue (B) and infra-red (IR). Each may be programmed into individual modulation components, or sequentially programmed into a single modulation component, for example. Thus, a projected image with an IR component can be provided. In applications where IR projection is desired, such as simulation of night vision conditions for example, this can be perceptible to viewers of the projection.

[00263] In such circumstances, in addition to the copy degradation aspects of the IR image, some applications exist where an accurately positioned dynamic IR image overlay is desired for training purposes. These applications include circumstances where IR sources are intentionally simulated for detection by IR

sensitive night vision devices or thermal viewing devices. Depending on the application and effects desired, IR images can be projected as dynamic video, pulsed non-dynamic images, or as static images. For dynamic images generated from digital video using RGB image chips such as in LCoS projectors the IR image is obtained by adding a fourth image chip.

[00264] The four chip projector could also be used for image degradation as this would allow, for example, the inverse of the red image to be shown in the IR so the illicit recorded image would show the red frame as of uniform brightness, causing the illicit video to show only blue and green frames, causing false colors and reducing image contrast. E.g., a formerly red object will appear black, and a formerly blue-green scene will appear white. Alternatively the green or blue image portions could be projected in the IR, and the scene would then show as red on top of the blue or green, generating odd colors, or the inverse image displayed could vary in a random sequence.

[00265] The overall system used with various implementations may also be instructive. Figure 36A illustrates an embodiment of a system using a computer and a projector. System 3610 includes a conventional computer 3620 coupled to a digital projector 3630. Thus, computer 3620 can control projector 3630, providing essentially instantaneous image data from memory in computer 3620 to projector 3630. Projector 3630 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 3620 may monitor conditions of projector 3630, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 3630.

[00266] Figure 36B illustrates another embodiment of a system using a computer and projector. System 3650 includes computer subsystem 3660 and optical subsystem 3680 as an integrated system. Computer 3660 is essentially a conventional computer with a processor 3665, memory 3670, an external communications interface 3673 and a projector communications interface 3676.

[00267] The external communications interface 3673 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 3676 provides for communication with projector subsystem 3680, allowing for control of LCoS chips (not shown) included in projector subsystem 3680, for example. Thus, projector communications interface 3676 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 3660, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 3650. System 3650 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00268] Figure 37 illustrates an embodiment of a computer which may be used with the projectors of Figures 30, 31 and 34, for example. The following description of Figure 37 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00269] Figure 37 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 3700 interfaces to external systems through the modem or network interface 3720. It will be appreciated that the modem or network interface 3720 can be considered to be part of the computer system 3700. This interface 3720 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00270] The computer system 3700 includes a processor 3710, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 3740 is coupled to the processor 3710 by a bus 3770. Memory 3740 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 3770 couples the processor 3710 to the memory 3740, also to non-volatile storage 3750, to display controller 3730, and to the input/output (I/O) controller 3760.

[00271] The display controller 3730 controls in the conventional manner a display on a display device 3735 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 3730 can, in some embodiments, also control a projector such as those illustrated in Figures 30 and 34, for example. The input/output devices 3755 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 30 and 34, which may be addressed as an output device, rather than as a display. The display controller 3730 and the I/O controller 3760 can be implemented with conventional well known technology. A digital image input device 3765 can be a digital camera which is coupled to an i/o controller 3760 in order to allow images from the digital camera to be input into the computer system 3700. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00272] The non-volatile storage 3750 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into

memory 3740 during execution of software in the computer system 3700. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 3710 and also encompasses a carrier wave that encodes a data signal.

[00273] The computer system 3700 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 3710 and the memory 3740 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00274] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 3740 for execution by the processor 3710. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 37, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00275] In addition, the computer system 3700 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 3750 and causes the processor 3710 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 3750.

[00276] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00277] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00278] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00279] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00280] At least one of the optical elements discussed previously bears further discussion. Figures 38A and 38B illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiment of Figure 34, for example. Various display systems using various light sources can be configured using a single image generation chip (LCoS) with maximum light efficiency if both polarizations from the light sources can be directed to the same image chip. This can be accomplished by means of a polarization combining prism which separates an input beam into two polarizations, and rotates one to be oriented similarly to the other. The two halves of the input beam illuminate the two halves of an image generating chip (or other reflective optical component) as shown in Figure 38A. A single polarization beam splitter would suffice if half the light from the light source were not used, but this allows for greater efficiency.

[00281] Using a light source similar to that of Fig. 30, one can interpose a more complex polarization beam splitter between the light source and an LCoS chip 3860 in display system 3800, resulting in creation of two output beams with the same polarization. Beam splitter 3850 splits a beam into two beams with the same polarization state. By including a half-wave plate 3840 at an interface within the beam splitter 3850, one of the

beams (the beam passing through the half-wave plate) is polarization rotated to the same state as the other (the beam passing through the mirror and around the half-wave plate) so each beam illuminates a different half of the LCoS chip with the same polarization. Note that the half-wave plate 3840 extends only through half of the interface with beam splitter 3850 – thus it only interacts with one of the beams and has no effect on the other beam. The result is two beams directed at the LCoS chip 3860 with the same polarization. The resulting output beams 3880 are then directed at a screen, potentially through further projection optics. Note that LCoS chip 3860 may need to have twice the width of the LCoS chips 3060 of Fig. 30, to accommodate the two beams from beam splitter 3850. Alternatively, a lower resolution image can be produced using half of one LCoS chip 3060 for each beam.

[00282] Figure 38B further illustrates the complex polarization beam splitter 3850. Prism 3855 receives light from a light source, and splits it into two light beams having orthogonal polarization states. Mirror 3865 reflects one beam with a first polarization state upward (in this perspective). Half wave plate 3840 rotates the polarization state of the other beam from a second polarization state to the first polarization state. As a result, two beams are transmitted through prism 3875 to a reflective optical component, such as LCoS 3860, with each having the same polarization state. Note that whether the first or second polarization state is chosen is not material. The reflective component then reflects light back (potentially modulated for an image) through prism 3875, which reflects the light from the reflective optical component 3860 as output light 3880.

[00283] Further consideration of various embodiments may prove helpful. In an embodiment, a system is provided. The system includes a visible light projector including a light source, light modulator, and projection optics. The system also includes an infra-red image generator to receive infra-red light from the light source. The system further includes focusing optics coupled to the infra-red image generator to produce an infra-red output beam.

[00284] In various embodiments, The light modulator may be a first LCoS assembly, a second LCoS assembly and a third LCoS assembly, each coupled to optical elements to receive light from the light source and each coupled to the projection optics to produce a visible light output beam. The optical elements may include an infra-red rejection filter interposed between the light modulator and the light source. Moreover, the optical elements may further include a first dichroic mirror interposed between the infra-red rejection filter and the first LCoS assembly and a second dichroic mirror interposed between the first dichroic mirror and each of the second LCoS assembly and the third LCoS assembly. The infra-red image generator may include an infra-red LCoS assembly.

[00285] In some embodiments, the system may further include a chopper wheel interposed between the infra-red image generator and the light source. The system may likewise include an infra-red image generator that includes a patterned slide. Moreover, the system may include an infra-red LCoS assembly that generates a pattern

displaying a location identifier and date code in the infra-red output beam. In other embodiments, the patterned slide includes a location identifier.

[00286] In some embodiments, each LCoS assembly includes a polarization beam splitter, a first LCoS chip coupled to the polarization beam splitter to receive light of a first polarization and a second LCoS chip coupled to the polarization beam splitter to receive light of a second polarization. In some embodiments, the infra-red LCoS assembly generates images for use in conjunction with night-vision equipment.

[00287] In another embodiment, a method is presented. The method includes projecting a conventional image in a visible light spectrum. The method further includes projecting an infra-red image simultaneously in an infra-red spectrum. The method may further include interrupting a light source for the projecting of the infra-red image.

[00288] The method may also include projecting an infra-red image that obscures the conventional images when both images are perceived. Likewise, the infra-red image may be an identifier of a date and location of projection. Similarly, the infra-red image may be an identifier of a location of projection. Moreover, the infra-red image may be an image for perception by night-vision apparatus. Additionally, the infra-red image may be a Jolly Roger pirate flag.

[00289] In yet another embodiment, a system is presented. The system includes a housing. The system further includes a first LCoS assembly coupled to the housing. The first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip.

[00290] The system further includes a second LCoS assembly coupled to the housing. The second LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization. The second LCoS chip is to receive and modulate light of a second polarization. The second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. The system also includes a third LCoS assembly coupled to the housing. The third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip.

[00291] The system further includes a coolant circulation system coupled to the housing and coupled to the heat sinks of the first, second and third LCoS assemblies. The system also includes a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter is arranged to split incoming light

between the first LCoS assembly and the second beam splitter. The second beam splitter is arranged to split incoming light between the second LCoS assembly and the third LCoS assembly. The system also includes an IR/UV rejection optical component disposed between the light source and the first beam splitter.

[00292] The system further includes a first dichroic mirror and a second dichroic mirror both coupled to the housing. The first dichroic mirror is arranged to receive light from the first LCoS assembly and the second LCoS assembly. The second dichroic mirror is arranged to receive light from the first beam recombiner and from the third LCoS assembly. The system also includes a first light source to provide incoming light to the first beam splitter. The system further includes an output optics element coupled to the housing and arranged to receive light from the second dichroic mirror and to focus an output light source.

[00293] The system further includes an infra-red image generator coupled to the housing to receive infra-red light from the light source. The system also includes focusing optics coupled to the housing and coupled to the infra-red image generator to produce an infra-red output beam. The system further includes a processor, a memory coupled to the processor, and a bus coupled to the memory and the processor. The system also includes a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies. The system further includes an interface coupled to the processor, the interface to receive data from a source external to the system.

[00294] The infra-red image generator may include (in some embodiments) an infra-red LCoS assembly. The infra-red LCoS assembly may include a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip. The first LCoS chip is to receive and modulate light of a first polarization and the second LCoS chip is to receive and modulate light of a second polarization. The second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip. The infra-red image generator may also include a chopper wheel and a patterned slide, each coupled to the housing and coupled to receive the infra-red light from the light source and modulate the infra-red light.

Arrays of LEDS /Laser Diodes for Large Screen Projection Displays

[00295] The projectors used to illuminate large screens with image generated by dynamic image chips such as LCoS devices typically use broad band optical sources that generate substantial optical energy outside the visible band of interest. Smaller display screens can use Laser Diodes (LD's) or Light Emitting Diodes (LED's) as sources that only emit light in the spectral region of interest. A major limitation of present LD/LED devices is limited brightness. One means to ameliorate this limitation is to use multiple devices and combine outputs optically. Typically this is achieved by dichroic mirrors, but this quickly becomes mechanically complex if more than a few sources are utilized.

[00296] The spectral band output by LEDs is typically about 30nm wide and that from LDs is even smaller, perhaps only 5nm wide. A number of these narrow spectral outputs with different wavelengths can be combined by reflecting each from the same region of a diffraction grating but with each input to the grating at a

different angle so that the multiple outputs are collinear. It is potentially useful that the output of each individual source first be collimated by use of a small lens close to the LD/LED as in Figure 39. The figure shows the sources arranged in a small circular arc with their individual collimating lenses centered on their respective output beams so that the collimated outputs illuminate the same area on the diffraction grating and combine to form a single output beam covering a wide spectral gamut, although an RGB array with only three sources is likewise feasible. Also, note that the arc arrangement is not necessarily required for operation – it is useful for illustration purposes in particular.

[00297] Referring in more detail to Figure 39, an array of sources is shown, along with focusing optics and a diffraction grating. System 3900 provides an output beam 3920 resulting from sources S1-Sn providing light to diffraction grating 3910 through focusing optics L1-Ln. Sources S1-Sn can be laser diodes or LEDs of selected wavelengths. Thus, a spectral distribution of light can be provided which varies depending on which sources are turned on or pulsed.

[00298] As illustrated, sources S1-Sn are arranged in an arc, with focusing optics L1-Ln (here represented as lenses) arranged in a corresponding arc. However, other arrangements resulting in a similar pattern of beams to diffraction grating 3910 can provide similar results. Moreover, diffraction grating 3910 can be replaced by a curved diffraction grating in some instances (with potentially different light output geometry).

[00299] The visible spectrum covers the range of wavelengths between nominally 400nm and 700nm, allowing for up to ten LEDs of different wavelengths, each with about a 30nm wide output, to be combined by the grating. For laser diodes with a 5nm or less spectral width the technique will, in principle, allow as many as sixty LD outputs of different wavelengths to be combined over the spectral region. The technique readily allows extension of the spectral region into the near infra-red if desired for simulation or security reasons.

[00300] The output wavelength of laser diodes and light emitting diodes changes with temperature so the block of sources shown in Figure 39 may be mounted in a single block of conductive material, e.g. copper, which is maintained at the same temperature by several thermo-electric coolers (TECs). These devices transfer heat from one side of the device to the other, and the hot side of the devices are cooled by an ambient air flow or by liquid coolant if desired. Temperature control of the sources will enable pulsing at higher output levels and various pulse rates and duration without significant output wavelength drift.

[00301] The outputs of LEDs are not polarized but LD outputs are plane polarized. This enables two oppositely polarized beams to be combined by means of a broadband polarizing beam splitter placed in the output beam from diffractive beam combining systems as in Figure 40. The two diffraction combiners may be out of plane, i.e. the arc of one at right angles to the arc of the other.

[00302] Turning to Figure 40 in more detail, a system 4000 is provided with two sets of sources (S1-Sn and S11-S1n), and corresponding optical elements. Sources S1-Sn are focused through focusing optics L1-Ln to provide light to diffraction grating 4010, leading to a beam of light to polarization combiner 4040. Sources S11-

S1n are likewise focused through focusing optics L11-L1n to provide light to diffraction grating 4030, similarly leading to a beam of light to polarization combiner 4040. Polarization combiner 4040 then combines the two beams of light to produce output beam 4020. In some embodiments, this results in an output beam with two orthogonal polarization components (which can then be separated again). Alternatively, one may pulse the two sets of sources (S1-Sn and S11-S1n) in an alternating sequence, resulting in time-varying polarization.

[00303] As mentioned previously, the arc geometry of sources may not be needed. It may also not be practical. Figure 41 illustrates an embodiment of an array of sources on a substrate. Substrate 4100 has fabricated thereon (or within) sources S1, S2, S3, S4 and Sn (each represented by pn junctions in a semiconductor substrate, for example). With appropriate optics arranged above, these sources can be focused on to a common optical element, such as a diffraction grating, leading to a similar arrangement to that shown in Figure 39, for example. Figure 42, in turn, provides apparatus 4200, which includes the substrate 4100 of Figure 41, and an additional cooling layer 4210. Cooling layer 4210 may include a simple high conductivity backing (e.g. copper), or may include a more sophisticated cooling apparatus, such as a heat sink or thermal electric cooler, for example. Cooling layer 4210 may be expected to maintain substrate 4100 at a common and desired temperature, assuming normal operation of the cooling layer 4210. Note that in some embodiments, substrates 4100 and 4200 will provide a surface for LEDs or diodes originally fabricated on other substrates. In such embodiments, substrates 4100 and 4200 provide a common cooling platform, which then allows for a relatively uniform wavelength of light generated over time.

[00304] Process 4300 of Figure 43 provides further illustration of creation of an array of sources. Process 4300 includes providing the light sources (e.g. fabricating a wafer with light sources), aligning a desired output with a beam collector, aligning optics and the source substrate with the beam collector, and providing cooling for the sources. Process 4300 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 4300 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00305] Process 4300 initiates with creation or provision of light sources, such as an array of LEDs or laser diodes at module 4310. At module 4320, a beam collector (a component such as a diffraction grating) is aligned with a desired output. At module 4330, a source substrate or other set of light sources is aligned with optical elements and the beam collector such that the light sources provide light to the desired output. At module 4340, cooling is provided for the light sources, such as through use of a thermo-electric cooler, for example. Through this process, one may provide a light source with a variety of sources.

[00306] To further increase brightness each source S in Figures 39 and 40 can be an array of LEDs or laser diodes. Each source can also be the output end of a closely packed bundle of fiber optic pigtails, the other

end of each fiber in a bundle being attached to a laser diode of like output wavelength. In this manner the outputs of many laser diodes can be combined, although the spatial separation of the fiber outputs increases the effective spread of the output beam.

[00307] Each source in figures 39 and 40 can be a small closely packed two dimensional (2D) array of LEDs or laser diodes of like wavelength. The optical system is configured so each source is located in a pupil of the optical system that illuminated the image generating chip, the size of each source 2D array being determined by the acceptance field angle of the final projection lens, referenced back to the source array location. For a typical projection lens with an input format of 12x24mm, for example, a number of LEDs/LDs combined to form a source in the array depends on the physical size of the semiconductor chip, LED or LD, in the array. For example with a 2x2mm chip (die) size the array can contain as many as 6x12 dies or 72 individual diode sources.

[00308] To gather the output of this many diodes into a single beam a similarly sized array of lenses with the same center to center spacing as the dies is placed just in front of the laser source array to collimate the individual beams. The output for an LED is typically a wide cone, and a spherical lens is used for collimation; a laser diode typically has an output beam that is 5x 30 degrees and requires a cylindrical lens to collimate the beam. The output of the diode array is thus collimated and reflected from the diffraction grating coaxial with other similar beams to illuminate an LCoS image generating chip.

[00309] One useful configuration is to use a remote pupil imaging system that images the diode array into the pupil of a lens used to relay the image of the LCoS chip to the input plane of a projection lens. If a 3D display is required utilizing a diode array source then two polarizations are required that can be pulsed sequentially. The outputs from two similar diode arrays can be combined through a polarization element, or each alternate diode in the array can be rotated in a checker-board pattern to provide both planes of polarization, so the output polarization is selectable on a pulse by pulse basis.

[00310] The arrays of closely packed optical diodes will generate significant heat load in a small area, for example with an array of 72 diodes with each diode consuming 1 Watt of input power, the 6x12 diode array will generate 72 watts in 2.88 square centimeters, a heat load of 25 watts per square centimeter. This will require active cooling of the common heat sink on which each diode array is mounted. The active cooling can be achieved by Thermo-electric coolers or by a closed or open cycle liquid cooler.

[00311] The estimated optical power to achieve full brightness on a large screen is in the order of 30-100watts, and with laser diodes at perhaps 20% efficiency this implies 150-500 watts of input power, or 150 to perhaps 750 separate sources. The lower end of this range is at least marginally feasible with existing diodes and the approach will become increasingly viable as optical diodes of greater output power and efficiency become available.

[00312] A process of operating the light source may also be useful. Figure 44 illustrates an embodiment of a process 4400 for operating a light source. Process 4400 includes illuminating light sources, focusing source output on a beam collector, collecting beams to form an output light beam, and projecting the output light.

[00313] Process 4400 initiates with projection or illumination of light sources at module 4410. At module 4420, the light source output is focused on a beam collector, such as a diffraction grating or a parabolic optical element. At module 4430, the various focused beams are collected to provide an output beam. At module 4440, the output beam is then projected, such as into a projection system.

[00314] The overall system used with various implementations (of the methods and apparatuses described above) may also be instructive. Figure 45A illustrates an embodiment of a system using a computer and a projector. System 4510 includes a conventional computer 4520 coupled to a digital projector 4530. Thus, computer 4520 can control projector 4530, providing essentially instantaneous image data from memory in computer 4520 to projector 4530. Projector 4530 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 4520 may monitor conditions of projector 4530, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 4530.

[00315] Figure 45B illustrates another embodiment of a system using a computer and projector. System 4550 includes computer subsystem 4560 and optical subsystem 4580 as an integrated system. Computer 4560 is essentially a conventional computer with a processor 4565, memory 4570, an external communications interface 4573 and a projector communications interface 4576.

[00316] The external communications interface 4573 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 4576 provides for communication with projector subsystem 4580, allowing for control of LCoS chips (not shown) included in projector subsystem 4580, for example. Thus, projector communications interface 4576 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 4560, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 4550. System 4550 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00317] Figure 46 illustrates an embodiment of a computer which may be used with systems of Figure 45, for example. The following description of Figure 46 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and

other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00318] Figure 46 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 4600 interfaces to external systems through the modem or network interface 4620. It will be appreciated that the modem or network interface 4620 can be considered to be part of the computer system 4600. This interface 4620 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00319] The computer system 4600 includes a processor 4610, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 4640 is coupled to the processor 4610 by a bus 4670. Memory 4640 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 4670 couples the processor 4610 to the memory 4640, also to non-volatile storage 4650, to display controller 4630, and to the input/output (I/O) controller 4660.

[00320] The display controller 4630 controls in the conventional manner a display on a display device 4635 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 4630 can, in some embodiments, also control a projector such as those illustrated in Figures 39 and 43, for example. The input/output devices 4655 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 39 and 43, which may be addressed as an output device, rather than as a display. The display controller 4630 and the I/O controller 4660 can be implemented with conventional well known technology. A digital image input device 4665 can be a digital camera which is coupled to an i/o controller 4660 in order to allow images from the digital camera to be input into the computer system 4600. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00321] The non-volatile storage 4650 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory 4640 during execution of software in the computer system 4600. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 4610 and also encompasses a carrier wave that encodes a data signal.

[00322] The computer system 4600 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 4610 and the memory 4640 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00323] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 4640 for execution by the processor 4610. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 46, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00324] In addition, the computer system 4600 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 4650 and causes the processor 4610 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 4650.

[00325] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00326] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or

"displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00327] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00328] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00329] Various projectors may be used with such a filter system. A high efficiency optical design for three color RGB (red, green, blue) image projectors is shown in Figure 47 that uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A light source (4710) is stripped of IR and UV components by an IR/UV rejection filter (4715) to provide input to a first dichroic mirror (DM1 – 4720) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 4730). The remainder of the spectrum passes through the dichroic mirror (4720) to a second dichroic mirror (DM2 – 4725), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 4745). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 4760).

[00330] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 4735, 4740, 4750, 4755, 4765 and 4770). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (4730, 4745 and 4760), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (4775 and 4780) to form a white image (at projection lens image plane 4785) which is focused on a remote screen using a projection lens (4790) to provide output light 4795.

[00331] Application of a voltage to an LCoS chip pixel that is insufficient for 90 degree rotation of the optical polarization results in a smaller rotation of the plane of polarization for a beam reflected from an LCoS chip. On passing back (of the beam) through the polarizing beam splitter the rotated beam is split into two orthogonal polarized components of different intensities that exit the beam splitter in different directions. Thus the intensity of the output beam is reduced in proportion to the degree of polarization rotation (i.e. voltage on the pixel), and the unrotated portion is returned along its entrance path back toward the source.

[00332] Although many optical projection systems have been designed, multicolor displays using reflective LCoS image generation chips, one design the inventor is aware of is not well suited to large high brightness displays. The LCoS image generation devices employ a liquid crystal layer sandwiched between a transparent optical surface and a silicon electronic chip which applies a voltage to the liquid crystal layer on a pixel by pixel basis, causing spatially localized polarization rotation of light and thereby enabling an image to be imparted to light input through the transparent surface and reflecting back from the chip surface. The LCoS devices are universally employed in a reflective mode where the reflected light contains the image information.

[00333] The above referenced design uses four beam splitting cubes and several color absorption filters. It suffers from a low light efficiency as the input light is first split into two polarizations, each of which is then passed through color filters. This implementation causes half of the polarized light to be absorbed in the color filters. The absorbed light significantly heats the filters, trapping the heat between the polarizing cubes. Consequently this design, although compact, is only compatible with low intensity light, perhaps small fractions of a watt. A large screen multi-media display must be capable of transmitting several hundred watts of light, with potentially tens of watts absorbed in the image generating chips.

[00334] In contrast the proposed optical design implementation first separates the input light on a spectral basis, blue, red, then green light, using color separating dichroic mirrors, and each color is then input to its own polarizing beam splitter which directs polarized light to two LCoS image planes, one for each light polarization state. The light is thus spread over six separate LCoS chips. The reflected output images from the three beam splitters each contain both optical polarizations for their respective color, and the colored images are then re-combined using dichroic mirrors. By this means no light is absorbed in color filters and the system is capable of much higher optical power throughput as the dichroic mirrors absorb comparatively little light, and each color path is very efficient with minimal light loss at the LCoS planes. The LCoS image chips are accessible from the rear (the non-image side) and active chip cooling may therefore be employed to maintain each chip within a preferable operating temperature range.

[00335] In one embodiment, the blue light is first separated using a blue reflecting, red and green transmitting dichroic mirror. Blue light is separated first as, for a maximum brightness display, it can least tolerate optical power losses, and some red and green light is lost at the blue reflecting dichroic mirror. Next the red light is separated as this is less tolerant to loss than the green portion of the spectrum.

[00336] After passing through their respective LCoS image planes each color is recombined using dichroic mirrors similar to those used in the initial color separation process. It is noted the two re-combining dichroic mirrors are very angle sensitive as rotations will move the image planes out of registration. In an embodiment, the optical path lengths from the optical source to each LCoS image plane is essentially the same to enable essentially the same illumination fill factor and pattern to be obtained for each image plane. Similarly the three output colored images from the LCoS are all essentially equidistant from the projection lens, thereby enabling all images to be projected in focus.

[00337] The three images are typically combined in the image plane of the projection lens enabling existing projection lenses to be used. The images from the LCoS image generation chips are relayed to the projection lens image plane using standard relay lens techniques to maximize light throughput. The optical paths are arranged so that a single set of relay optics relays the image from each LCoS chip to the projector lens image plane. The relay optics is configured so the magnification from the LCoS image chips to the output image plane matches the output image plane format.

[00338] The basic optical system of Figure 47 lies in a plane in some embodiments, which minimizes the number of optical elements, thereby minimizing scattered light and maintaining maximum image contrast. Each beam splitting cube is mounted on the same surface and all optical paths are co-planar. This facilitates fabrication and optical alignment. The co-planar layout also facilitates thermal control of the LCoS image generators as 'through the support-plate' airflow in a direction perpendicular to the plane of the optical system is easily configured and keeps the cooling air away from the optical path, reducing the possibility of optical artifacts created by air turbulence.

[00339] The LCoS image projector may use existing projection display components such as lamp hoses and associated power supplies, and available projection lenses. Both lamp houses and projection lenses are typically close to the image plane in film projectors. The light output from the lamp house is therefore relayed to the LCoS image chips by illumination relay optics with a magnification that matches the lamp output area to the image chip area.

[00340] A further discussion of potential embodiments may be useful. In one embodiment, a system is provided. The system includes an array of a first plurality of narrowband light sources. The system also includes a first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources. In one embodiment, the light sources are laser diodes. In another embodiment, the light sources are light emitting diodes (LEDs).

[00341] Furthermore, in one embodiment using LEDs, the first plurality of light sources includes light sources with 10 unique frequency spectra. Moreover, in one embodiment, the system further includes a substrate

upon which the first plurality of light sources is formed, the substrate having heat conductive properties. Additionally, in some embodiments, a cooling component is coupled to the substrate.

[00342] Also, in some embodiments, a first plurality of focusing optical components is disposed between each light source of the first plurality of light sources and the first beam collecting component. In some embodiments, the first beam collecting component is a substantially flat diffraction grating. In other embodiments, the first beam collecting component is a curved diffraction grating.

[00343] Some embodiments further include an array of a second plurality of narrowband light sources. Such embodiments may also include a second beam collecting component arranged to receive light from the second plurality of narrowband light sources and arranged to output light including light from each light source of the second plurality of narrowband light sources.

[00344] Such embodiments may also include a beam combining component arranged to receive output light from the first beam collecting component and the second beam collecting component. The beam combining component may be a polarization combiner in some embodiments. Moreover, the first plurality of light sources may be arranged to produce light of a first polarization and the second plurality of light sources may be arranged to produce light of a second polarization.

[00345] In some embodiments, the system may further include a housing coupled to the first plurality of light sources and to the beam combining element. The system may also further include a first LCoS assembly coupled to the housing. The system may also include a second LCoS assembly coupled to the housing. The system may further include a third LCoS assembly coupled to the housing. The system may also include a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter may be arranged to split incoming light from the beam combining element between the first LCoS assembly and the second beam splitter. The second beam splitter may be arranged to split incoming light between the second LCoS assembly and the third LCoS assembly. The system may also include a first beam recombiner and a second beam recombiner both coupled to the housing, the first beam recombiner arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second beam recombiner arranged to receive light from the first beam recombiner and from the third LCoS assembly. The system may also include an output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source.

[00346] In some embodiments, the system further includes a processor and a memory coupled to the processor. The system also includes a bus coupled to the memory and the processor. The system further includes a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies.

[00347] In another embodiment, a system is provided. The system includes an array of a first plurality of narrowband light sources. The light sources are formed from light emitting diodes (LEDs). The system also

includes a substrate upon which the first plurality of light sources is formed. The substrate has heat conductive properties. The system further includes a cooling component coupled to the substrate. The system also includes a first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources.

[00348] The system may also involve, in some embodiments, each light source including a plurality of LEDs of similar spectral character. In some embodiments, the plurality of light sources includes 10 distinct light sources, with each light source having a substantially non-overlapping output spectrum relative to other light sources of the plurality of light sources. In other embodiments, the plurality of light sources includes 20 distinct light sources, some light sources having output spectrums overlapping output spectra of one or more other light sources of the plurality of light sources.

[00349] In yet another embodiment, a system is provided. The system includes an array of a first plurality of narrowband light sources. The light sources are formed from laser diodes (LDs). The system also includes a substrate upon which the first plurality of light sources is formed. The substrate has heat conductive properties. The system further includes a cooling component coupled to the substrate. The system also includes a first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources. Moreover, the system may involve each light source of the plurality of light sources including multiples LDs having similar spectral character. Likewise, the system may involve each light source of the plurality of light sources having a substantially non-overlapping output spectrum relative to other light sources of the plurality of light sources.

Aligning Multiple Image Frames in an LCoS Projector

[00350] High resolution projector designs utilizing multiple LCoS imaging chips require the various LCoS images that make up the entire image to be accurately aligned to achieve an optimum or near-optimum display. This requires each of the images to be exactly the same size on the projection screen, (essentially no magnification variance), located in exactly the same position laterally and vertically, and not rotated with respect to each other (e.g. essentially no registration errors). A display is considered optimum when the projected image from each LCoS chip is aligned within one half pixel tolerance of all the images from the other LCoS chips in the projector, i.e. all images fall within half a pixel of an intended position.

[00351] It is not economical to manufacture projectors with the close mechanical tolerances necessary for each projector to achieve and maintain the alignment of each LCoS component image to within the desired projected image tolerances. The desired alignment is achieved by mechanical alignment that overlaps the images on the screen to a given extent, and then electronically moving each image within its own chip until precise alignment with the primary image is achieved. This is accomplished by an optical alignment system and associated electronics and software program that sequentially generates the same test pattern on the screen for

each LCoS component image, and which is re-imaged onto the same set of detectors in an image detection system. This system determines the precise location of the component image (frame) from the primary image, and is aligned with the primary image by digitally moving the image within the LCoS chip. During the alignment process each image (frame) location is defined by a bright, high contrast 'hollow' rectangular test pattern loaded into each LCoS chip so the outer edges of the projected 4096 x 2160 pixel image are well defined and in focus on the screen as shown in Figure 48. The figure shows the use of CCD detectors but other detectors are also usable, e.g. diagonally split silicon detectors.

[00352] Turning specifically to Figure 48, System 4900 provides a system for aligning images in an LCoS projector, and includes a screen 4910, an outer band 4920, an outer image band 4930, and an inner image area 4940, and detectors 4950. In one embodiment detectors 4950 are CCD detectors as described further below. The objective of use of system 4900 is to align the image on screen 4910 so that the image occupies outer image band 4930, without spilling over to outer band 4920. Detectors 4950 allow a determination as to whether an image projected on screen 4910 is achieving this objective. In one embodiment, the detectors 4950 are each 6 pixels wide. Furthermore, in one embodiment, the outside dimensions of outer image band 4930 are 4096 x 2160 pixels, as specified by the studio consortium for digital projection. Moreover, in such an embodiment, the overall dimensions of screen 4910 (and potentially the outer dimensions of outer band 4920) are approximately 4128 x 2192 pixels. This allows for some space around the edges of the screen.

[00353] Placement of the detectors 4950 at predetermined locations along the interface between outer band 4920 and outer image band 4930 allows for determination of whether an image is within outer image band 4930 or not. Note that in some embodiments, a screen is not used – rather, detection occurs in a sensor integrated with the projector. In such an instance, screen 4910, outer band 4920, outer image band 4930 and inner image area 4940 are portions of a sensor array. In particular, such portions of the system may be defined in relation to positioning of a set of detectors 4950 within such a system, and the detectors 4950 may be the only detection components present. Moreover, in such a system, detectors 4950 need not have the same pixel size in absolute dimensions that one would have on a projector screen – a closer detector with smaller pixels would provide appropriate functionality.

[00354] Referring to digital LCoS projectors generally, the primary image in a projector is electronically centered in its LCoS chip. To effectively move the image of each other LCoS chip, the chip has to be larger than the 4096 x 2160 primary image in an amount determined by the mechanical mounting accuracy of each LCoS chip. For example, if each LCoS chip in the projector is mechanically aligned to within ± 0.0047 inches of a correct location relative to the primary, and the chip is 1.200 inches wide, the alignment range is $(\pm 0.0047/1.200) \times 4096$ or ± 16 pixels. The LCoS chip must then be 4096 ± 16 pixels wide, and 2160 ± 16 pixels high. Thus, one may use an LCoS chip that is 4128 pixels wide by 2192 pixels wide to achieve the desired

tolerances. Other tolerances may be achievable, depending on available manufacturing capabilities and LCoS components in various embodiments.

[00355] The full image is composed of separate RGB and polarization images, a 3D RGB image includes six separate component images, with each type of image potentially assigned to a specific chip. Each frame can be individually moved within the chip by adjusting the clock counts for the rows and/or columns of each frame. The six frames are optically combined to form a single image by aligning each frame within the 4128 x 2192 pixel chip. E.g. the first pixel of the primary image is located at chip column location +16 and row location +16. The first pixel of the second chip can be adjusted by ± 16 pixels in both columns and rows to exactly overlay the first pixel of the first chip, etc. As a result, the top left corner of each frame can be placed exactly in the same position on the screen (or very nearly so). Rotation and magnification adjustments can be achieved by adjusting clock counts within the image rows or columns. A suggested system for doing this is shown in Figure 49.

[00356] Turning more specifically to Figure 49, system 4960 provides a system for adjusting image position in LCoS chips on an individual basis. System 4960 includes video image inputs 4995, image buffers 4985, sensor inputs 4990, calibration logic 4980, image adjustment logic 4975 and LCoS chips 4970. System 4960 operates with data flowing in through video image inputs 4995 – such as from an associated computer or from a video sensor, for example. Image buffers 4985 receive the video data and provide the data to LCoS chips. Logic controlling a bus between inputs 4995 and buffers 4985 may steer data to correct buffers – such as in a graphics processor, for example.

[00357] Separately, sensor inputs 4990 collect information about the projected image, and provide that information to calibration logic 4980. This may occur on a continuous basis, on an incidental basis as requested by a system or a user, or it may occur based on affirmative steps for calibration (such as deploying and connecting calibration sensors, for example). Calibration logic 4980 interprets data from sensors 4990 to determine registration/alignment errors in the projected image, and determines appropriate adjustments to image data for each LCoS chip. Image adjustment logic 4975 then uses data from calibration logic 4980 to adjust the flow of data from image buffers 4985 to LCoS chips 4970. Each LCoS chip 4970 may have associated adjustment parameters implemented by an associated image adjustment logic module 4975. This may, in turn, result in corresponding pixel data going into different pixels depending on which LCoS chip 4970 is being provided data to account for registration and alignment errors.

[00358] The alignment system may be co-located or integrated with the projector and may contain a number of linear CCD detector arrays positioned as shown in Figure 48 in some embodiments. Image focus is determined by the steepness of the edge read out by the CCD sensor array, such as that shown in Figure 50. This allows image focusing on the screen to be performed electronically if required. Focusing the initial image (frame) on the screen is achieved by activating the primary LCoS chip and maximizing the difference in signals between

the test pattern image outer edge (e.g. outer image band 4930) and adjacent background (outer band 4920) outside the test pattern. All LCoS chips may be positioned within the optical system so that each individual frame image is in focus at the output image plane of the final projection lens. For the primary image the steep step response can be located anywhere on the CCD detector, but subsequent LCoS images must be aligned to the same detector element in all detectors. That is, the primary image may have a relatively arbitrary location, but the remaining images then need to be aligned to the primary image.

[00359] Turning more specifically to the readout of Figure 50, a readout of a detector such as a CCD over time (reading out detector positions serially over time) is provided. A relative signal value 5070 is plotted over time 5030. For a 128 element CCD sensor 5010, a readout over time provides a readout along a series of positions. Thus, a portion of the readout corresponds to area 5060 – the area outside the image, and an expected value here is roughly the ambient light value. Additionally, an image area 5050 corresponds to a portion of the screen which is dark – no image data is expected. Light leakage or dark currents may result in a value somewhat greater than ambient for this area. Screen area 5040 is the portion of the image that is to be illuminated, and has a correspondingly higher signal 5070. The breakpoint between dark image area 5050 and screen area 5040 thus represents outer edge 5020. The location of outer edge 5020, as adjusted by any calibration, can allow for proper registration of separate images. That is, causing the outer edges 5020 of different images to line up should lead to desired alignment.

[00360] If diagonally split silicon detectors are employed the image positioning system (IPS) must first be precisely aligned with the primary image so the signals from each half of the detector are equal. The diagonal detectors do not provide a signal for image focusing and require the primary image of the rectangular test pattern be of a specific size on the detectors. This is best achieved by electronically adjusting the primary image test pattern size, orientation, and location to the detector pattern, rather than permitting a relatively arbitrary image position for the primary image.

[00361] After focusing the initial image (frame) on the screen, alignment is achieved by activating primary LCoS chip with the hollow rectangular test pattern and adjusting the image position within an electronic memory to center the image of the projected display in the focal plane of a pre-aligned image sensor. For an image of say 4096 pixels horizontally, the image memory should be about ± 16 pixels (pxls) larger, i.e. 4,128 pixels wide, corresponding to $\pm 1/258$ of the image width in some embodiments. For an image chip of 1.2 inches width this corresponds to a mechanical positional tolerance range of ± 0.0047 inches.

[00362] Image Alignment Functions

[00363] Top edge alignment and image rotation: In an embodiment, two CCD sensor arrays are located each nominally $1/8$ of the distance in from the image sides so as to cross symmetrically the top edge of the projected image with each sensor array having 128 sensor elements arranged vertically. The sensor optical system magnification is designed so one sensor element corresponds to $1/4$ pixel. The remaining chips each

illuminate the screen in sequence and their images are adjusted vertically and rotated within the electronic memories to match the CCD detector patterns for each chip. That is, images for succeeding LCoS chips are adjusted to match a primary image profile on the detectors in question. This aligns the top edges of each chip image and eliminates rotation between the images, both to within less than one pixel.

[00364] Magnification: In one embodiment, a single CCD array is positioned at nominally the midpoint of the image bottom edge so the edge of the projected image crosses about midpoint on the vertically aligned sensor. The magnification of each individual image of each LCoS chip is adjusted within the electronic memory so that each image is of the same magnification to within one pixel of the primary image.

[00365] Side edge alignment: In one embodiment, two CCD array sensors are positioned within the alignment system so as to cross the two edges of the projected image horizontally, at about the mid point of the image vertical sides. The images are electronically moved sideways within the memory to align the edges of all images with each other – each image from the various LCoS chips is adjusted to match the primary image.

[00366] As all LCoS chips are fabricated from the same mask set the image aspect ratio is expected to be the same for all images and the image magnification need only be adjusted in one axis. However, adjustment along a side can be used to adjust magnification issues if such adjustment is deemed necessary.

[00367] The Image Positioning System (IPS) includes a lens and a set of detectors as shown in Figure 48 located in an image plane of all the image generators and may either be integrated with or separate from the projector. If separate from the projector the IPS obtains power from the projector and returns signals to the projector, and is operated by mechanically aligning the system so the primary image is located with respect to the image detectors as shown in Figure 48. The IPS is focused on the projected image on the screen and must be manually aligned to the image. One factor in an IPS that is separate from the projector is that changing projection lenses changes the image size at the screen and therefore the image size at the IPS. In some embodiments, the IPS is integrated with the basic projector and a portion of the beam with all the images is passed from the projector to the IPS as shown in Figure 51. The dichroic mirror that combines the blue and red/green images is not perfect and a small amount of the blue light reflects from it into the IPS. Similarly a small portion of the red/green light is transmitted through the dichroic mirror to the IPS. Hence all colors and polarizations are passed to the IPS and may be sequentially aligned with the chosen primary image. With an integrated IPS using CCD sensors it is only necessary that each image generate a similar CCD output signal in the same location on each sensor, the reference being the primary image.

[00368] The integrated IPS does not view the image on the projection screen and is not useful for automatically focusing the image on the screen. Automatic focusing could be obtained by sampling the light output from the projection lens, but then changing lenses to rescale the projected image would complicate the alignment system as both the image size and focus in the IPS would vary with the lens used. Rather, a separate

focusing system (potentially a manual focusing system) may be used instead of a focus system integrated with the alignment (IPS) system.

[00369] Turning now to Figure 51, a basic projector 4800 is shown as part of system 5100 along with an associated IPS 5110. A high efficiency optical design for three color RGB (red, green, blue) image projectors is shown in projector 4800 that uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A randomly polarized white light source (4810) is stripped of IR and UV components by an IR/UV rejection filter (4815) input to a first dichroic mirror (4820) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 4830). The remainder of the spectrum passes through the dichroic mirror (4820) to a second dichroic mirror (4825), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 4845). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 4860).

[00370] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 4835, 4840, 4850, 4855, 4865 and 4870). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (4830, 4845 and 4860), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (4875 and 4880) to form a white image (at projection lens image plane 4885) which is focused on a remote screen using a projection lens (4890) to provide output light 4895.

[00371] Application of a voltage to an LCoS chip pixel that is insufficient for 90 degree rotation of the optical polarization results in a smaller rotation of the plane of polarization for a beam reflected from an LCoS chip. On passing back (of the beam) through the polarizing beam splitter the rotated beam is split into two orthogonal polarized components of different intensities that exit the beam splitter in different directions. Thus the intensity of the output beam is reduced in proportion to the degree of polarization rotation (i.e. voltage on the pixel), and the unrotated portion is returned along its entrance path back toward the source.

[00372] Although many optical projection systems have been designed, multicolor displays using reflective LCoS image generation chips, one design the inventor is aware of is not well suited to large high brightness displays. The LCoS image generation devices employ a liquid crystal layer sandwiched between a transparent optical surface and a silicon electronic chip which applies a voltage to the liquid crystal layer on a pixel by pixel basis, causing spatially localized polarization rotation of light and thereby enabling an image to be imparted to light input through the transparent surface and reflecting back from the chip surface. The LCoS devices are universally employed in a reflective mode where the reflected light contains the image information.

[00373] The above referenced design uses four beam splitting cubes and several color absorption filters. It suffers from a low light efficiency as the input light is first split into two polarizations, each of which is then passed through color filters. This implementation causes half of the polarized light to be absorbed in the color filters. The absorbed light significantly heats the filters, trapping the heat between the polarizing cubes. Consequently this design, although compact, is only compatible with low intensity light, perhaps small fractions of a watt. A large screen multi-media display must be capable of transmitting several hundred watts of light, with potentially tens of watts absorbed in the image generating chips.

[00374] In contrast the proposed optical design implementation first separates the input light on a spectral basis, blue, red, then green light, using color separating dichroic mirrors, and each color is then input to its own polarizing beam splitter which directs polarized light to two LCoS image planes, one for each light polarization state. The light is thus spread over six separate LCoS chips. The reflected output images from the three beam splitters each contain both optical polarizations for their respective color, and the colored images are then re-combined using dichroic mirrors. By this means no light is absorbed in color filters and the system is capable of much higher optical power throughput as the dichroic mirrors absorb comparatively little light, and each color path is very efficient with minimal light loss at the LCoS planes. The LCoS image chips are accessible from the rear (the non-image side) and active chip cooling may therefore be employed to maintain each chip within a preferable operating temperature range.

[00375] In one embodiment, the blue light is first separated using a blue reflecting, red and green transmitting dichroic mirror. Blue light is separated first as, for a maximum brightness display, it can least tolerate optical power losses, and some red and green light is lost at the blue reflecting dichroic mirror. Next the red light is separated as this is less tolerant to loss than the green portion of the spectrum. Reflection spectra of typical dichroic mirrors are shown in Figure 49, with Figure 49A showing a blue reflecting dichroic mirror and Figure 49B showing a red reflecting dichroic mirror.

[00376] After passing through their respective LCoS image planes each color is recombined using dichroic mirrors similar to those used in the initial color separation process. It is noted the two re-combining dichroic mirrors are very angle sensitive as rotations will move the image planes out of registration. In an embodiment, the optical path lengths from the optical source to each LCoS image plane is essentially the same to enable essentially the same illumination fill factor and pattern to be obtained for each image plane. Similarly the three output colored images from the LCoS are all essentially equidistant from the projection lens, thereby enabling all images to be projected in focus.

[00377] The three images are typically combined in the image plane of the projection lens enabling existing projection lenses to be used. The images from the LCoS image generation chips are relayed to the projection lens image plane using standard relay lens techniques to maximize light throughput. The optical paths are arranged so that a single set of relay optics relays the image from each LCoS chip to the projector lens image

plane. The relay optics is configured so the magnification from the LCoS image chips to the output image plane matches the output image plane format.

[00378] The basic optical system of projector 4800 lies in a plane in some embodiments, which minimizes the number of optical elements, thereby minimizing scattered light and maintaining maximum image contrast. Each beam splitting cube is mounted on the same surface and all optical paths are co-planar. This facilitates fabrication and optical alignment. The co-planar layout also facilitates thermal control of the LCoS image generators as 'through the support-plate' airflow in a direction perpendicular to the plane of the optical system is easily configured and keeps the cooling air away from the optical path, reducing the possibility of optical artifacts created by air turbulence.

[00379] The LCoS image projector may use existing projection display components such as lamp houses and associated power supplies, and available projection lenses. Both lamp houses and projection lenses are typically close to the image plane in film projectors. The light output from the lamp house is therefore relayed to the LCoS image chips by illumination relay optics with a magnification that matches the lamp output area to the image chip area.

[00380] IPS 5110 receives what would otherwise be wasted light – light from dichroic mirror 4880 which would not go to projection lens 4885. The received light is focused by lens 5130 and reflects off of mirror 5125 to alignment detectors 5120. Alignment detectors 5120 may then be used to adjust image input data for each of LCoS chips 4835, 4840, 4850, 4855, 4865 and 4870.

[00381] The systems described herein may be expected to implement various processes. Examples of an alignment process and a projection process are provided in Figures 52 and 6. Additionally, the processes of Figures 52 and 6 may be implemented in a simultaneous manner, to adjust alignment/registration in a dynamic manner.

[00382] Figure 52 illustrates a process of aligning images from a projector. Process 5200 includes projecting a test image, detecting alignment, shifting the test image if necessary, further detecting alignment, determining if alignment is acceptable, and recording settings for the image. Process 5200 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 5200 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00383] Process 5200 begins in an embodiment with projection of a test image at module 5210. Alternatively, any image expected to provide illumination in parts of the image where calibration is tested may be projected. At module 5220, alignment of the image with the desired projection of the image is detected. This may refer to alignment with a reference image, or to alignment with a predetermined standard, for example.

[00384] If necessary, at module 5230, a shift is made in the test image, based on an indication that the image is out of alignment. Depending on the type of alignment tested in a given process, this may involve “raising” or “lowering” the image (shifting vertically), translating the image to one or another side (shifting horizontally) or rotating the image. Following the shift to the test image, alignment is detected again at module 5220. At module 5240, a determination is made as to whether the alignment status is now acceptable. If not, the process returns to module 5230. If so, the process moves to module 5250.

[00385] Process 5200 may be repeated for each of a set of LCoS chips in some embodiments. Additionally, in some embodiments, process 5200 may be repeated for each of a set of different types of alignment, such as rotation, linear translation (horizontal and/or vertical) and magnification. Thus, the alignment process may include a number of different instances of process 5200, some of which may be executed in parallel in some embodiments.

[00386] In contrast, Figure 53 provides an illustration of an embodiment of a process of projecting an aligned image. Process 5300 includes receiving raw image data, translating the data with calibration settings, transferring translated data to LCoS projection chips, and projecting the translated data. Process 5300 begins with receipt of raw image data at module 5310. At module 5320, the raw image data is translated to new coordinates based on calibration (alignment) data. At module 5330, the translated data is provided to a projection mechanism (such as an LCoS chip) and at module 5340, the translated data is projected.

[00387] Figure 54 illustrates an embodiment of a system using a computer and a projector. System 5410 includes a conventional computer 5420 coupled to a digital projector 5430. Thus, computer 5420 can control projector 5430, providing essentially instantaneous image data from memory in computer 5420 to projector 5430. Moreover, computer 5420 can implement calibration and image translation functions internally, based on feedback from an associated IPS of projector 5430. Projector 5430 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 5420 may monitor conditions of projector 5430, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 5430.

[00388] Figure 55 illustrates an embodiment of a computer which may be used with the projectors of Figure 521, for example. The following description of Figure 55 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing

environments where tasks are performed by remote processing devices that are linked through a communications network.

[00389] Figure 55 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 5500 interfaces to external systems through the modem or network interface 5520. It will be appreciated that the modem or network interface 5520 can be considered to be part of the computer system 5500. This interface 5520 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00390] The computer system 5500 includes a processor 5510, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 5540 is coupled to the processor 5510 by a bus 5570. Memory 5540 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 5570 couples the processor 5510 to the memory 5540, also to non-volatile storage 5550, to display controller 5530, and to the input/output (I/O) controller 5560.

[00391] The display controller 5530 controls in the conventional manner a display on a display device 5535 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 5530 can, in some embodiments, also control a projector such as those illustrated in Figures 48 and 52, for example. The input/output devices 5555 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 48 and 52, which may be addressed as an output device, rather than as a display. The display controller 5530 and the I/O controller 5560 can be implemented with conventional well known technology. A digital image input device 5565 can be a digital camera which is coupled to an i/o controller 5560 in order to allow images from the digital camera to be input into the computer system 5500. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00392] The non-volatile storage 5550 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory 5540 during execution of software in the computer system 5500. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 5510 and also encompasses a carrier wave that encodes a data signal.

[00393] The computer system 5500 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the

processor 5510 and the memory 5540 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00394] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 5540 for execution by the processor 5510. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 55, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00395] In addition, the computer system 5500 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 5550 and causes the processor 5510 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 5550.

[00396] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00397] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer

system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00398] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00399] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00400] Figure 56 illustrates another embodiment of a system using a computer and projector. System 5650 includes computer subsystem 5660 and optical subsystem 5680 as an integrated system. Computer 5660 is essentially a conventional computer with a processor 5665, memory 5670, an external communications interface 5673 and a projector communications interface 5676.

[00401] The external communications interface 5673 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 5676 provides for communication with projector subsystem 5680, allowing for control of LCoS chips (not shown) included in projector subsystem 5680, for example. Thus, projector communications interface 5676 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 5660, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 5650. Moreover, computer 5660 can implement calibration and image translation functions internally, based on feedback from an associated IPS of projector 5680. System 5650 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00402] It may be useful to provide network services for a projection system. Figure 57 shows an embodiment of several computer systems that are coupled together through a network 5705, such as the internet. The term "internet" as used herein refers to a network of networks which uses certain protocols, such as the tcp/ip

protocol, and possibly other protocols such as the hypertext transfer protocol (HTTP) for hypertext markup language (HTML) documents that make up the world wide web (web). The physical connections of the internet and the protocols and communication procedures of the internet are well known to those of skill in the art.

[00403] Access to the internet 5705 is typically provided by internet service providers (ISP), such as the ISPs 5710 and 5715. Users on client systems, such as client computer systems 5730, 5740, 5750, and 5760 obtain access to the internet through the internet service providers, such as ISPs 5710 and 5715. Access to the internet allows users of the client computer systems to exchange information, receive and send e-mails, and view documents, such as documents which have been prepared in the HTML format. These documents are often provided by web servers, such as web server 5720 which is considered to be "on" the internet. Often these web servers are provided by the ISPs, such as ISP 5710, although a computer system can be set up and connected to the internet without that system also being an ISP.

[00404] The web server 5720 is typically at least one computer system which operates as a server computer system and is configured to operate with the protocols of the world wide web and is coupled to the internet. Optionally, the web server 5720 can be part of an ISP which provides access to the internet for client systems. The web server 5720 is shown coupled to the server computer system 5725 which itself is coupled to web content 5795, which can be considered a form of a media database. While two computer systems 5720 and 5725 are shown in Fig. 57, the web server system 5720 and the server computer system 5725 can be one computer system having different software components providing the web server functionality and the server functionality provided by the server computer system 5725 which will be described further below.

[00405] Client computer systems 5730, 5740, 5750, and 5760 can each, with the appropriate web browsing software, view HTML pages provided by the web server 5720. The ISP 5710 provides internet connectivity to the client computer system 5730 through the modem interface 5735 which can be considered part of the client computer system 5730. The client computer system can be a personal computer system, a network computer, a web tv system, or other such computer system.

[00406] Similarly, the ISP 5715 provides internet connectivity for client systems 5740, 5750, and 5760, although as shown in Fig. 57, the connections are not the same for these three computer systems. Client computer system 5740 is coupled through a modem interface 5745 while client computer systems 5750 and 5760 are part of a LAN. While Fig. 57 shows the interfaces 5735 and 5745 as generically as a "modem," each of these interfaces can be an analog modem, isdn modem, cable modem, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems.

[00407] Client computer systems 5750 and 5760 are coupled to a LAN 5770 through network interfaces 5755 and 5765, which can be ethernet network or other network interfaces. The LAN 5770 is also coupled to a gateway computer system 5775 which can provide firewall and other internet related services for the local area network. This gateway computer system 5775 is coupled to the ISP 5715 to provide internet connectivity to the

client computer systems 5750 and 5760. The gateway computer system 5775 can be a conventional server computer system. Also, the web server system 5720 can be a conventional server computer system.

[00408] Alternatively, a server computer system 5780 can be directly coupled to the LAN 5770 through a network interface 5785 to provide files 5790 and other services to the clients 5750, 5760, without the need to connect to the internet through the gateway system 5775.

[00409] Ultimately, various embodiments can be implemented. In one embodiment, a system for aligning multiple image frames in an LCoS projector is provided. The system includes a plurality of detectors aligned with a desired projection image of a projector. The plurality of detectors is coupled to the projector. Each detector of the plurality of detectors is aligned with an edge of the desired projection image. The plurality of detectors may be coupled to a screen distant from the projector, or part of a calibration unit associated more directly with the projector. The system may further include calibration logic in the projector. The calibration logic is to receive data from the plurality of detectors and to adjust an image of the projectors responsive to the data from the plurality of detectors.

[00410] In some embodiments, an optical component is positioned at an outlet of the projector to receive calibration light from the projector. The calibration light correspond to light provided as an output beam by the projector. The calibration light is separate from the output beam. The optical component is further positioned to provide the calibration light to the plurality of detectors. In some such embodiments, the optical component includes a lens coupled to a mirror.

[00411] In some embodiments, the detectors of the plurality of detectors are CCD row elements. Moreover, in some embodiments, the CCD row elements each include 128 CCD sensors. In other embodiments, the detectors of the plurality of detectors are each split silicon light detectors. In some embodiments, the calibration logic is in the projector, and includes a set of delay logic modules coupled to image modulation components of the projector. Moreover, the calibration logic may further include control logic to receive data from the plurality of detectors and to control the delay logic modules responsive to the data from the plurality of detectors.

[00412] In another embodiment, a system is provided. The system includes a housing and first, second and third LCoS assemblies coupled to the housing. The system may further include a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter is arranged to split incoming light between the first LCoS assembly and the second beam splitter. The second beam splitter is arranged to split incoming light between the second LCoS assembly and the third LCoS assembly. The system also includes a first beam recombiner and a second beam recombiner both coupled to the housing. The first beam recombiner is arranged to receive light from the first LCoS assembly and the second LCoS assembly. The second beam recombiner is arranged to receive light from the first beam recombiner and from the third LCoS assembly.

[00413] The system further includes a first light source to provide incoming light to the first beam splitter. The system also includes an output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source. Note that the first and second beam recombiners may be dichroic mirrors in some embodiments. The system further includes a plurality of detectors aligned with a desired projection image of a projector. The plurality of detectors is coupled to the projector. Each detector of the plurality of detectors is aligned with an edge of the desired projection image. The system also includes calibration logic. The calibration logic includes a set of delay logic modules coupled to the first, second and third LCoS assemblies. The calibration logic also includes control logic to receive data from the plurality of detectors and to control the delay logic modules responsive to the data from the plurality of detectors.

[00414] In some embodiments, the detectors are positioned on a screen. The screen is positioned at a distance from the output optics element to receive an image from the output optics element for viewing by a group of people. In other embodiments, the detectors are coupled to the housing physically in a calibration subsystem proximate to the housing and apart from a screen distant from the housing for receiving images from the housing. Moreover, in some embodiments, the system also includes an optical component positioned at an outlet of the housing to receive calibration light from the second beam recombiner. The calibration light corresponds to light provided by the output optics. The optical component is further positioned to provide the calibration light to the plurality of detectors. In some embodiments, the optical component includes a lens coupled to a mirror. Furthermore, in some embodiments, the detectors of the plurality of detectors are CCD row elements. In other embodiments, the detectors of the plurality of detectors are each split silicon light detectors.

[00415] In yet another embodiment, a method is provided. The method includes detecting alignment of a first image. The method also includes providing data indicating alignment of the first image. The method further includes adjusting the first image responsive to the data. The method may further include detecting alignment of a second image. The method may also include providing data indicating alignment of the first image with the second image. The method may further include adjusting the second image responsive to the data. Moreover, detecting alignment may include detecting registration errors, magnification and rotation in some embodiments.

Integrated Optical Polarization Combining Prism for Projection Displays

[00416] Full color projection displays of dynamic digital images can be achieved by optically merging the output images from multiple electrically driven image generator chips. These chips often achieve the image modulation by optical polarization switching on a pixel by pixel basis. For efficient use of all the input light from a standard white light source, such as a projection lamp, this requires six separate image generation chips be used to provide full spectrum color displays by projecting the spectral components, (e.g. red, green, and blue (RGB), or magenta cyan and yellow), of each image in both optical polarizations. An embodiment of such an optical system is shown in block diagram form in Figure 58. Generally the image generation chips and their associated optical

elements and electronic drive circuits constitute the most expensive components of the system, and both cost and complexity can be reduced if the number of image chips can be reduced. Not only may this reduce initial costs of manufacturing, but ongoing maintenance costs may similarly be reduced through use of fewer such components.

[00417] A high efficiency optical design for three color RGB (red, green, blue) image projectors is shown in Figure 58 that uses six LCoS image planes to obtain both optical polarizations in all colors and is suitable for slide or dynamic video presentations to large screens. A randomly polarized white light source (5810) is stripped of IR and UV components by an IR/UV rejection filter (5815) input to a first dichroic mirror (5820) which reflects the blue portion of the spectrum to a polarizing beam splitter (PB1 – 5830). The remainder of the spectrum passes through the dichroic mirror (5820) to a second dichroic mirror (5825), which reflects the red portion of the spectrum to a second polarizing beam splitter (PB2 – 5845). The remaining spectrum passes to a third polarizing beam splitter (PB3 – 5860).

[00418] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, each of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 5835, 5840, 5850, 5855, 5865 and 5870). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (5830, 5845 and 5860), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (5875 and 5880) to form a white image. The white image (formed at projection lens image plane 5885) is focused on a remote screen using a projection lens (5890) to provide output light 5895.

[00419] Application of a voltage to an LCoS chip pixel that is insufficient for 90 degree rotation of the optical polarization results in a smaller rotation of the plane of polarization for a beam reflected from an LCoS chip. On passing back (of the beam) through the polarizing beam splitter the rotated beam is split into two orthogonal polarized components of different intensities that exit the beam splitter in different directions. Thus the intensity of the output beam is reduced in proportion to the degree of polarization rotation (i.e. voltage on the pixel), and the unrotated portion is returned along its entrance path back toward the source.

[00420] Although many optical projection systems have been designed, including multicolor displays using reflective LCoS image generation chips, one design the inventor is aware of is not well suited to large high brightness displays. The LCoS image generation devices employ a liquid crystal layer sandwiched between a transparent optical surface and a silicon electronic chip which applies a voltage to the liquid crystal layer on a pixel by pixel basis, causing spatially localized polarization rotation of light and thereby enabling an image to be imparted to light input through the transparent surface and reflecting back from the chip surface. The LCoS devices are universally employed in a reflective mode where the reflected light contains the image information.

[00421] The above referenced design (not shown) uses four beam splitting cubes and several color absorption filters. It suffers from a low light efficiency as the input light is first split into two polarizations, each of which is then passed through color filters. This implementation causes half of the polarized light to be absorbed in the color filters. The absorbed light significantly heats the filters, trapping the heat between the polarizing cubes. Consequently this design, although compact, is only compatible with low intensity light, perhaps small fractions of a watt. A large screen multi-media display must be capable of transmitting several hundred watts of light, with potentially tens of watts absorbed in the image generating chips.

[00422] In contrast the proposed optical design implementation first separates the input light on a spectral basis, blue, red, then green light, using color separating dichroic mirrors, and each color is then input to its own polarizing beam splitter which directs polarized light to two LCoS image planes, one for each light polarization state. The light is thus spread over six separate LCoS chips. The reflected output images from the three beam splitters each contain both optical polarizations for their respective color, and the colored images are then re-combined using dichroic mirrors. As a result, no light is absorbed in color filters and the system is capable of much higher optical power throughput as the dichroic mirrors absorb comparatively little light, and each color path is very efficient with minimal light loss at the LCoS planes. The LCoS image chips are accessible from the rear (the non-image side) and active chip cooling may therefore be employed to maintain each chip within a preferable operating temperature range.

[00423] One option for reducing the number of imaging chips and associated components is to utilize a polarization combining optical prism assembly so that both polarizations in each portion of the spectrum can be applied to a single image generator chip. This can be achieved if the output light from the projection lamp is first split into the required spectral components, e.g. RGB, and each spectral component is then split into its two orthogonal polarizations, one of which is then rotated through ninety degrees by a wave plate before recombining with the other. In this manner the entire optical output of a lamp can be mapped into one polarization and the number of image chips and associated components reduced by half, requiring only one per color.

[00424] The laws of physics prevent the simultaneous mapping of one polarization onto another of the same color without changing either the angle of the optical beam or its position. As the angle of the beam is usually constrained by the acceptance angle of the projection lens the most feasible approach is to use the two polarization components, each now of the same orientation, to illuminate separate halves of a single image generator chip. Figure 59 shows an optical system configuration in which an input optical beam is separated into three spectral components with each passing to a prism where the colored beam is split into two polarizations which illuminate different halves of each image chip as described above.

[00425] Referring more specifically to Figure 59, system 5900 bears some similarities to system 5800 of Figure 58, while including variations on some components. For example, focusing optics 5905 focus incoming light prior to splitting off blue light at dichroic mirror 5820. Each of polarizing beamsplitters 5930, 5945 and

5960 split incoming light into two polarizations, rotate one polarization to align with the other, and allow both resulting light beams to be modulated by associated LCoS chips 5940, 5950 and 5970. Resulting output light is recombined at dichroic mirrors 5975 and 5980, resulting in an output beam at output optics 5890 which combines modulated red, green and blue light – an RGB display.

[00426] Referring more specifically to polarization beamsplitters 5930, 5945 and 5960, each is an optical assembly made up of two prisms and a half-wave plate. Taking as an example assembly 5930, light enters a first prism and is split into a first polarization state that is reflected toward an LCoS chip 5940 and a second polarization state orthogonal to the first polarization state. Light in the second polarization state is transmitted through the intervening half-wave plate and into a second prism. Note that the half-wave plate is chosen based on the expected color spectrum for the associated prism, and is designed to rotate a second polarization state to the orthogonal first polarization state. In the second prism, the light, now in the first polarization state, is reflected toward the LCoS chip 5940. The LCoS chip 5940 modulates light based on whether a given pixel should be reflective or non-reflective (light or dark).

[00427] Light reflected from the LCoS chip 5940 into both prisms is then either transmitted through or reflected back along the input optical path, depending on its polarization state. Light that is associated with “light” pixels is in a polarization state to transmit through the assembly 5930 and eventually reach output optics 5890. Light that is associated with “dark” pixels is in a polarization state that is reflected back through the prisms toward dichroic mirror 5820.

[00428] The orientation of the optical prism assembly shown in Figure 59 can be rotated from the vertical configuration shown in the figure to a horizontal configuration producing a more compact optical package as shown in Figure 60. The two halves of each colored beam are separated horizontally instead of vertically as in Figure 59. Similarly the optical path can be configured vertically to allow use of the double cubes as in Figure 58, but where the cubes are in a vertical array above each other. The design of Figure 60 may provide more guidance in this area.

[00429] In an embodiment using polarization combining optics to reduce the number of LCoS image chips to three as shown in Figure 60, one may provide a projection system with fewer LCoS chips. Thus, Figure 60 provides an illustration of another embodiment of an LCoS image projector. A randomly polarized white light source (6010) is stripped of IR and UV components by an IR/UV rejection filter (6015) input to a first dichroic mirror (6015) which reflects the blue portion of the spectrum to a prism 6040 that converts the entire beam to the same polarization by means of a half-wave plate and passes it to a polarizing beam splitter (6030). The remainder of the spectrum passes through the dichroic mirror (6015) to a second dichroic mirror (6020), which reflects the red portion of the spectrum to a second polarization combining prism 6055 and polarizing beam splitter (6045). The remaining spectrum passes to a third polarization combining prism 6070 and polarizing beam splitter (6060).

[00430] Each of the three beam splitters separates its portion of the spectrum into two orthogonal polarization components, one of which is directed to an active LCoS (Liquid Crystal on Silicon) image generation plane (chips 6035, 6050 and 6065). Both polarization components are selectively polarization rotated on a pixel by pixel basis by an electrical signal applied to the LCoS display chips, so as to modulate the input light and impart an image onto the throughput light. Polarization modulated light is reflected from each LCoS chip back through the polarizing beam splitters (6030, 6045 and 6060), so that both polarizations exit from the polarizing beam splitter and are re-combined with similarly processed light of the other spectral portions via dichroic mirrors (6075 and 6080) to form a white image (at projection lens image plane 6085) which is focused on a remote screen using a projection optics (6090) to provide output light 6095. Focusing to plane 6085 may involve additional optics 6083. Furthermore, each of LCoS chips 6035, 6050 and 6065 are provided with a TEC (thermo-electric coolers 6037, 6052 and 6067 respectively) and associated air plenum (6039, 6054 and 6068 respectively) to provide cooling.

[00431] The optical designs in Figures 58, 59 and 60 lend themselves to fabrication in a plane so multiple projectors are easily mounted side by side in close proximity. In such embodiments, cooling air flow to each LCoS is perpendicular to the plane of the optics, e.g. into the page, and need not pass through the optical path.

[00432] An embodiment of a prism configuration showing how the two polarizations are combined into a single beam of the same polarization covering both halves of the image generator, e.g. an LCoS chip, is shown in Figure 61. The LCoS image chip is sufficiently far from the polarization integrating prism that the light output from the prism in the boundary between the two halves has a soft transition.

[00433] Figures 61A, 61B and 61C illustrate an embodiment of a complex polarizing beamsplitter which may be used with the embodiment of Figure 60, for example. Various display systems using various light sources can be configured using a single image generation chip (LCoS) with maximum light efficiency if both polarizations from the light sources can be directed to the same image chip. This can be accomplished by means of a polarization combining prism which separates an input beam into two polarizations, and rotates one to be oriented similarly to the other. The two halves of the input beam illuminate the two halves of an image generating chip (or other reflective optical component) as shown in Figure 61A (and 61C). A single polarization beam splitter would suffice if half the light from the light source were not used, but this allows for greater efficiency.

[00434] Using a light source similar to that of Figure 58, for example, one can interpose a more complex polarization beam splitter between the light source and an LCoS chip 5860 in display system 6100, resulting in creation of two output beams with the same polarization. Beam splitter 6150 splits a beam into two beams with the same polarization state. By including a half-wave plate 6140 at an interface within the beam splitter 6150, one of the beams (the beam passing through the half-wave plate) is polarization rotated to the same state as the other (the beam passing through the mirror and around the half-wave plate) so each beam illuminates a

different half of the LCoS chip with the same polarization. Note that the half-wave plate 6140 extends only through half of the interface with prism 6175 – thus it only interacts with one of the beams and has no effect on the other beam. The result is two beams directed at the LCoS chip 5860 with the same polarization. The resulting output beams 6180 are then directed at a screen, potentially through further projection optics. Note that LCoS chip 5860 may need to have twice the width of the LCoS chips 5860 of Fig. 58, to accommodate the two beams from beam splitter 6150. Alternatively, a lower resolution image can be produced using half of one LCoS chip 5860 for each beam.

[00435] Figure 61B further illustrates the complex polarization beam splitter 6150. Prism 6155 receives light from a light source, and splits it into two light beams having orthogonal polarization states. Mirror 6165 reflects one beam with a first polarization state upward (in this perspective). Half wave plate 6140 rotates the polarization state of the other beam from a second polarization state to the first polarization state. As a result, two beams are transmitted through prism 6175 to a reflective optical component, such as LCoS 5860, with each having the same polarization state. Note that whether the first or second polarization state is chosen is not material. The reflective component then reflects light back (potentially modulated for an image) through prism 6175, which reflects the light from the reflective optical component 5860 as output light 6180.

[00436] One may further understand the operation of beamsplitter 6150 with reference to the lettered portions of Figure 61C. A beam entering at A passes into a prism (6155), the S polarization reflects at B, and the P polarization continues through prism 6155. After 90 degrees polarization rotation by half wave plate 6140, the beam passes through prism 6175 to LCoS 5860. Light reflected at B reflects up at C (mirror 6165) through prism 6175 to LCoS 5860. Upward directed beams reflecting down from LCoS 5860 (modulated light), are polarization rotated by 90 degrees, and reflect from D (in prism 6175), passing out of prism along paths E (providing output light 6180).

[00437] The process by which the polarization beamsplitter of Figures 61A-61C operates may also be useful to understanding. Process 6110 of Figure 61D provides further illustration of operation of the polarization beamsplitter of Figures 61A-61C. Process 6110 and other processes of this document are implemented as a set of modules, which may be process modules or operations, software modules with associated functions or effects, hardware modules designed to fulfill the process operations, or some combination of the various types of modules, for example. The modules of process 6110 and other processes described herein may be rearranged, such as in a parallel or serial fashion, and may be reordered, combined, or subdivided in various embodiments.

[00438] Process 6110 begins with receipt of input light at module 6120. The input light is then split into two orthogonal polarizations at module 6125, such as through use of a prism. At module 6130, light of the first polarization is transmitted through a half-wave plate (transforming it to light of the second polarization) up to an external optical component. At module 6135, light of the second polarization (from the input light) is reflected and transmitted up to the external optical component (or to a second external optical component). Modules 6130

and 6135 may be expected to operate in parallel or simultaneously in some embodiments. At module 6140, the light transmitted to the external optical component is received back, as transformed by the external optical component. At module 6145, the light from the external optical component is reflected as output light. Thus, a beam of input light of unknown polarization may be received, transformed into a known polarization, modulated, and provided as output light.

[00439] Using the polarization beamsplitter of Figures 61A-61C, one may use all available light (or nearly all) in a projector such as system 6000 of Figure 60. As in any system, design optimization for one characteristic reduces another aspect of the design. Combining the two polarizations as described above to reduce the number of image generator chips results in the output projected image having only one polarization. This is not typically a limitation, but it is not possible to project a three dimensional representation of the displayed image by providing separate polarized images to each eye of the viewer with only one polarization state available. This limitation can be overcome if the frame rate of the projected images is doubled and every other set of image frames is polarization rotated before projection. For a typical 24 frame per second large screen projector this requires the frame rate to be increased from 24 to 48 frames per second or greater.

[00440] A number of different techniques can be employed to rotate the output polarization of a projected beam. For example, a rotating prism assembly may be employed, but such post image mechanical devices require extreme precision alignment to avoid image degradation due to jitter. To optimally (or near-optimally) utilize the full output of a projection lamp it may be more useful to use an electronically activated polarization switch so that the output beam is in one of two polarizations for most of the time, i.e. the time to switch between polarization states is short compared to the 'on' time for each polarization.

[00441] Any such polarization switch should enable a high level of optical throughput power, so any heat sensitive polarization switch would be limited for high brightness, large screen displays. Potential options include a transmission liquid crystal or PLZT ceramic polarization switch. Although easily fabricated and electrically driven the large aperture required (typically 5 centimeters, 2 inches), will generate thermal gradients across the aperture, and if one switch is used for the combined colors a wavelength optimization issue potentially exists as the blue wavelength at 450nm is significantly far from that of red at 680nm. Alternatively, a LC switch located in and optimized for each wavelength section of the optics may be employed. If fabricated on thermally conducting material such as sapphire the lower heat flux and a well designed thermal path may enable a viable solution requiring only a low dc voltage. A liquid cooled switch would also potentially eliminate this problem but would require a circulation pump and be prone to leakage and other thermally induced issues. One option to alleviate such issues is to use a reflective liquid crystal switch where temperature control is maintained via the back plate, and which can also act as an electrode, however the optical insertion of such a switch into the optical path is potentially problematic.

[00442] Use of such a switch in a system may be understood with reference to Figure 62. A set of polarization switching liquid crystal devices, each optimized for its associated wavelength, could be located in each color path immediately after the integrated prism assembly as shown in Figure 62. Thus, polarization switch 6233 is located at the output of beamsplitter 6030, polarization switch 6248 is located at the output of beamsplitter 6045, and polarization switch 6263 is located at the output of beamsplitter 6060.

[00443] Each LC optical polarization switch, in some embodiments, is a thin sandwich of LC material between two sapphire plates, coated on the inside with transparent conductive coating, and separated by a non-conducting spacer. The plates may be heat sunk around their periphery (not shown). Simulated 3D imagery is obtained if the polarization of sequential color sets of images are rotated to permit discrimination by the viewer. This can be achieved with either orthogonal linear polarizations or with opposed circular polarizations, the latter mitigating against image cross-talk when a viewer rotates his head from a vertical alignment. One may also expect that all elements of the optics are anti-reflection coated on their operating surfaces in the various embodiments for the appropriate wavelength as per standard practice.

[00444] As mentioned, generally it is desirable to minimize the number of moving parts in any system. One option for doing this in a projector is to use an electrically programmable filter that can withstand the high optical energy flux near the lamp source. While the liquid crystal switch described above is one option, this can also be achieved by a filter made from PLZT ceramic, an electro-optic material that effectively rotates the plane of polarization of an optical beam to a degree set by an applied voltage. The PLZT ceramic wafer is coated with inter-digitated electrodes as shown in Figure 63. The PLZT can have similar electrode patterns on both sides as the polarizing field propagates only a small distance into the material. A typical electrode material is a transparent layer of Tin Oxide, and the electrodes on the two sides are offset to provide relatively uniform transmission. Typical drive voltages are a few hundred volts and the response is limited by the device capacitance and is often about one millisecond.

[00445] With further reference to Figure 63, one may further understand the structure and function of the PLZT. PLZT wafer system 6300 is illustrated with PLZT wafer 6310 having two electrodes 6320 and 6330, and an external voltage source 6340. The electrodes 6320 and 6330 may constitute first and second electrodes, and each may be placed on opposite sides (first and second sides) of wafer 6310. With a reasonable thickness of wafer 6310, the electric field between electrodes 6320 and 6330 will sufficiently penetrate wafer 6310 to change its transmission characteristics. For a material such as tin oxide, the interdigitated electrodes shown will generally suffice to provide a change in transmission characteristics throughout the wafer 6310. The typical effect is a polarization rotation which in conjunction with a linear polarizer produces the effect of a filter with electrically controllable transmission. Edge effects can be avoided by over-sizing the wafer somewhat relative to the optical path for projection. Note that a similar structure can be used for the liquid crystal switch described above – one having skill in the art will understand the differences between the two structures.

[00446] Keeping all of this equipment cooled enough to maintain desired optical transmission properties can also be a challenge. For a theater, where hundreds of watts of output may be desired, much heat will be generated, and even small inefficiencies of a few percent result in much heat that needs to be dissipated. Projector 6400 of Figure 64 provides a simplified representation of a housing 6497 which may be used to house and cool such a system.

[00447] Housing 6497 includes two cavities (more may be included), one in which optical components are mounted or coupled to the housing and another cavity in which other components such as electronic components and/or printed circuit boards are housed. Thus, PC boards 6499 may be mounted to or coupled to housing 6497 in a second cavity. Optics 6430 (such as beamsplitters, dichroic mirrors, lenses, etc.), LCoS chips 6435 and TEC 6437 may all be mounted in the first cavity as illustrated. Additionally, an associated heat sink may be placed directly in the illustrated air flow, coupled to mounted directly to TEC 6437. Moreover, air flow through the second cavity generally may be provided, both for overall cooling and for cooling of the PC boards 6499 or any other associated components. Plenum 6439 allows for flow of air to an outlet, and potentially for recirculation. One advantage of this design is that the cooling air flow as shown is kept away from the optics – thereby reducing potential artifacts due to temperature differentials in the optical path.

[00448] The projector in various embodiments may be used with a computer and generally used as part of a larger system. Figure 65 illustrates an embodiment of a computer which may be used with the projectors of Figures 58 and 62, for example. The following description of Figure 65 is intended to provide an overview of computer hardware and other operating components suitable for performing the methods of the invention described above and hereafter, but is not intended to limit the applicable environments. Similarly, the computer hardware and other operating components may be suitable as part of the apparatuses and systems of the invention described above. The invention can be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention can also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network.

[00449] Figure 65 shows one example of a conventional computer system that can be used as a client computer system or a server computer system or as a web server system. The computer system 6500 interfaces to external systems through the modem or network interface 6520. It will be appreciated that the modem or network interface 6520 can be considered to be part of the computer system 6500. This interface 6520 can be an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems. In the case of a closed network, a hardwired physical network may be preferred for added security.

[00450] The computer system 6500 includes a processor 6510, which can be a conventional microprocessor such as microprocessors available from Intel or Motorola. Memory 6540 is coupled to the processor 6510 by a bus 6570. Memory 6540 can be dynamic random access memory (dram) and can also include static ram (sram). The bus 6570 couples the processor 6510 to the memory 6540, also to non-volatile storage 6550, to display controller 6530, and to the input/output (I/O) controller 6560.

[00451] The display controller 6530 controls in the conventional manner a display on a display device 6535 which can be a cathode ray tube (CRT) or liquid crystal display (LCD). Display controller 6530 can, in some embodiments, also control a projector such as those illustrated in Figures 58 and 62, for example. The input/output devices 6555 can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The input/output devices may also include a projector such as those in Figures 58 and 62, which may be addressed as an output device, rather than as a display. The display controller 6530 and the I/O controller 6560 can be implemented with conventional well known technology. A digital image input device 6565 can be a digital camera which is coupled to an i/o controller 6560 in order to allow images from the digital camera to be input into the computer system 6500. Digital image data may be provided from other sources, such as portable media (e.g. FLASH drives or DVD media).

[00452] The non-volatile storage 6550 is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory 6540 during execution of software in the computer system 6500. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor 6510 and also encompasses a carrier wave that encodes a data signal.

[00453] The computer system 6500 is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an input/output (I/O) bus for the peripherals and one that directly connects the processor 6510 and the memory 6540 (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

[00454] Network computers are another type of computer system that can be used with the present invention. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory 6540 for execution by the processor 6510. A Web TV system, which is known in the art, is also considered to be a computer system according to the present invention, but it may lack some of the features shown in Fig. 65, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

[00455] In addition, the computer system 6500 is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of an operating system software with its associated file management system software is the family of operating systems known as Windows(r) from Microsoft Corporation of Redmond, Washington, and their associated file management systems. Another example of an operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage 6550 and causes the processor 6510 to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage 6550.

[00456] Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[00457] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[00458] The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00459] The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

[00460] Figure 66A illustrates an embodiment of a system using a computer and a projector. System 6610 includes a conventional computer 6620 coupled to a digital projector 6630. Thus, computer 6620 can control projector 6630, providing essentially instantaneous image data from memory in computer 6620 to projector 6630. Projector 6630 can use the provided image data to determine which pixels of included LCoS display chips are used to project an image. Additionally, computer 6620 may monitor conditions of projector 6630, and may initiate active control to shut down an overheating component or to initiate startup commands for projector 6630.

[00461] Figure 66B illustrates another embodiment of a system using a computer and projector. System 6650 includes computer subsystem 6660 and optical subsystem 6680 as an integrated system. Computer 6660 is essentially a conventional computer with a processor 6665, memory 6670, an external communications interface 6673 and a projector communications interface 6676.

[00462] The external communications interface 6673 may use a proprietary (a standard developed for such a device but not publicized by its developer), or a publicly available communications standard, and may be used to receive both digital image data and commands from a user. The projector communications interface 6676 provides for communication with projector subsystem 6680, allowing for control of LCoS chips (not shown) included in projector subsystem 6680, for example. Thus, projector communications interface 6676 may be implemented with cables coupled to LCoS chips, or with other communications technology (e.g. wires or traces on a printed circuit board) coupled to included LCoS chips. Other components of computer subsystem 6660, such as dedicated user input and output modules, may be included, depending on the needs for functionality of a conventional computer system in system 6650. System 6650 may be used as an integrated, standalone system – thus allowing for the possibility that each theater may use its own projector with a built-in control system, for example.

[00463] Various implementations of different embodiments may ultimately be provided. In an embodiment, an optical component is provided. The optical component includes a first polarizing prism having a first face, a second face and a third face. The light beam may be received incident on the first face. Light having a first polarization may be output through a second face and light having a second polarization may be output through a third face. The optical component further includes a half-wave plate fastened to the second face of the first polarizing prism. The optical component further includes a first reflecting prism connected to the third face

of the first polarizing prism. The first reflecting prism has a first face and a second face, the first face connected to the third face of the first polarizing prism. The optical component further includes a second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism. The second reflecting prism has a first face, a second face and a third face. The first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism. The optical component may be used in a projector, among other potential applications in some embodiments.

[00464] In some embodiments, the half-wave plate is designed for light in the blue portion of the visible spectrum. Similarly, in some embodiments, the half-wave plate is designed for light in the green portion of the visible spectrum. Likewise, in some embodiments, the half-wave plate is designed for light in the red portion of the visible spectrum. Moreover, in other embodiments, the half-wave plate may be designed for light in other parts of the visible spectrum - such as light used in a cyan-magenta-yellow-based display, for example.

[00465] The optical component may further include an external optical component coupled to the second face of the second reflecting prism to receive light output from the second reflecting prism and to reflect light back to the second reflecting prism. In some embodiments, the external optical component is an LCoS chip. In other embodiments, the optical component may further include a first external optical component coupled to the second face of the second reflecting prism to receive light output from the second reflecting prism and to reflect light back to the second reflecting prism and a second external optical component coupled to the third face of the second reflecting prism.

[00466] In another embodiment, a system is presented. The system includes a light source and a housing coupled to the light source. The system also includes first, second and third LCoS assemblies coupled to the housing. Each LCoS assembly includes a first polarizing prism having a first face, a second face and a third face. The light beam may be received incident on the first face. Light having a first polarization may be output through a second face and light having a second polarization may be output through a third face. The optical component further includes a half-wave plate fastened to the second face of the first polarizing prism. The optical component further includes a first reflecting prism connected to the third face of the first polarizing prism. The first reflecting prism has a first face and a second face, the first face connected to the third face of the first polarizing prism. The optical component further includes a second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism. The second reflecting prism has a first face, a second face and a third face. The first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism.

[00467] The system further includes a first beam splitter and a second beam splitter both coupled to the housing. The first beam splitter is arranged to split incoming light from the beam combining element between the first LCoS assembly and the second beam splitter. The second beam splitter is arranged to split incoming light between the second LCoS assembly and the third LCoS assembly.

[00468] The system further includes a first beam recombiner and a second beam recombiner both coupled to the housing. The beam recombiners may be dichroic mirrors, for example. The first beam recombiner is arranged to receive light from the first LCoS assembly and the second LCoS assembly. The second beam recombiner is arranged to receive light from the first beam recombiner and from the third LCoS assembly. The system also includes an output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source.

[00469] The system may further include the half-wave plate of the first LCoS assembly being designed for light in the blue portion of the spectrum of visible light; the half-wave plate of the second LCoS assembly being designed for light in the red portion of the spectrum of visible light; and the half-wave plate of the third LCoS assembly being designed for light in the green portion of the spectrum of visible light. Moreover, the system may involve a first polarization switch coupled to the first LCoS assembly, a second polarization switch coupled to the first LCoS assembly and a third polarization switch coupled to the first LCoS assembly. In some embodiments, the first polarization switch, the second polarization switch and the third polarization switch each are liquid crystal switches. In other embodiments, the first polarization switch, the second polarization switch and the third polarization switch each are PLZT switches. In some embodiments, each of the first LCoS assembly, second LCoS assembly and the third LCoS assembly include a thermoelectric cooler coupled to the LCoS chip of each LCoS assembly. Moreover, in some embodiments, each of the first LCoS assembly, second LCoS assembly and the third LCoS assembly include a heat sink coupled to the thermoelectric cooler of each LCoS assembly.

[00470] In some embodiments, the system further includes a processor and a memory coupled to the processor. Moreover, the system may include a bus coupled to the memory and the processor. Additionally, the system may include a communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies. In some embodiments, the housing includes an air plenum separate from an optical path defined by the beam splitters, LCoS assemblies and beam recombiners.

[00471] In yet another embodiment, a method is provided. The method includes receiving input light in a polarization splitting prism. The method further includes splitting the input light into a first polarization and a second polarization orthogonal to the first polarization. The method also includes transmitting the first polarization through a half-wave plate to a first external optical component. The method further includes transmitting the second polarization to a second external optical component. The method also includes receiving light from the first and second external optical components. Moreover, the method includes reflecting light from the first and second external optical components as output light. In some embodiments, the first optical component and the second optical component are portions of a single unitary optical component. In some embodiments, the first optical component and the second optical component are portions of an LCoS chip.

[00472] One skilled in the art will appreciate that although specific examples and embodiments of the system and methods have been described for purposes of illustration, various modifications can be made without

deviating from present invention. For example, embodiments of the present invention may be applied to many different types of databases, systems and application programs. Moreover, features of one embodiment may be incorporated into other embodiments, even where those features are not described together in a single embodiment within the present document.

CLAIMS

1. A system comprising:

A housing;

A first LCoS assembly coupled to the housing;

A second LCoS assembly coupled to the housing;

A third LCoS assembly coupled to the housing;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

A first beam recombiner and a second beam recombiner both coupled to the housing, the first beam recombiner arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second beam recombiner arranged to receive light from the first beam recombiner and from the third LCoS assembly;

A first light source to provide incoming light to the first beam splitter;

And

An output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source.

2. A system comprising:

A housing;

A first LCoS assembly coupled to the housing, the first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A second LCoS assembly coupled to the housing, the second LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A third LCoS assembly coupled to the housing, the third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

A first dichroic mirror and a second dichroic mirror both coupled to the housing, the first dichroic mirror arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second dichroic mirror arranged to receive light from the first beam recombining and from the third LCoS assembly;

A first light source to provide incoming light to the first beam splitter;

An output optics element coupled to the housing and arranged to receive light from the second dichroic mirror and to focus an output light source;

A processor;

A memory coupled to the processor;

A bus coupled to the memory and the processor;

And

A communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies.

3. A system comprising:

A housing;

A first LCoS assembly coupled to the housing, the first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A second LCoS assembly coupled to the housing, the second LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A third LCoS assembly coupled to the housing, the third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A coolant circulation system coupled to the housing and coupled to the heat sinks of the first, second and third LCoS assemblies;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

An IR/UV rejection optical component disposed between the light source and the first beam splitter;

A first dichroic mirror and a second dichroic mirror both coupled to the housing, the first dichroic mirror arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second dichroic mirror arranged to receive light from the first beam recombiner and from the third LCoS assembly;

A first light source to provide incoming light to the first beam splitter;

An output optics element coupled to the housing and arranged to receive light from the second dichroic mirror and to focus an output light source;

A processor;

A memory coupled to the processor;

A bus coupled to the memory and the processor;

A communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies;

And

An interface coupled to the processor, the interface to receive data from a source external to the system.

4. An apparatus, comprising:

A first polarizing beam splitter to receive light from an input source and provide a first output with a first polarization and a second output with a second polarization;

A half-wave plate arranged to receive the first output of the first polarizing beam splitter and provide a half-wave plate output having the second polarization;

And

A mirror arranged to receive the second output beam of the first polarizing beam splitter and provide a mirror output having the second polarization.

5. A system comprising:

A housing;

A first light source coupled to the housing, the first light source providing red light;

A second light source coupled to the housing, the second light source providing green light;

A third light source coupled to the housing, the third light source providing blue light;

A first beam combining optical element and a second beam combining optical element both coupled to the housing, the first beam combining optical element arranged to receive light from the first light source and the second light source, the second beam combining optical element arranged to receive light from the first beam combining optical element and from the third light source;

An LCoS assembly coupled to the housing and arranged to receive light from the second beam recombining element, the LCoS assembly including:

A polarization beam splitter arranged to receive light from the second beam combining element, the polarization beam splitter including:

A first polarizing beam splitter to receive light from the second beam combining element and provide a first output with a first polarization and a second output with a second polarization;

A half-wave plate arranged to receive the first output of the first polarizing beam splitter and provide a half-wave plate output having the second polarization;

A mirror arranged to receive the second output beam of the first polarizing beam splitter and provide a mirror output having the second polarization;

And

A second polarizing beam splitter to receive the half-wave plate output and the mirror output and transmit the half-wave plate output and the mirror output to an external reflective component, the second polarizing beam splitter further to receive reflected light from the reflective component and to transmit the light from the reflective component as an external output beam;

A first LCoS chip coupled to receive light from the polarization beam splitter and to reflect modulated light to the polarization beam splitter;

And

A second LCoS chip coupled to receive light from the polarization beam splitter and to reflect modulated light to the polarization beam splitter.

6. A method, comprising:

Programming a light modulator with a blue image;

Illuminating a blue light source;

Programming a light modulator with a red image;

Illuminating a red light source;

Programming a light modulator with a green image;

and

Illuminating a green light source.

7. A system comprising:

A housing;

A light source coupled to the housing;

A light transmission modulating element coupled to the housing and arranged to receive light from the light source;

An image modulating subsystem arranged to receive light from the light transmission modulating element and coupled to the housing;

And

Output focusing optics arranged to receive light from the image modulating subsystem and coupled to the housing.

8. A method, comprising:

Observing a light level of an image of a projector;

Shifting a light transmissivity level of the projector;

And

Projecting the image based on the light transmissivity level of the projector.

9. A method, comprising:

Reviewing image data to be projected;

Recording light transmissivity level settings based on reviewing the image data to be projected;

Determining a current light transmissivity level setting based on image data associated with an image of a projector;

Shifting the light transmissivity level of the projector to the current light transmissivity level setting;

And

Projecting the image based on the light transmissivity level of the projector.

10. A system, comprising:

A visible light projector including a light source, light modulator, and projection optics;

An infra-red image generator to receive infra-red light from the light source;

And

Focusing optics coupled to the infra-red image generator to produce an infra-red output beam.

11. A method, comprising:

Projecting a conventional image in a visible light spectrum;

Projecting an infra-red image simultaneously in an infra-red spectrum.

12. A system comprising:

A housing;

A first LCoS assembly coupled to the housing, the first LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the first LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A second LCoS assembly coupled to the housing, the second LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the second LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A third LCoS assembly coupled to the housing, the third LCoS assembly includes a polarization beam splitter coupled optically to a first LCoS chip and a second LCoS chip, the first LCoS chip to receive and modulate light of a first polarization and the second LCoS chip to receive and modulate light of a second polarization, and the third LCoS assembly further includes a first heat sink mounted on the first LCoS chip and a second heat sink mounted on the second LCoS chip;

A coolant circulation system coupled to the housing and coupled to the heat sinks of the first, second and third LCoS assemblies;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

An IR/UV rejection optical component disposed between the light source and the first beam splitter;

A first dichroic mirror and a second dichroic mirror both coupled to the housing, the first dichroic mirror arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second dichroic mirror arranged to receive light from the first beam recombining and from the third LCoS assembly;

A first light source to provide incoming light to the first beam splitter;

An output optics element coupled to the housing and arranged to receive light from the second beam recombining and to focus an output light source;

An infra-red image generator coupled to the housing to receive infra-red light from the light source;

Focusing optics coupled to the housing and coupled to the infra-red image generator to produce an infra-red output beam;

A processor;

A memory coupled to the processor;

A bus coupled to the memory and the processor;

A communications path between the processor and each of the first and second LCoS chips of the first, second and third LCoS assemblies;

And

An interface coupled to the processor, the interface to receive data from a source external to the system.

13. A system comprising:

An array of a first plurality of narrowband light sources;

And

A first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources.

14. A system comprising:

An array of a first plurality of narrowband light sources, the light sources formed from light emitting diodes (LEDs);

A substrate upon which the first plurality of light sources is formed, the substrate having heat conductive properties;

A cooling component coupled to the substrate;

And

A first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources.

15. A system comprising:

An array of a first plurality of narrowband light sources, the light sources formed from laser diodes (LDs);

A substrate upon which the first plurality of light sources is formed, the substrate having heat conductive properties;

A cooling component coupled to the substrate;

And

A first beam collecting component arranged to receive light from the first plurality of narrowband light sources and arranged to output light including light from each light source of the first plurality of narrowband light sources.

16. An apparatus, comprising:

A plurality of detectors aligned with a desired projection image of a projector, the plurality of detectors coupled to the projector, each detector of the plurality of detectors aligned with an edge of the desired projection image.

17. A system comprising:

A housing;

A first LCoS assembly coupled to the housing;

A second LCoS assembly coupled to the housing;

A third LCoS assembly coupled to the housing;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

A first beam recombiner and a second beam recombiner both coupled to the housing, the first beam recombiner arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second beam recombiner arranged to receive light from the first beam recombiner and from the third LCoS assembly;

A first light source to provide incoming light to the first beam splitter;

An output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source;

A plurality of detectors aligned with a desired projection image of a projector, the plurality of detectors coupled to the projector, each detector of the plurality of detectors aligned with an edge of the desired projection image;

And

Calibration logic, the calibration logic including:

a set of delay logic modules coupled to the first, second and third LCoS assemblies,

and

control logic to receive data from the plurality of detectors and to control the delay logic modules responsive to the data from the plurality of detectors.

18. A method, comprising:

Detecting alignment of a first image;

Providing data indicating alignment of the first image;

And

Adjusting the first image responsive to the data.

19. An optical component, comprising:

A first polarizing prism having a first face, a second face and a third face, wherein a light beam may be received incident on the first face, light having a first polarization may be output through a second face and light having a second polarization may be output through a third face;

A half-wave plate fastened to the second face of the first polarizing prism;

A first reflecting prism connected to the third face of the first polarizing prism, the first reflecting prism having a first face and a second face, the first face connected to the third face of the first polarizing prism;

And

A second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism, the second reflecting prism having a first face, a second face and a third face, the first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism.

20. A system, comprising:

A light source;

A housing coupled to the light source;

A first LCoS assembly coupled to the housing, the first LCoS assembly including:

A first polarizing prism having a first face, a second face and a third face, wherein a light beam may be received incident on the first face, light having a first polarization may be output through a second face and light having a second polarization may be output through a third face;

A half-wave plate fastened to the second face of the first polarizing prism;

A first reflecting prism connected to the third face of the first polarizing prism, the first reflecting prism having a first face and a second face, the first face connected to the third face of the first polarizing prism;

A second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism, the second reflecting prism having a first face, a second face and a third face, the first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism.

And

An LCoS chip coupled to the second face of the second reflecting prism;

A second LCoS assembly coupled to the housing, the second LCoS assembly including:

A first polarizing prism having a first face, a second face and a third face, wherein a light beam may be received incident on the first face, light having a first polarization may be output through a second face and light having a second polarization may be output through a third face;

A half-wave plate fastened to the second face of the first polarizing prism;

A first reflecting prism connected to the third face of the first polarizing prism, the first reflecting prism having a first face and a second face, the first face connected to the third face of the first polarizing prism;

A second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism, the second reflecting prism having a first face, a second face and a third face, the first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism.

And

An LCoS chip coupled to the second face of the second reflecting prism;

A third LCoS assembly coupled to the housing, the third LCoS assembly including:

A first polarizing prism having a first face, a second face and a third face, wherein a light beam may be received incident on the first face, light having a first polarization may be output through a second face and light having a second polarization may be output through a third face;

A half-wave plate fastened to the second face of the first polarizing prism;

A first reflecting prism connected to the third face of the first polarizing prism, the first reflecting prism having a first face and a second face, the first face connected to the third face of the first polarizing prism;

A second reflecting prism connected to the half-wave plate and to the second face of the first reflecting prism, the second reflecting prism having a first face, a second face and a third face, the first face of the second reflecting prism connected to the half-wave plate and the second face of the first reflecting prism.

And

An LCoS chip coupled to the second face of the second reflecting prism;

A first beam splitter and a second beam splitter both coupled to the housing, the first beam splitter arranged to split incoming light from the beam combining element between the first LCoS assembly and the second beam splitter, the second beam splitter arranged to split incoming light between the second LCoS assembly and the third LCoS assembly;

A first beam recombiner and a second beam recombiner both coupled to the housing, the first beam recombiner arranged to receive light from the first LCoS assembly and the second LCoS assembly, the second beam recombiner arranged to receive light from the first beam recombiner and from the third LCoS assembly;

And

An output optics element coupled to the housing and arranged to receive light from the second beam recombiner and to focus an output light source.

21. A method, comprising:

Receiving input light in a polarization splitting prism;

Splitting the input light into a first polarization and a second polarization orthogonal to the first polarization;

Transmitting the first polarization through a half-wave plate to a first external optical component;

Transmitting the second polarization to a second external optical component;

Receiving light from the first and second external optical components;

And

Reflecting light from the first and second external optical components as output light.

22. That which is described and equivalents thereof.

23. The features of the various embodiments of the description, alone or in combination.

24. The methods found in claims 1-23, embodied in instructions embodied in a medium, the instructions, when executed by a processor, causing the corresponding method to be executed.
25. The apparatuses found in Figures 1-66 and associated text, alone or in combination.
26. The systems found in Figures 1-66 and associated text, alone or in combination.
27. The methods found in Figures 1-66 and associated text, alone or in combination.
28. The apparatuses found in claims 1-23, as they may be combined.
29. The methods found in claims 1-23, as they may be combined.
30. The systems found in claims 1-23, as they may be combined.

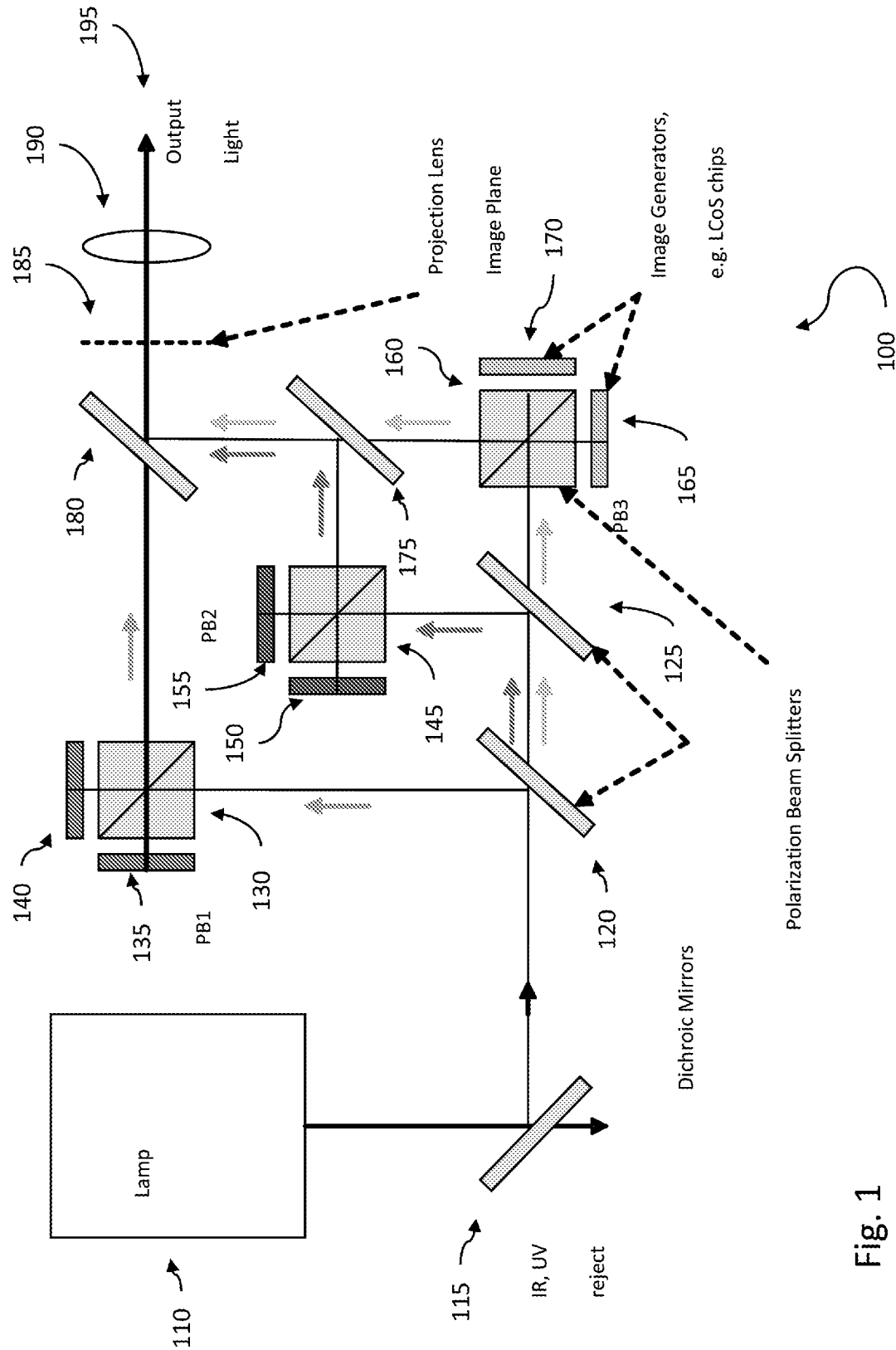


Fig. 1

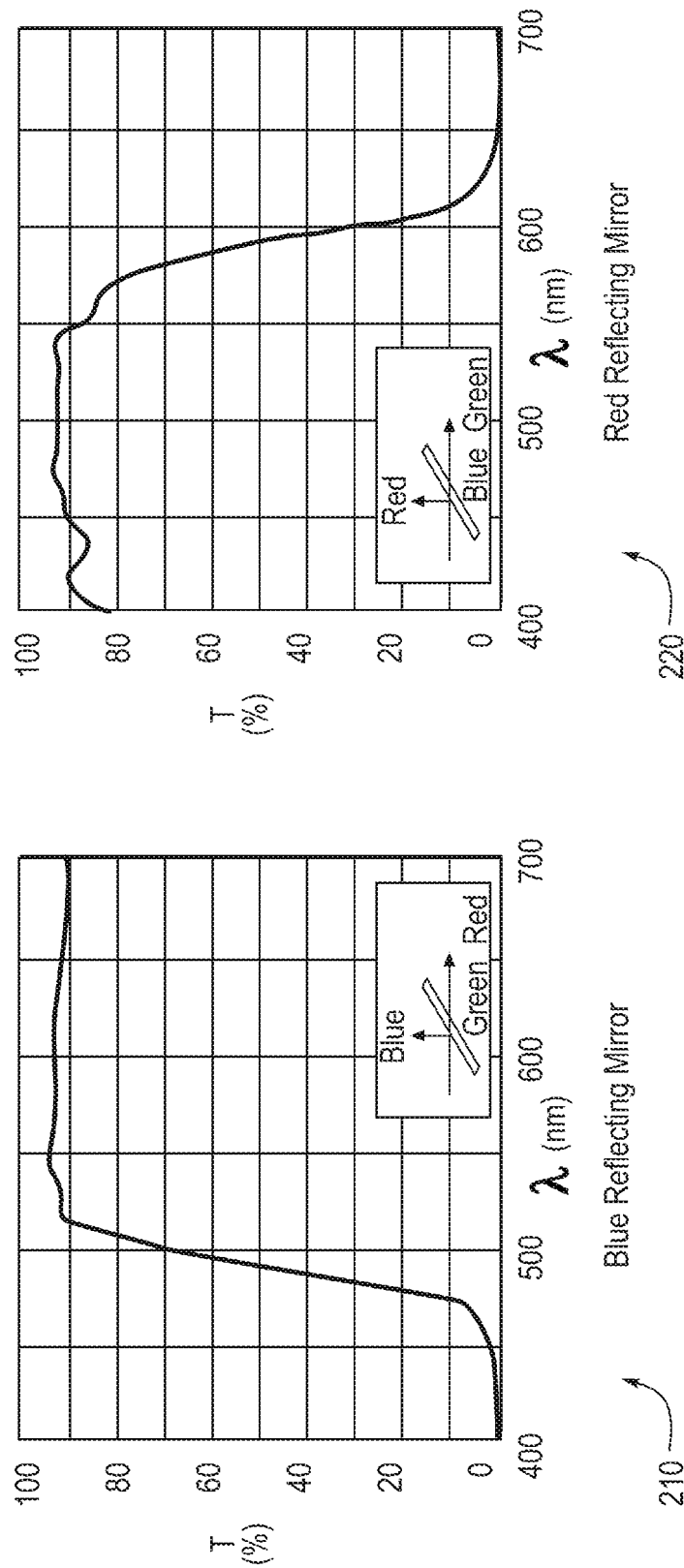


FIG. 2A

FIG. 2B

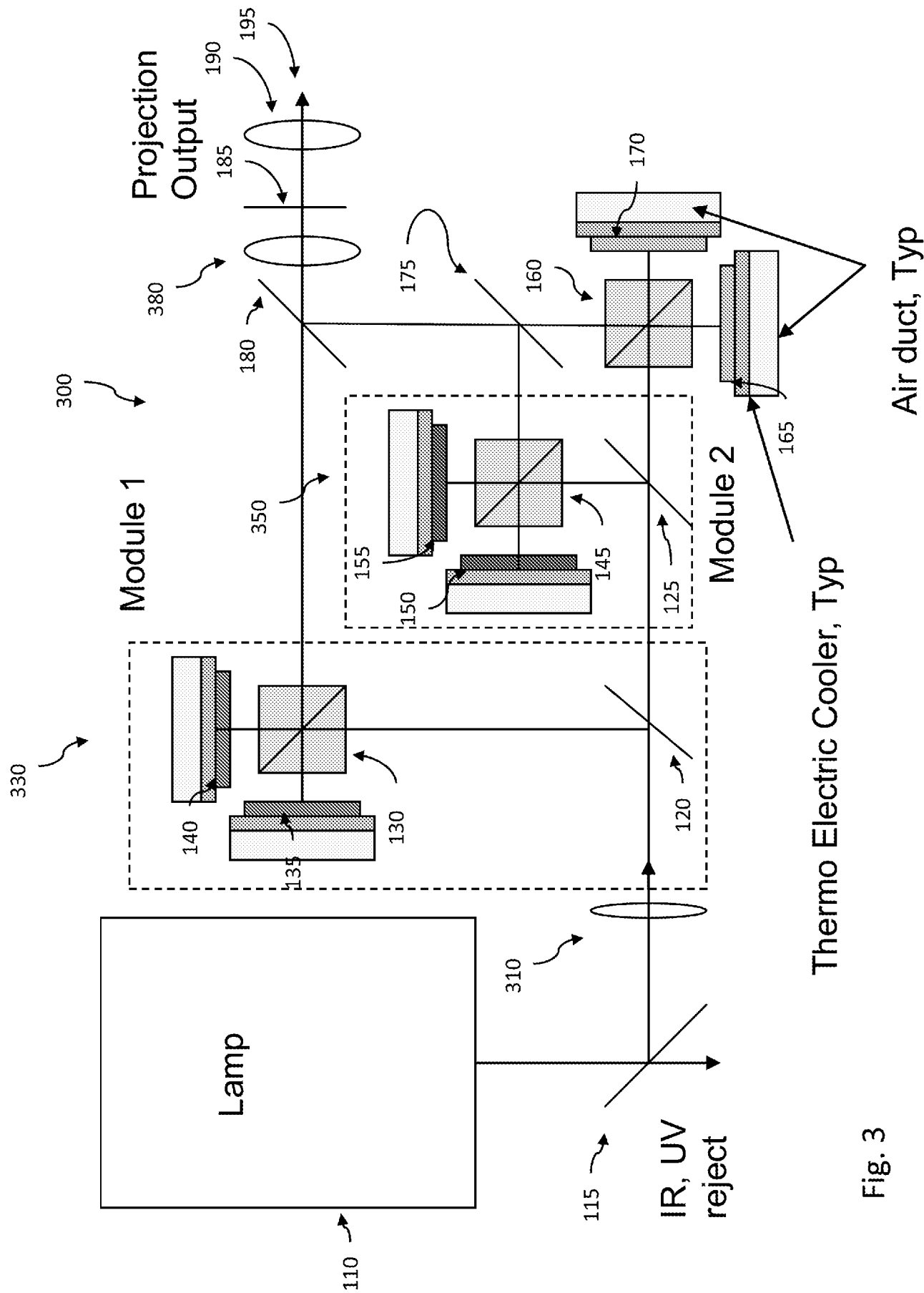


Fig. 3

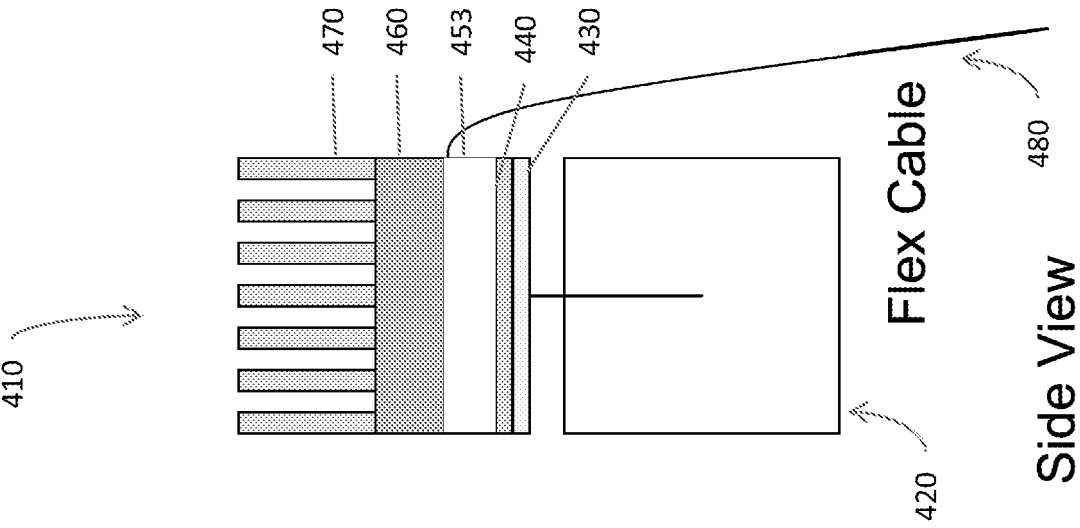


Fig. 4B

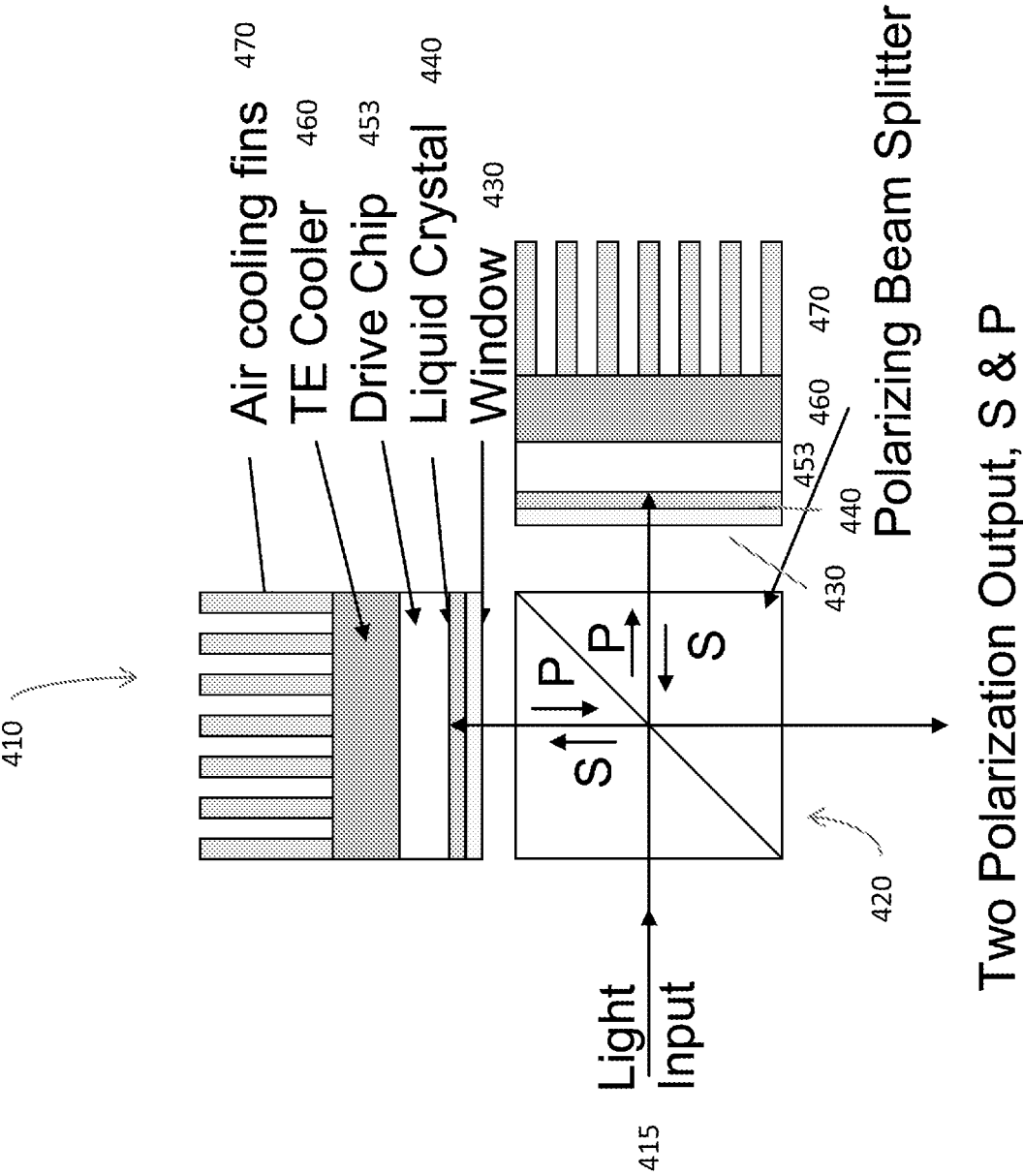


Fig. 4A

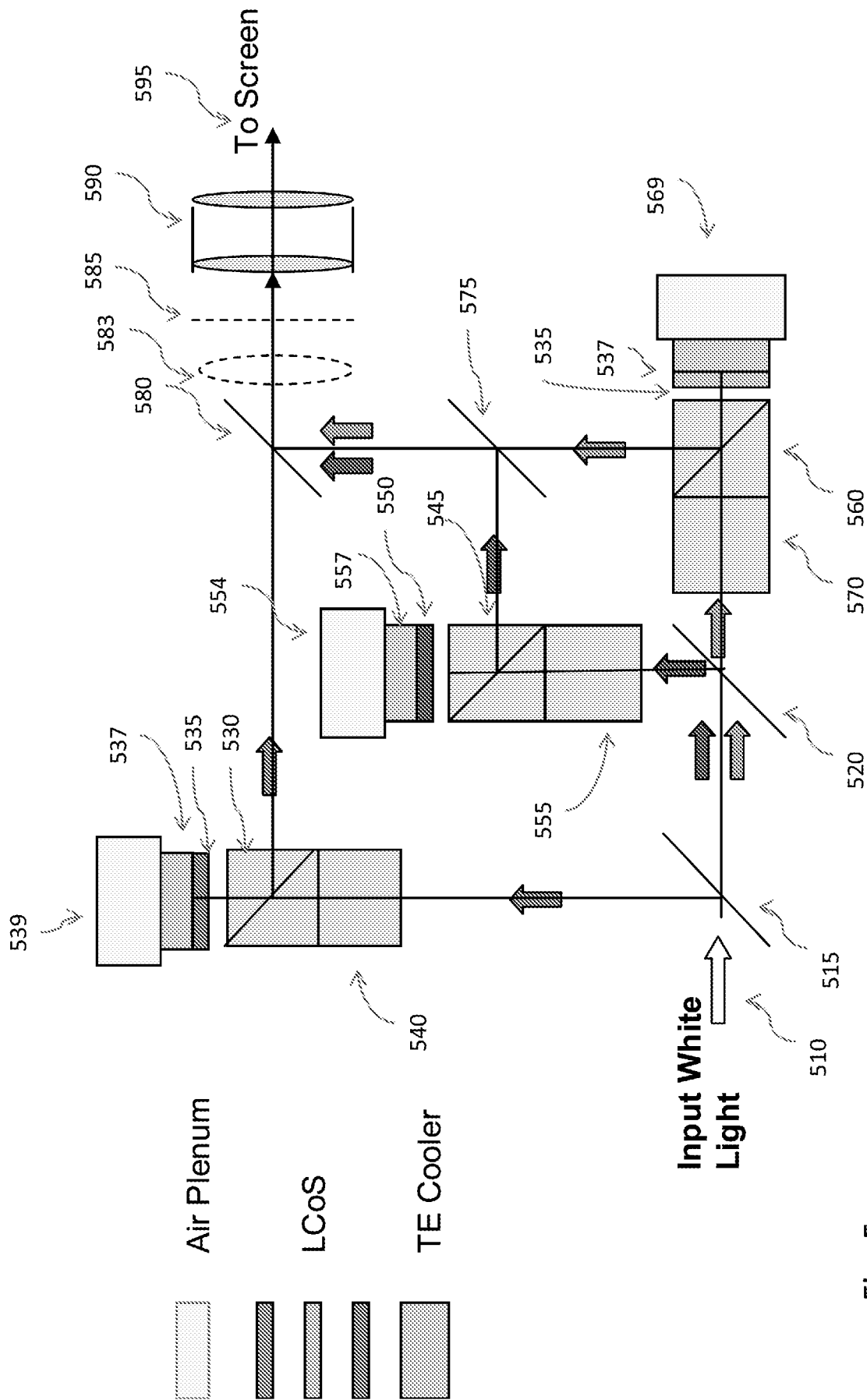


Fig. 5

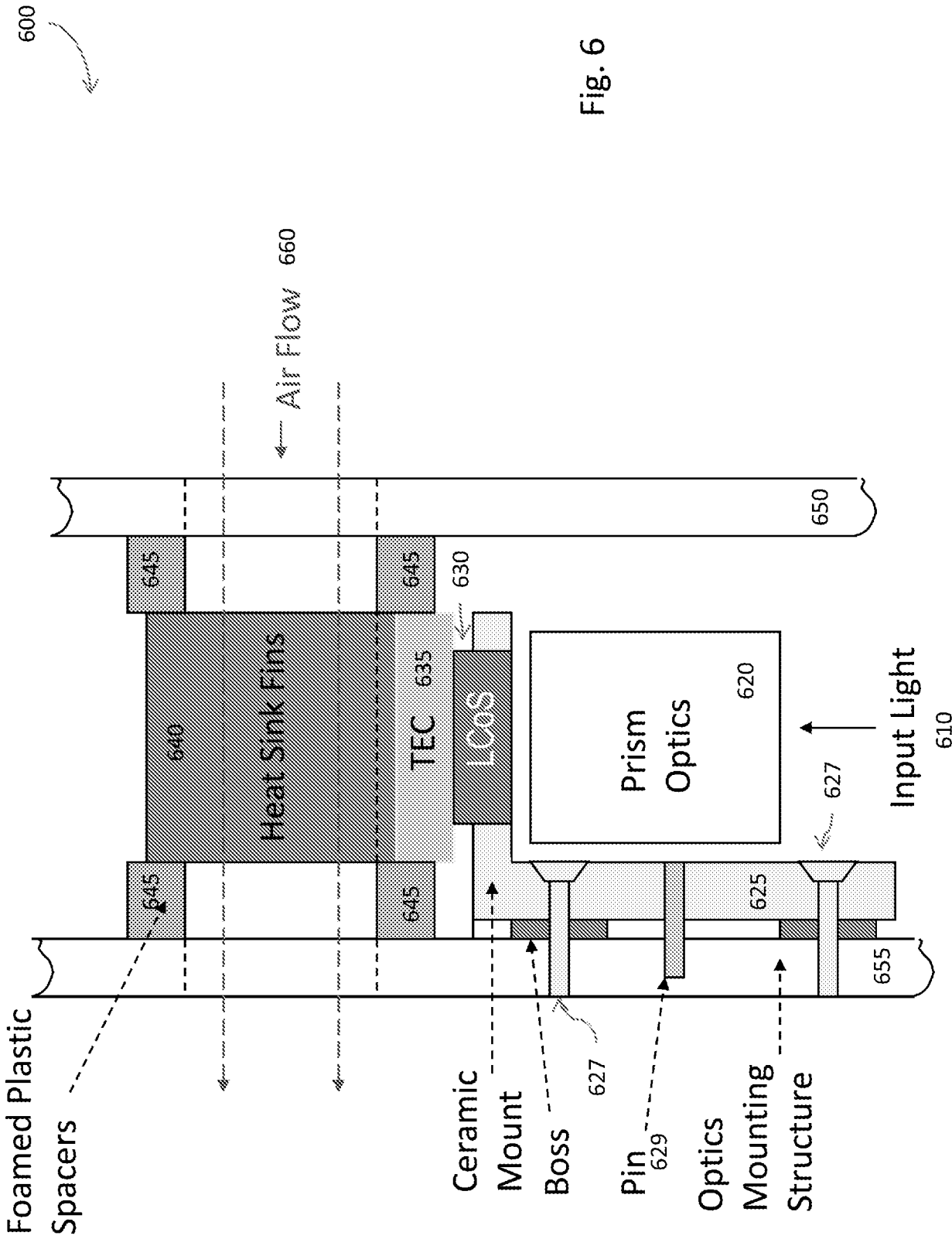


Fig. 6

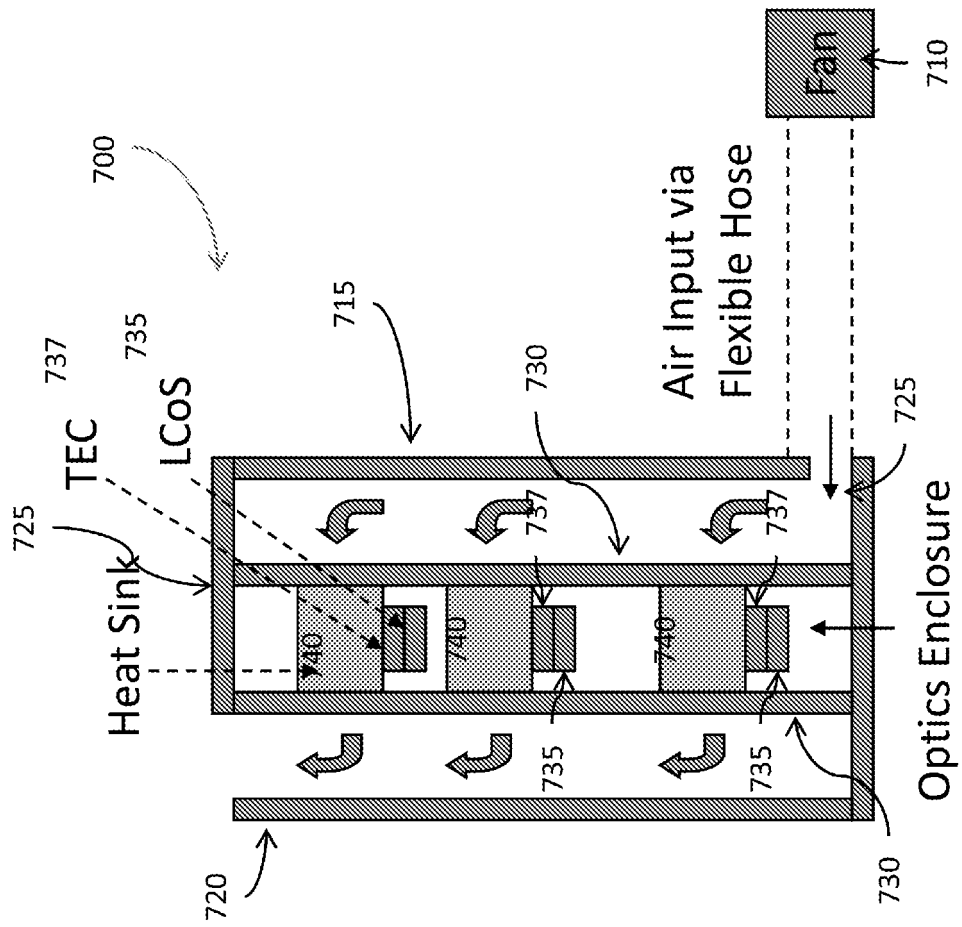


Fig. 7A

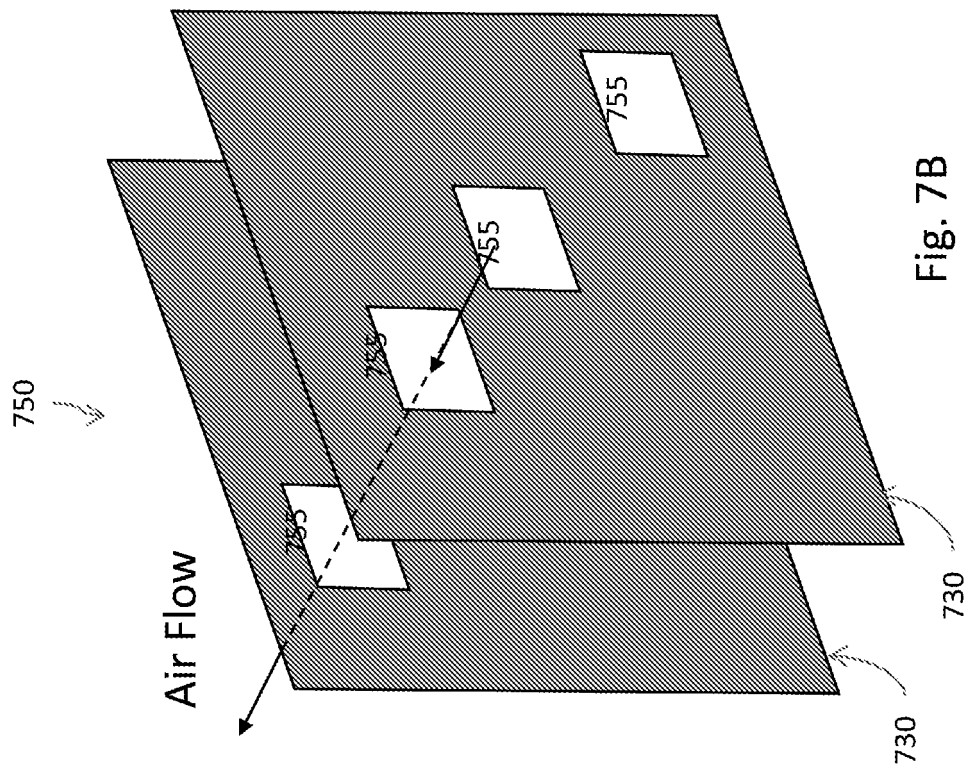


Fig. 7B

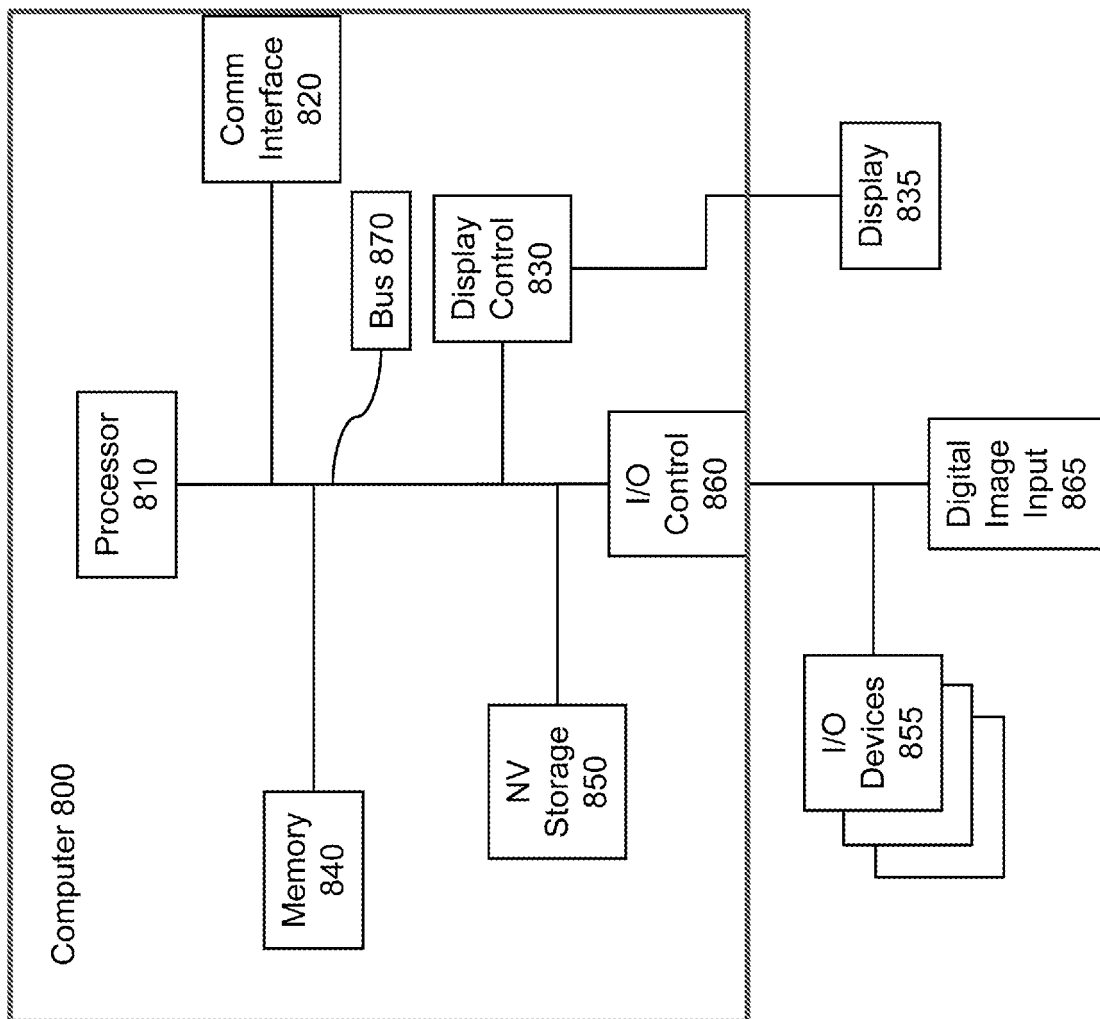


Fig. 8

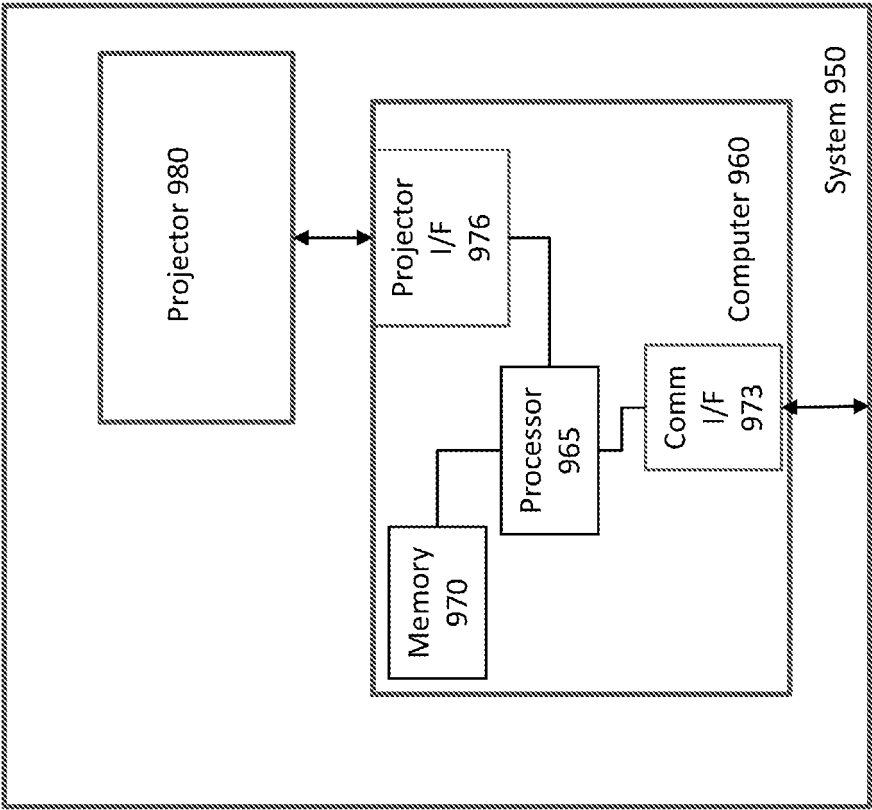


Fig. 9B

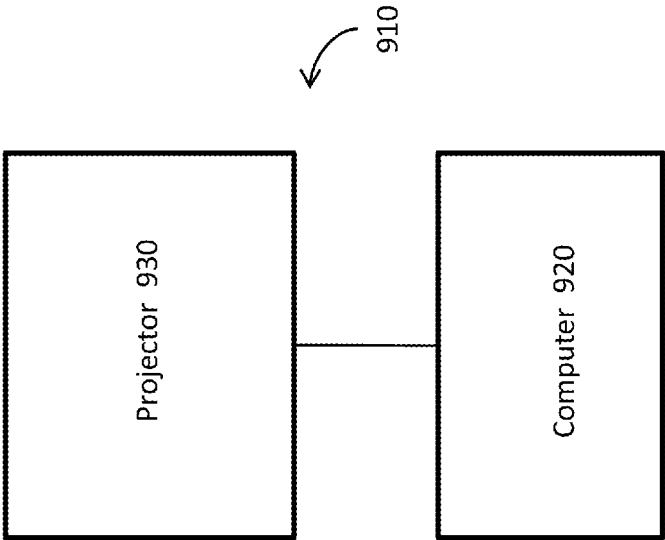


Fig. 9A

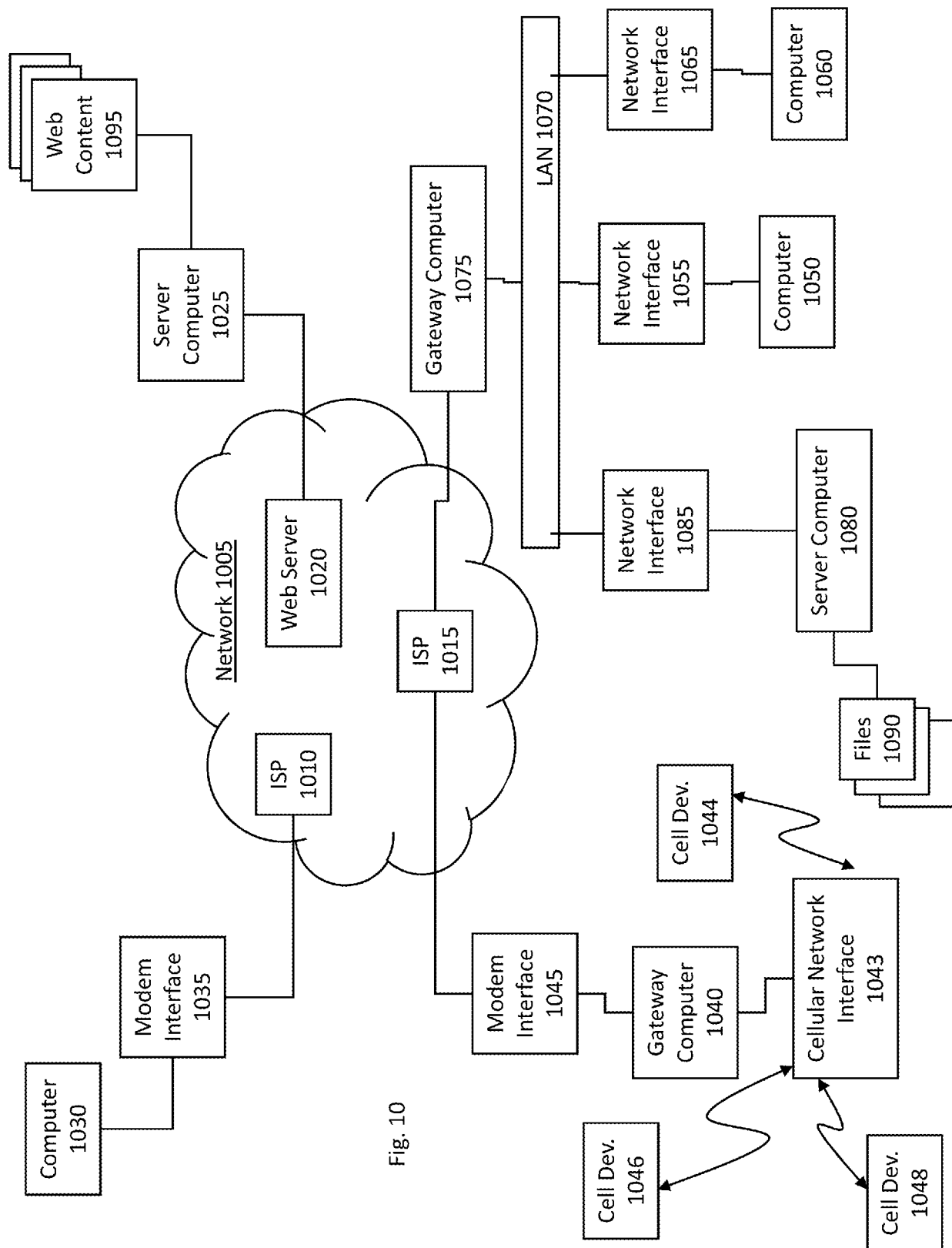


Fig. 10

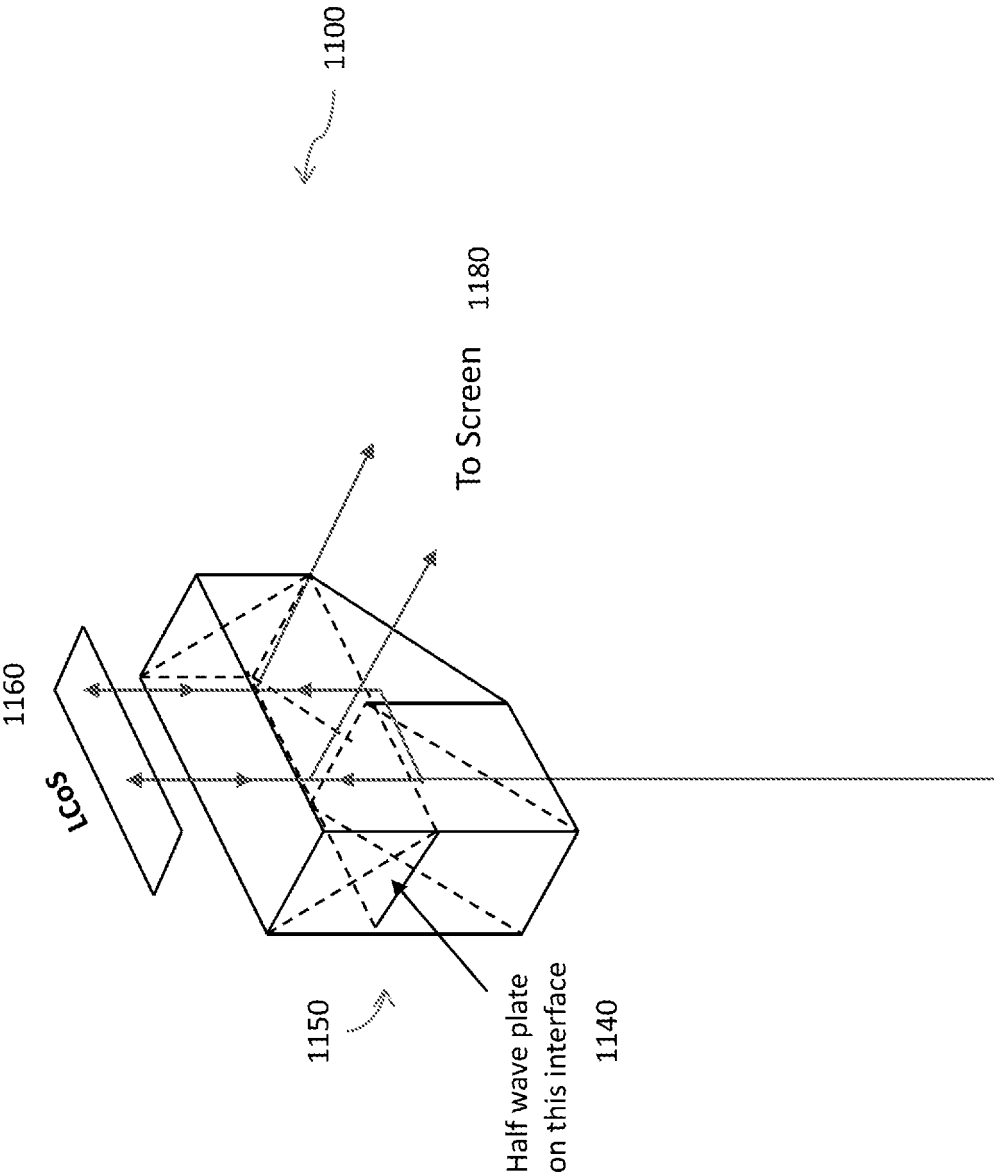


Fig. 11

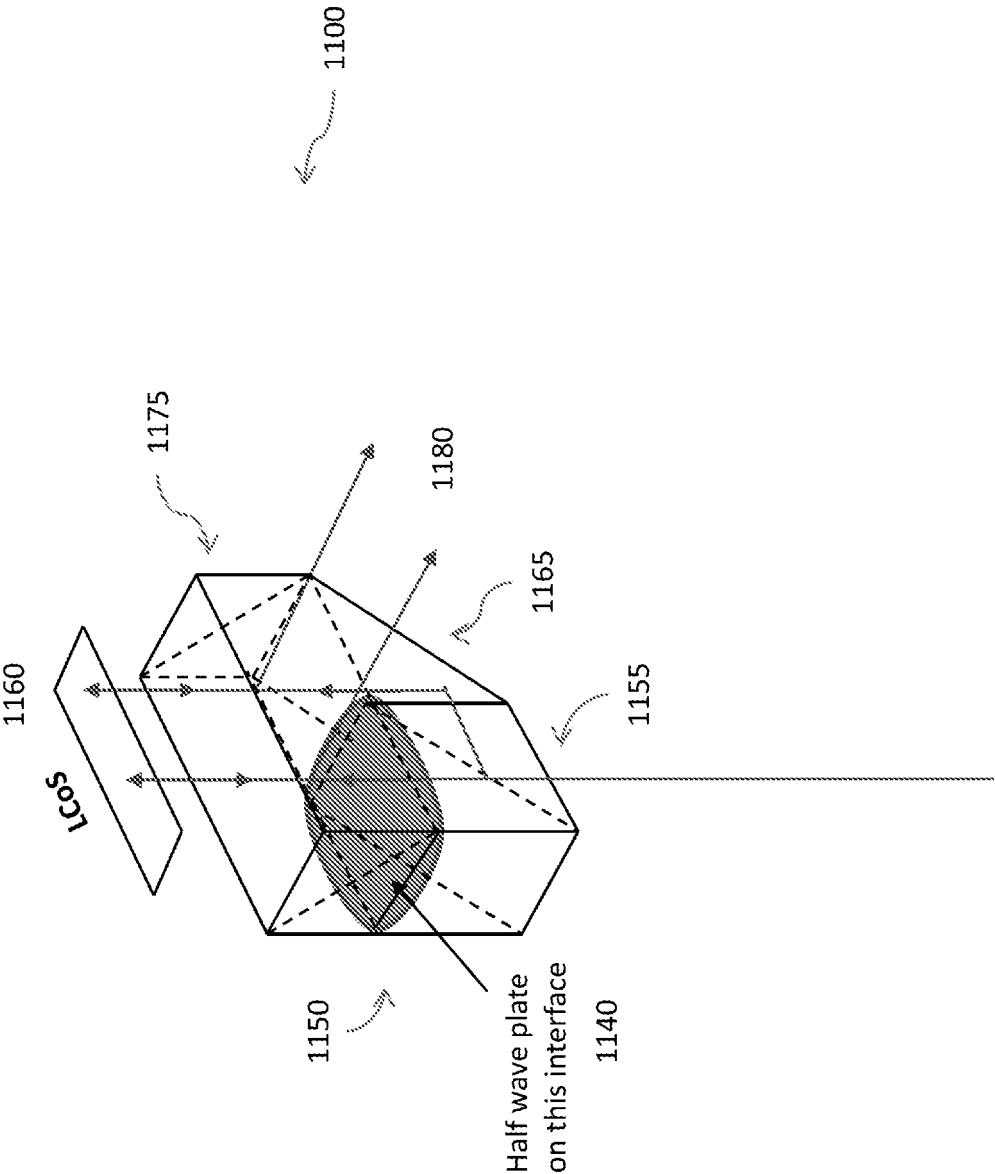


Fig. 12

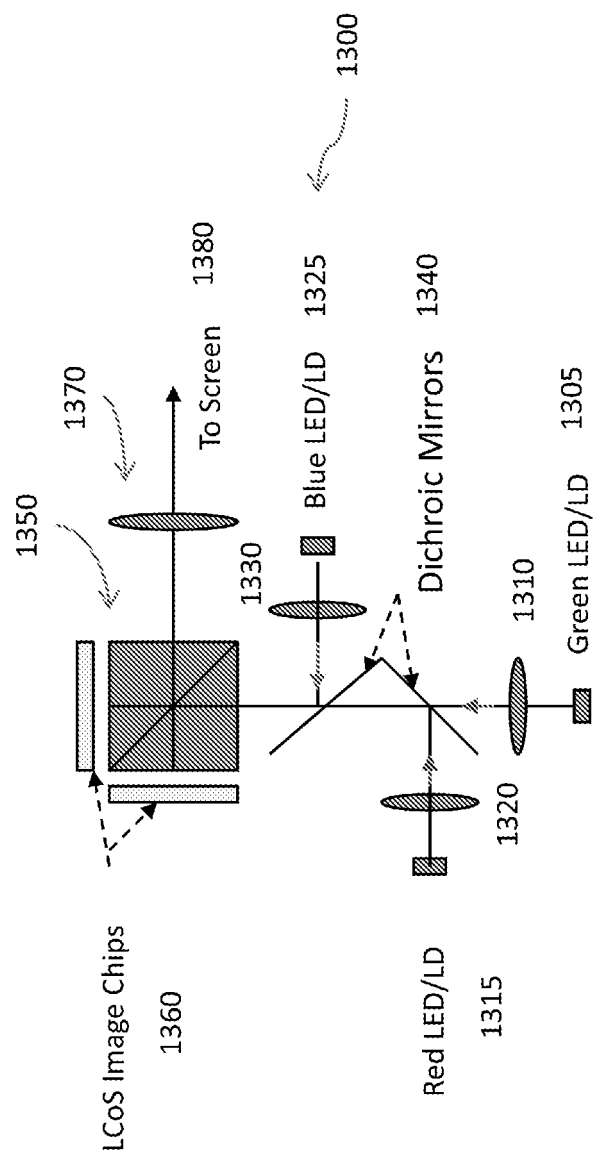


Fig. 13

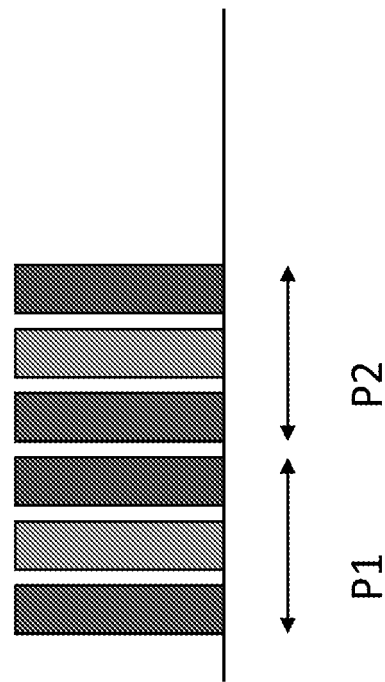


Fig. 14

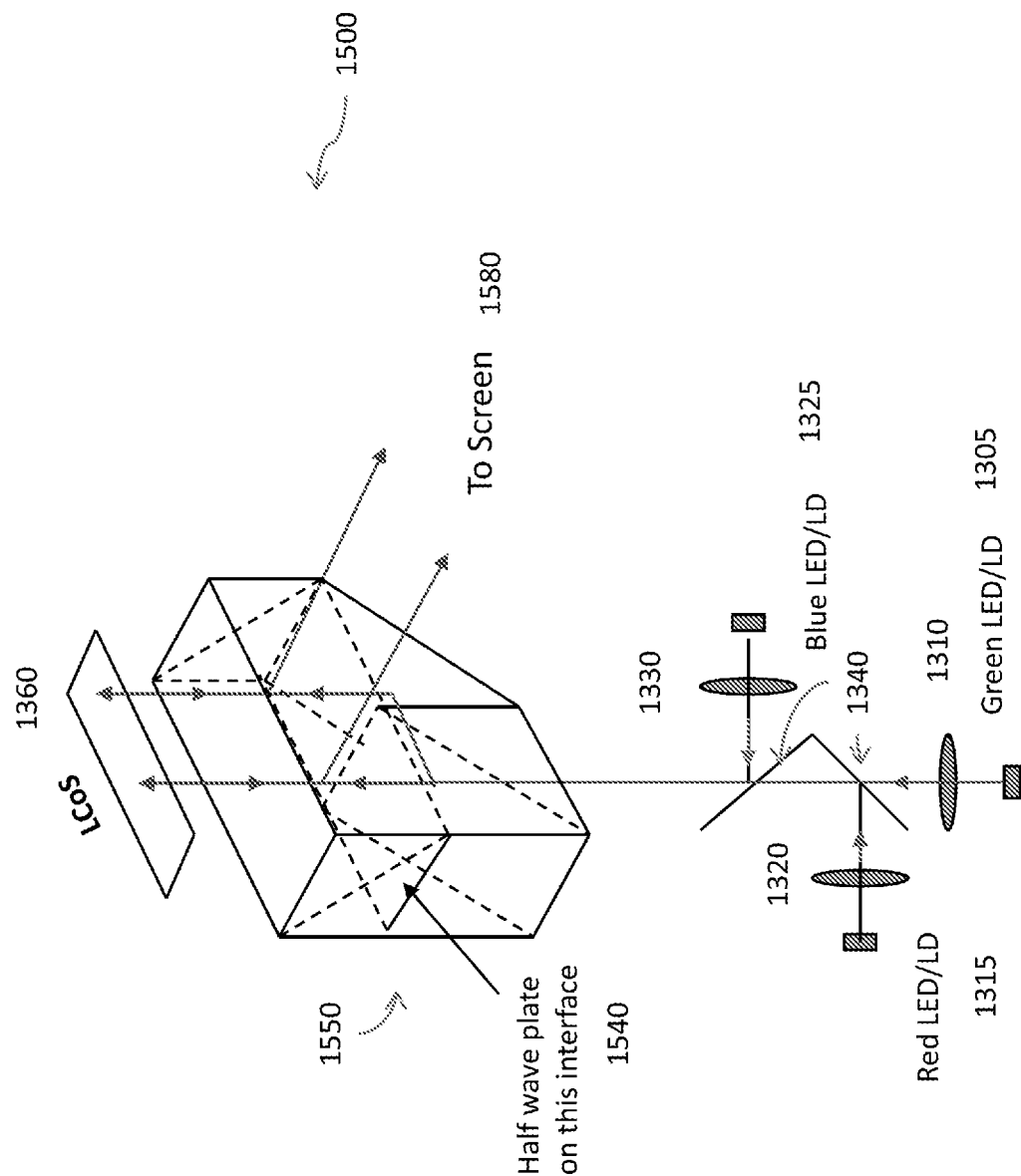


Fig. 15A

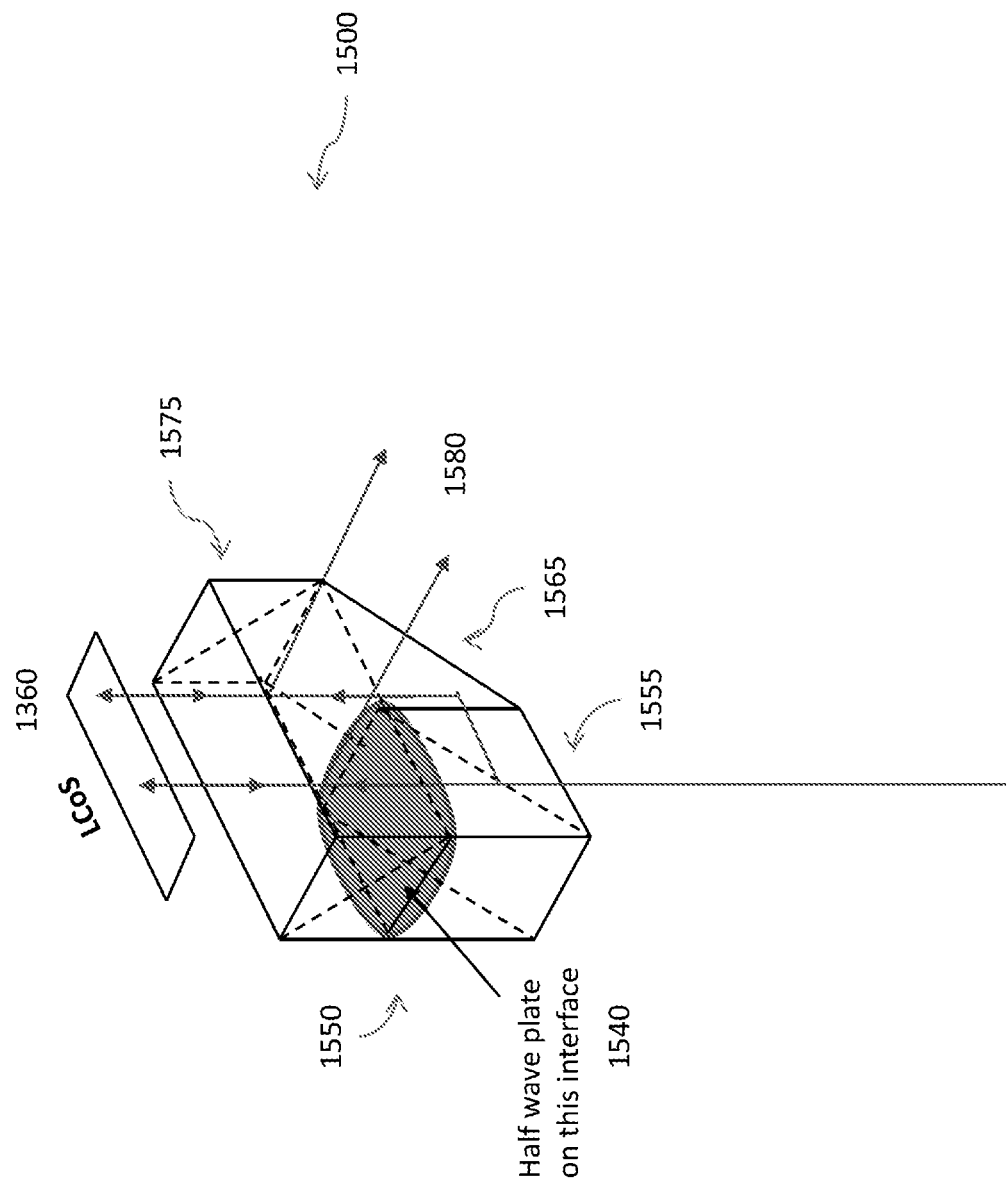


Fig. 15B

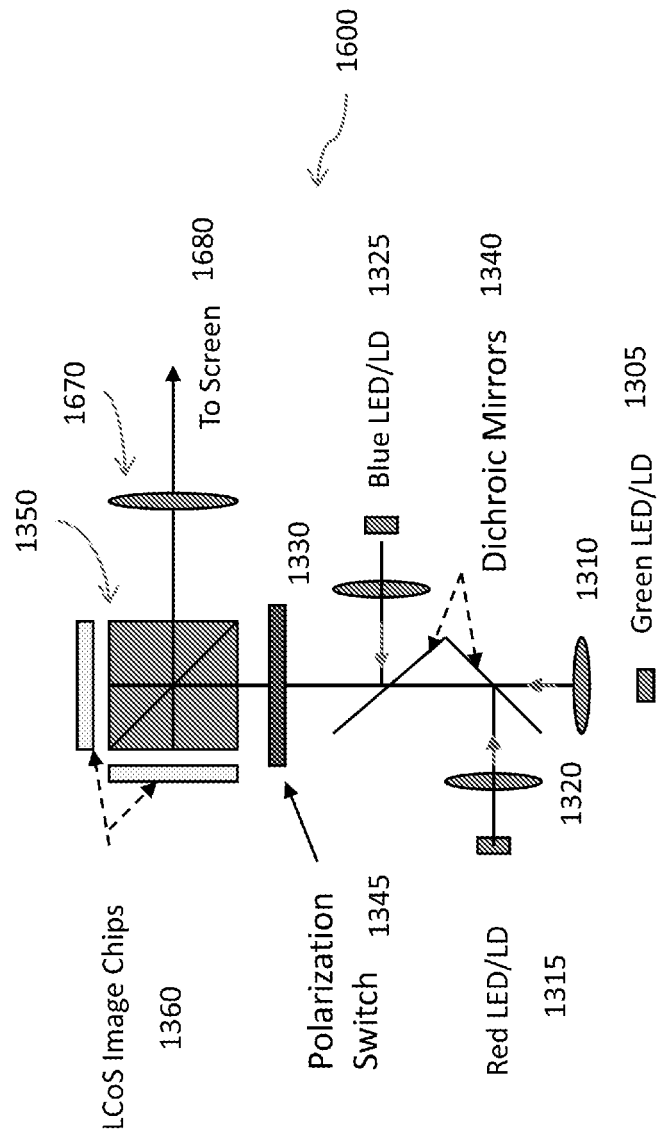


Fig. 16

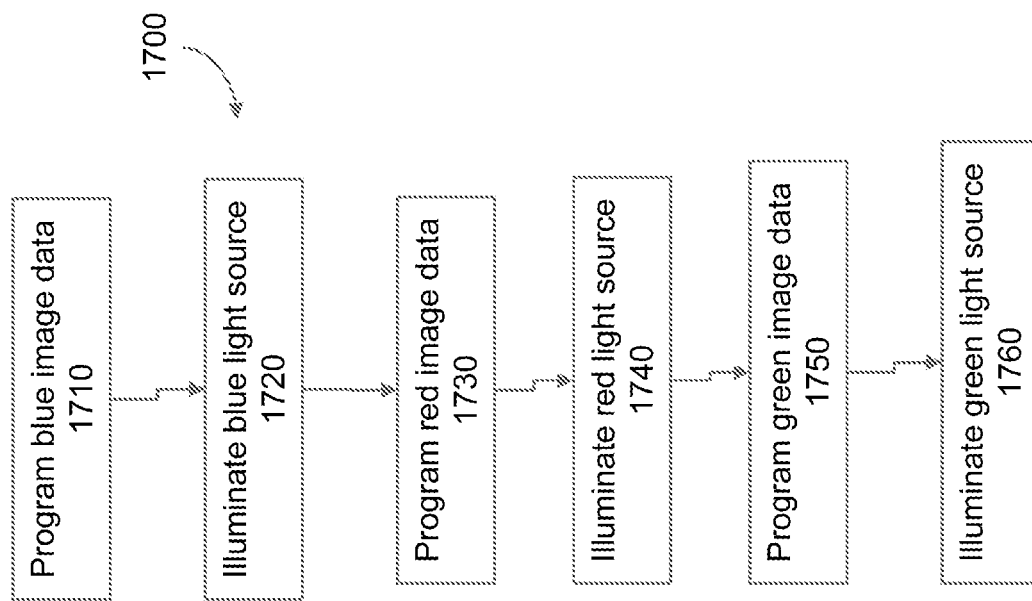


Fig. 17

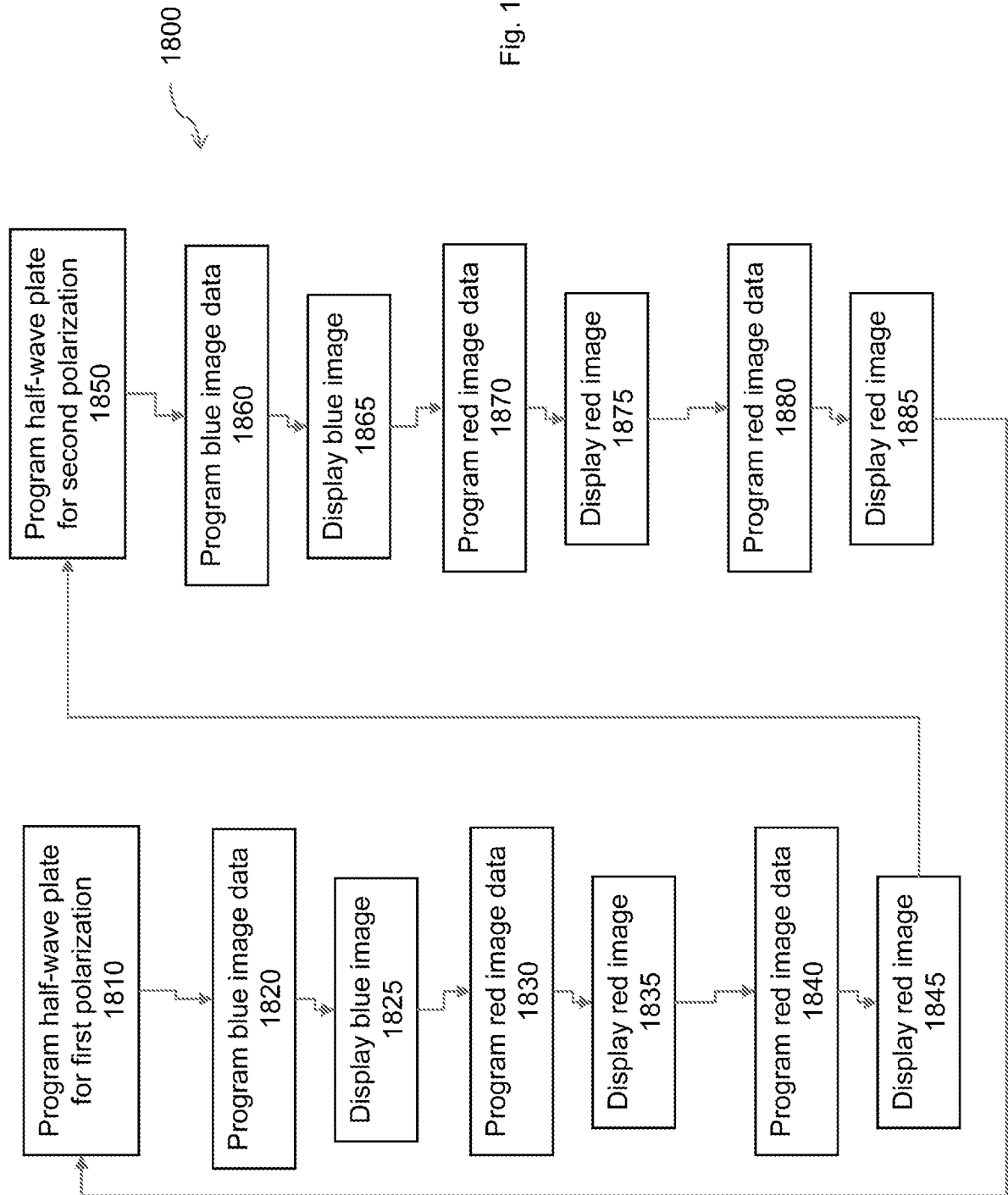


Fig. 18

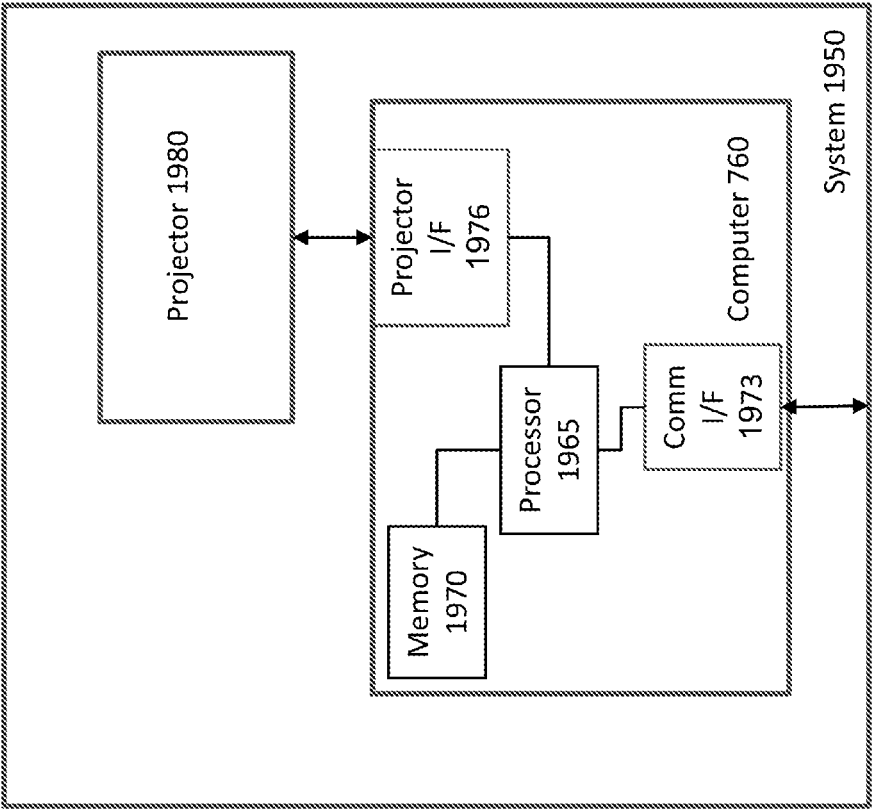


Fig. 19B

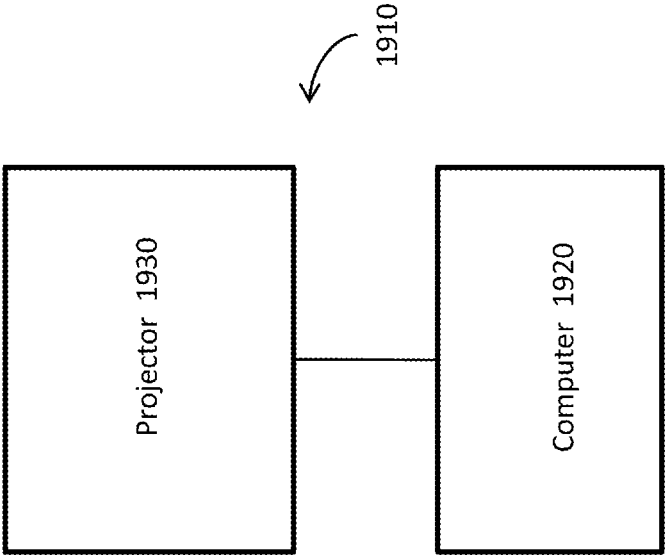


Fig. 19A

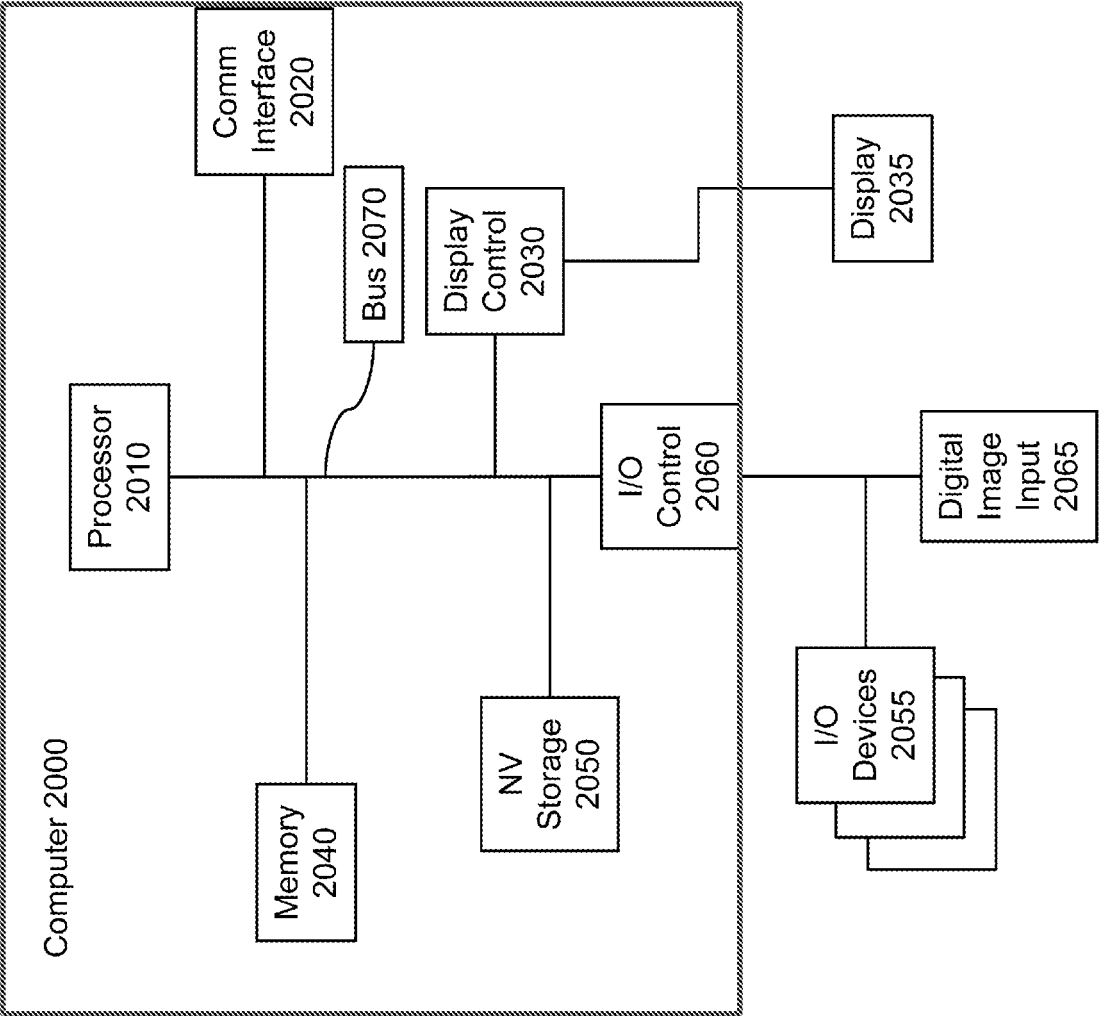


Fig. 20

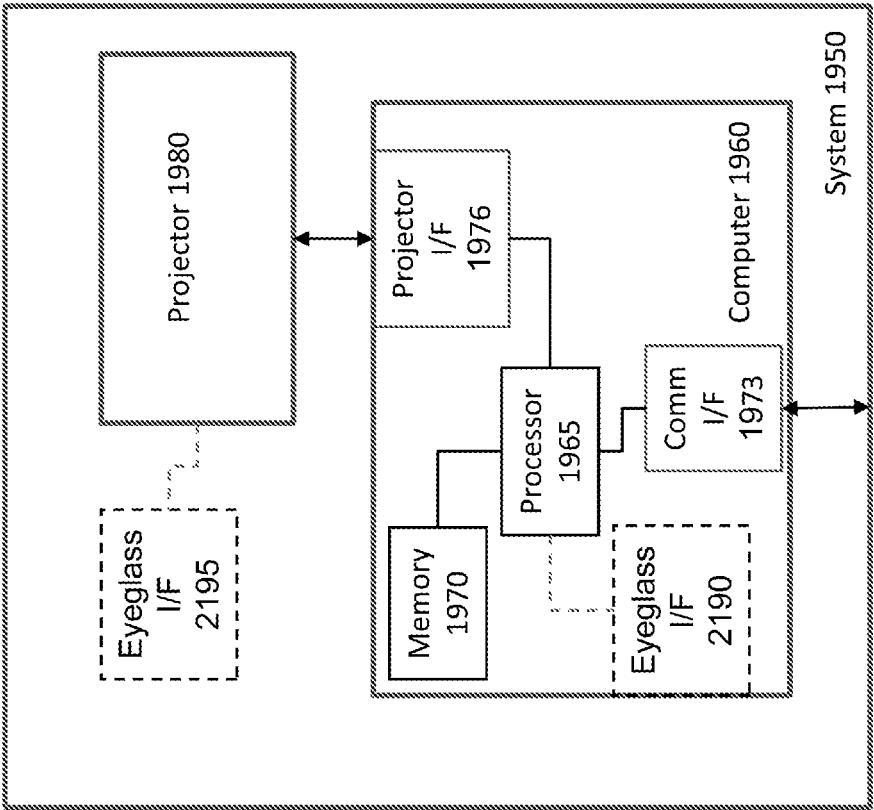
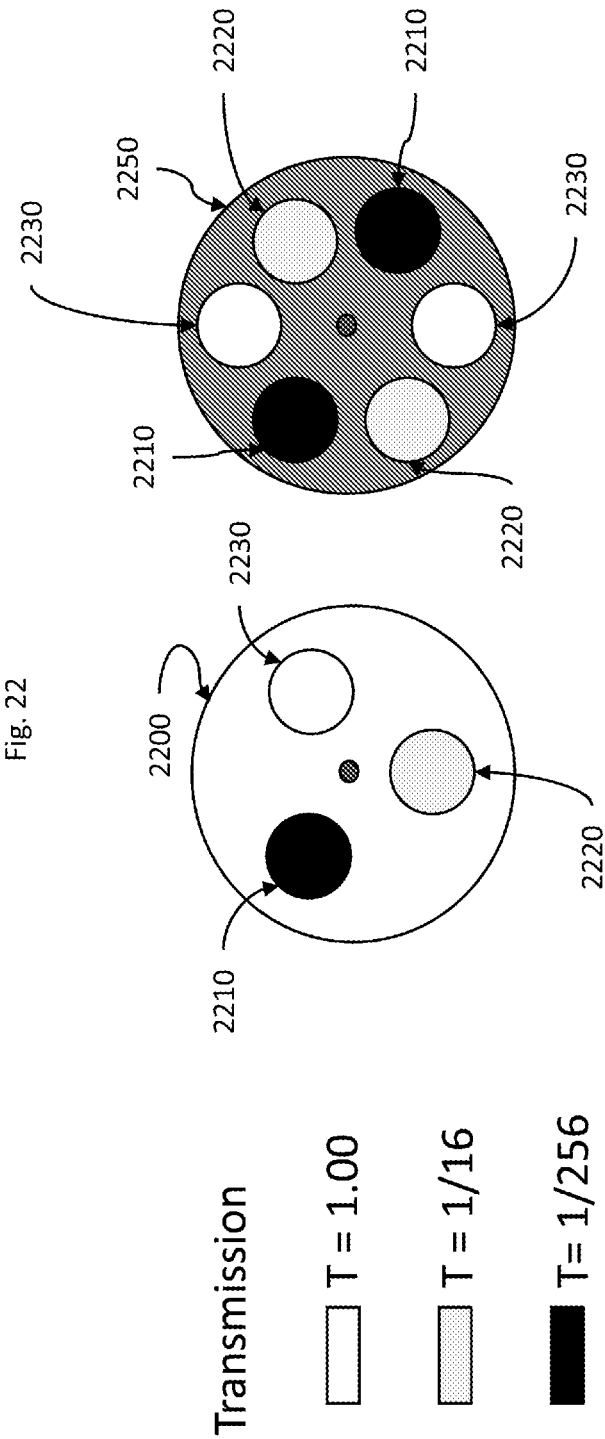


Fig. 21



Three Position and Six Position Filter Wheels

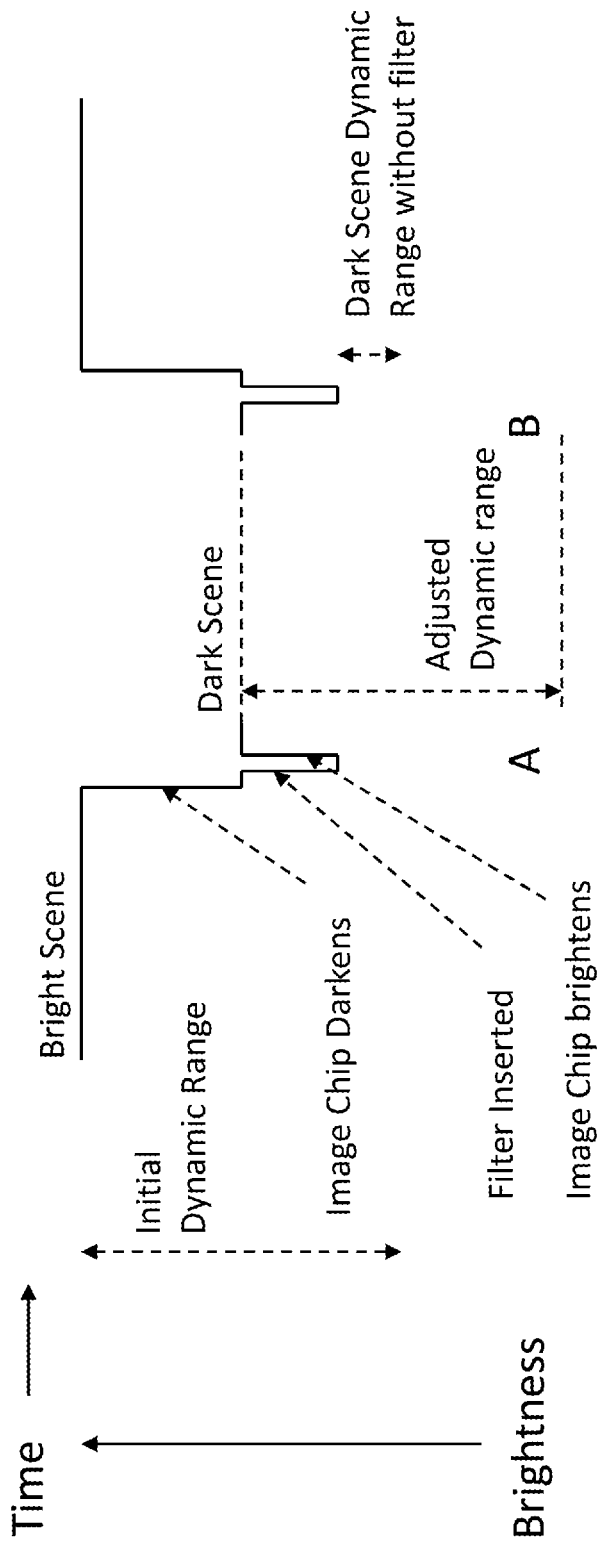


Fig. 23

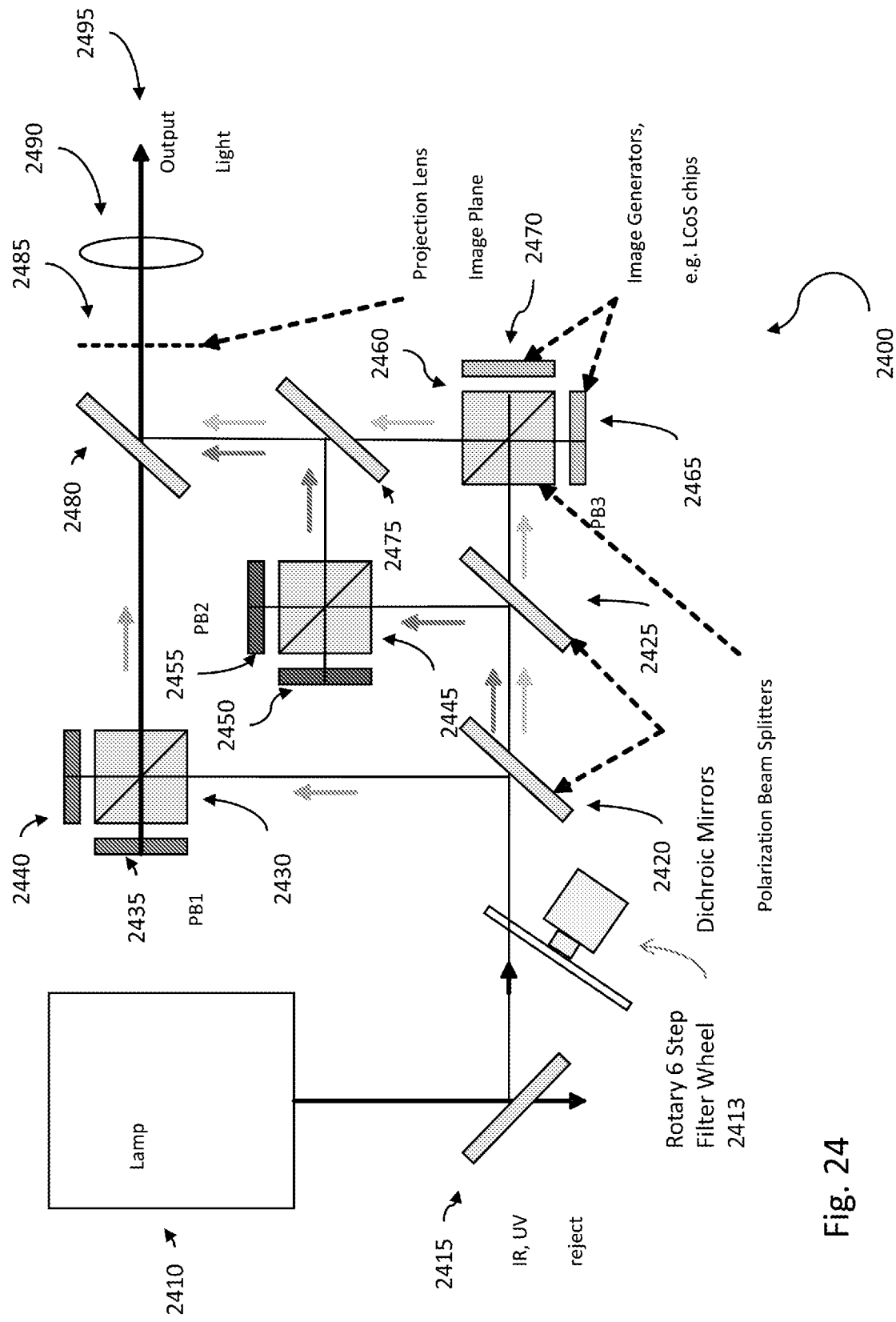


Fig. 24

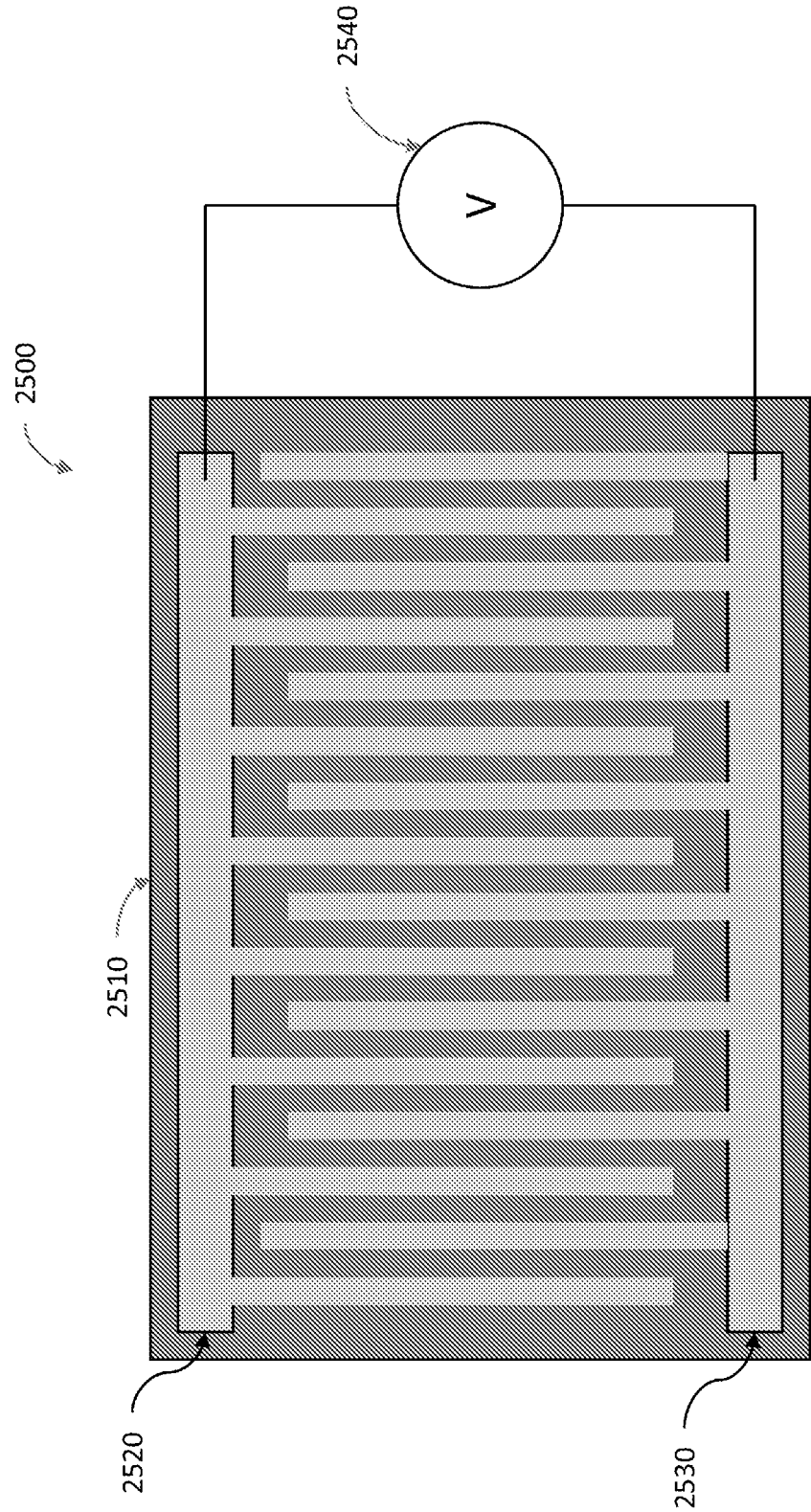


Fig. 25

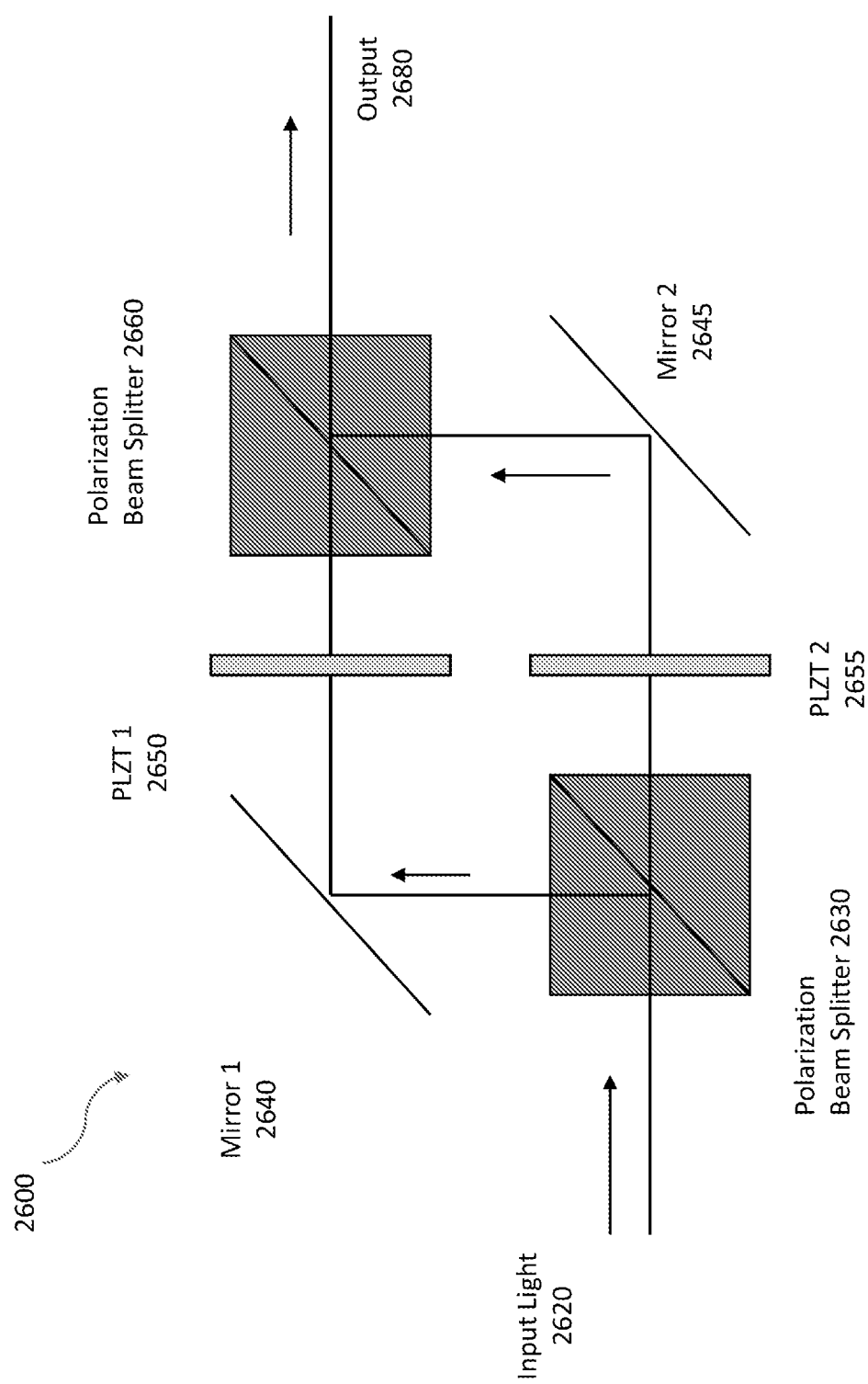


Fig. 26

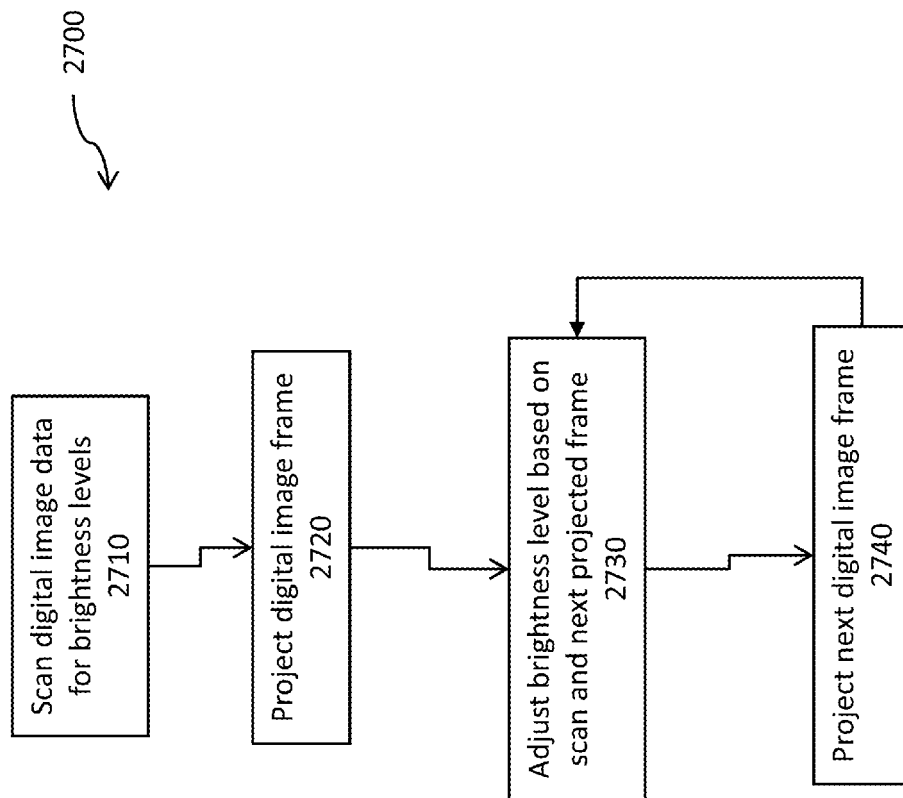


Fig. 27

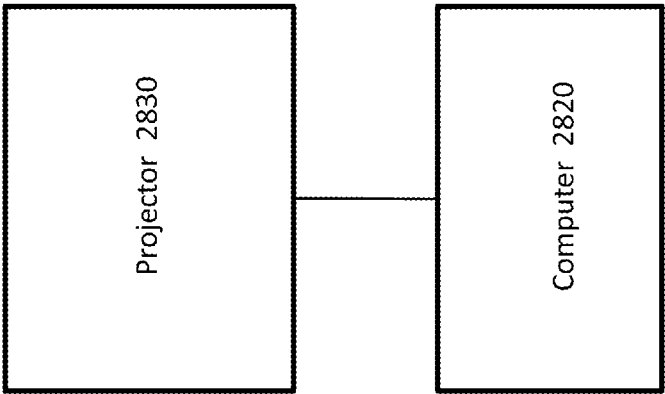


Fig. 28A

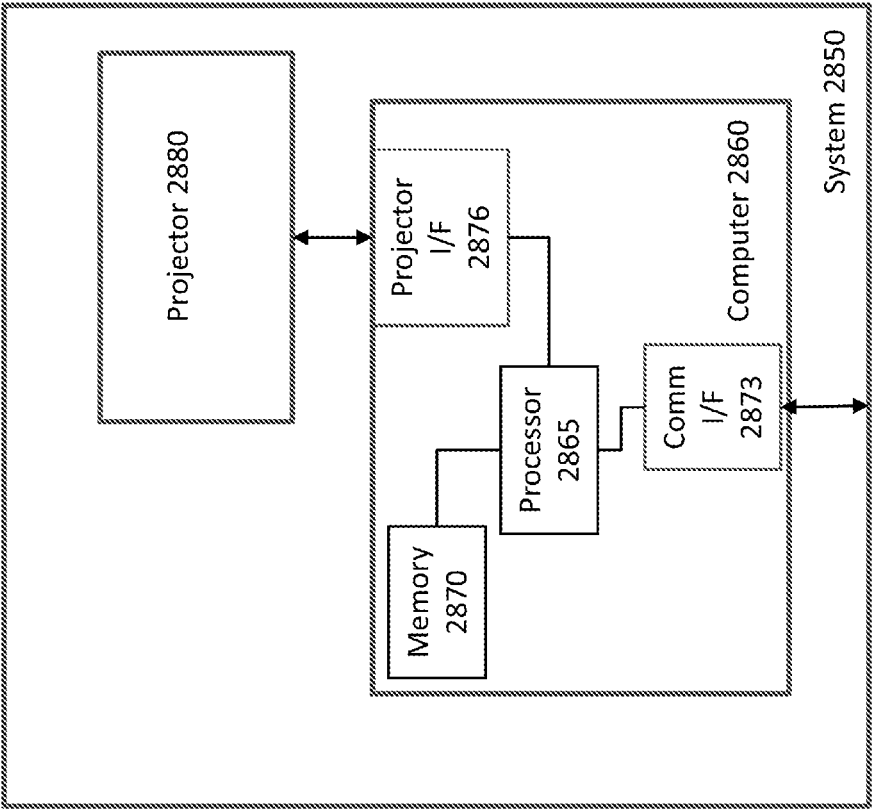


Fig. 28B

2810

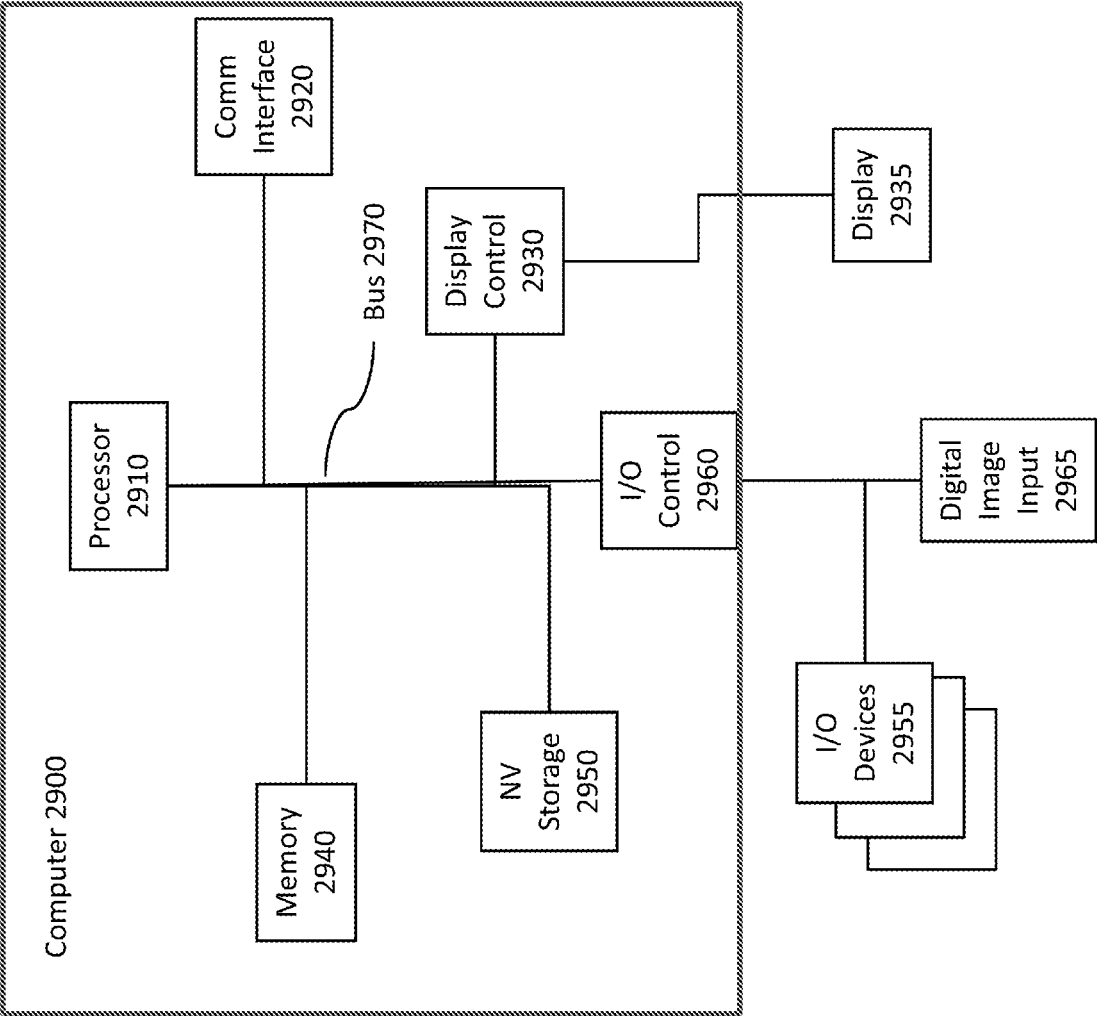


Fig. 29

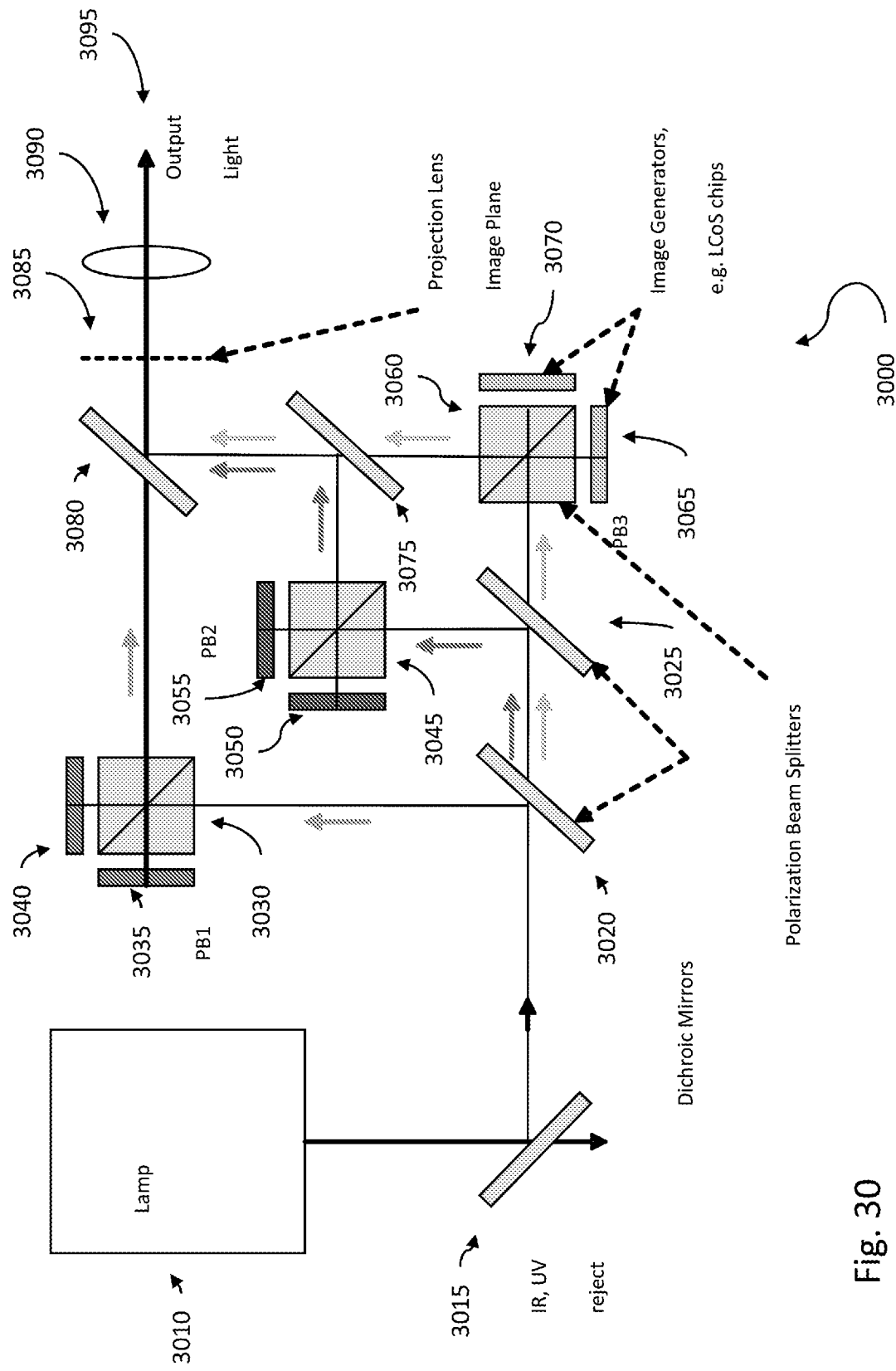


Fig. 30

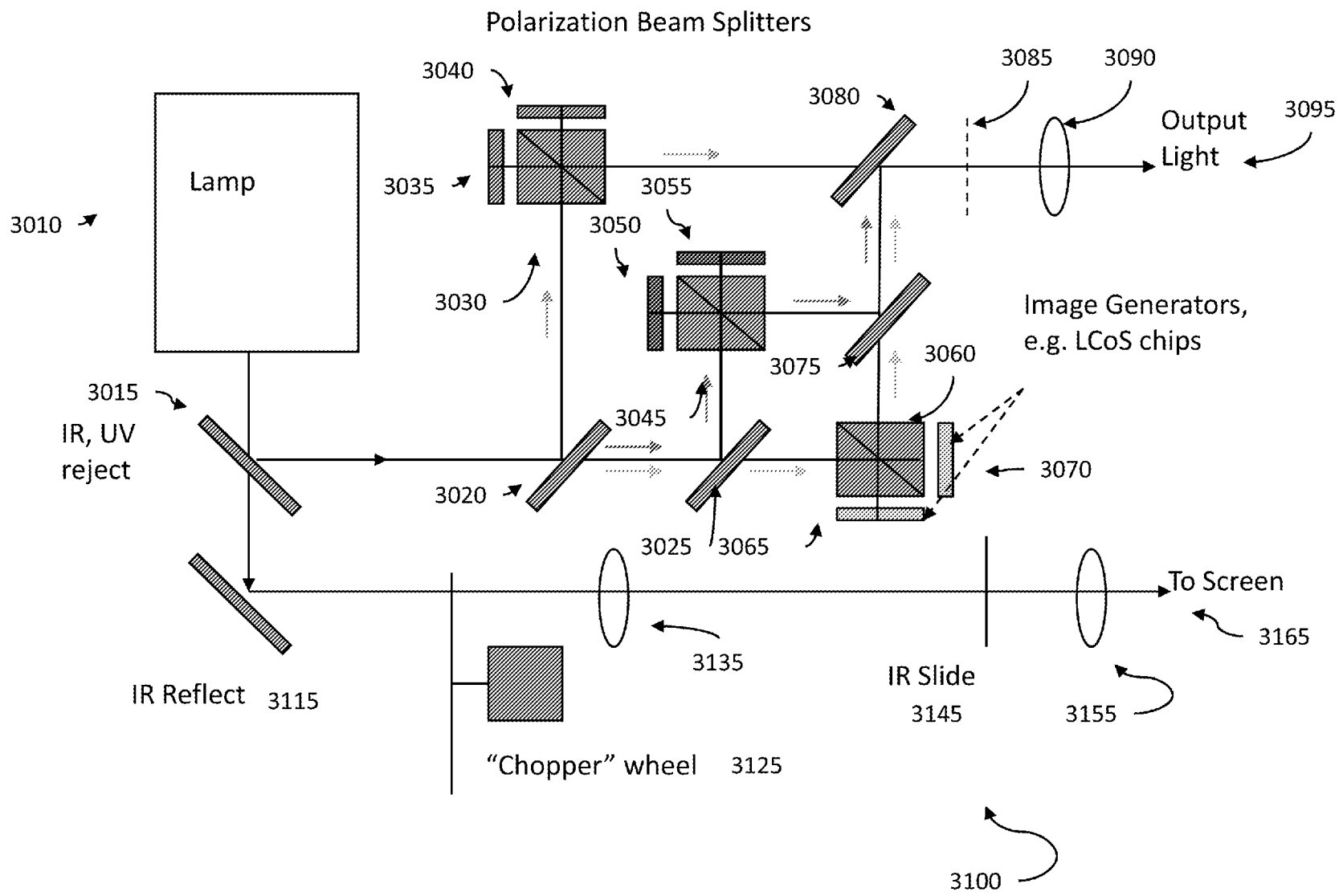


Fig. 31

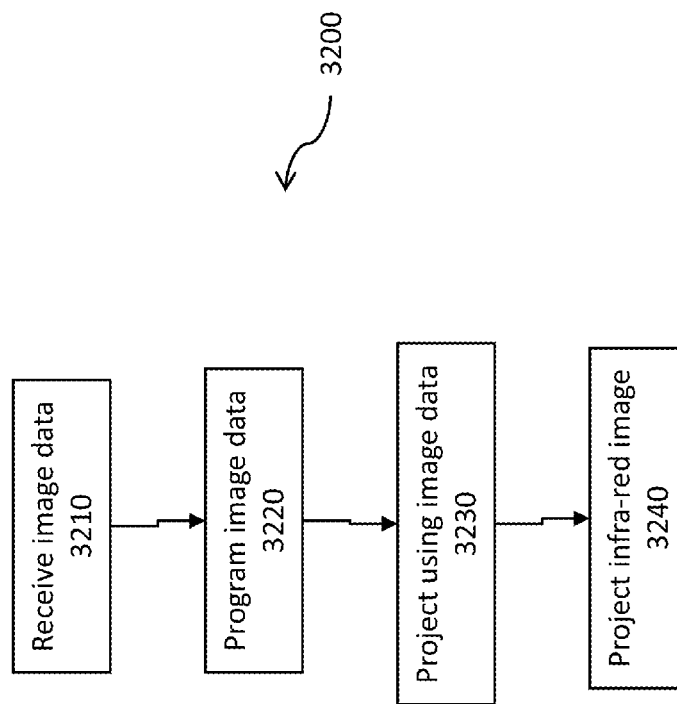


Fig. 32

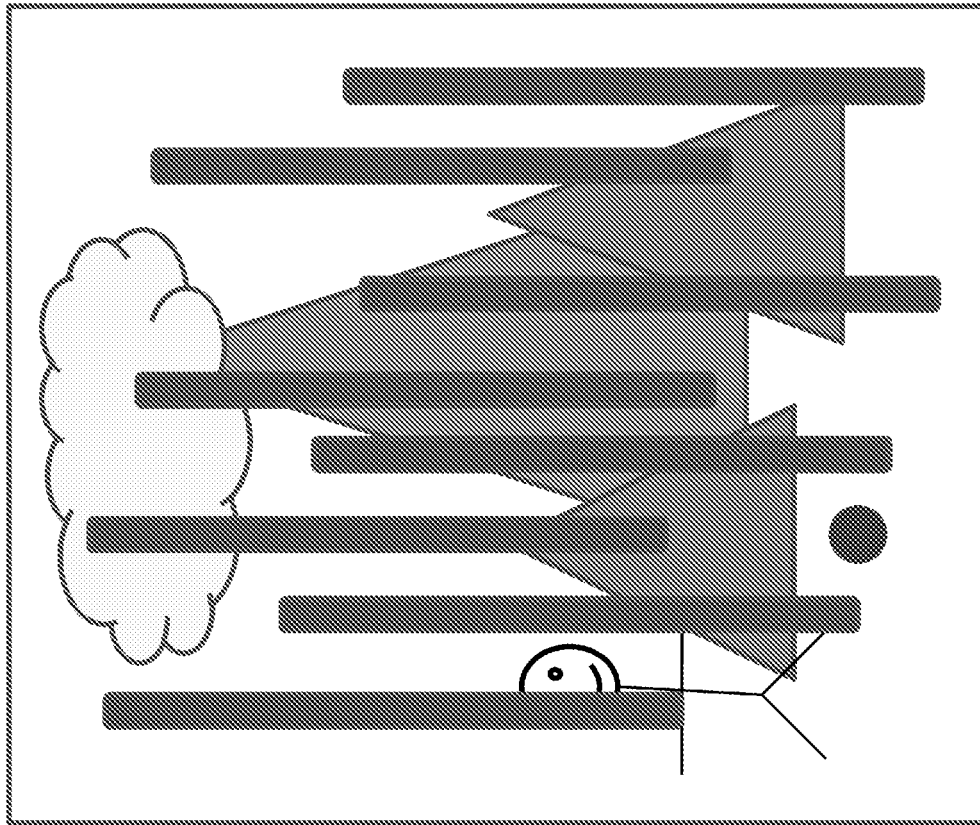


Fig. 33B

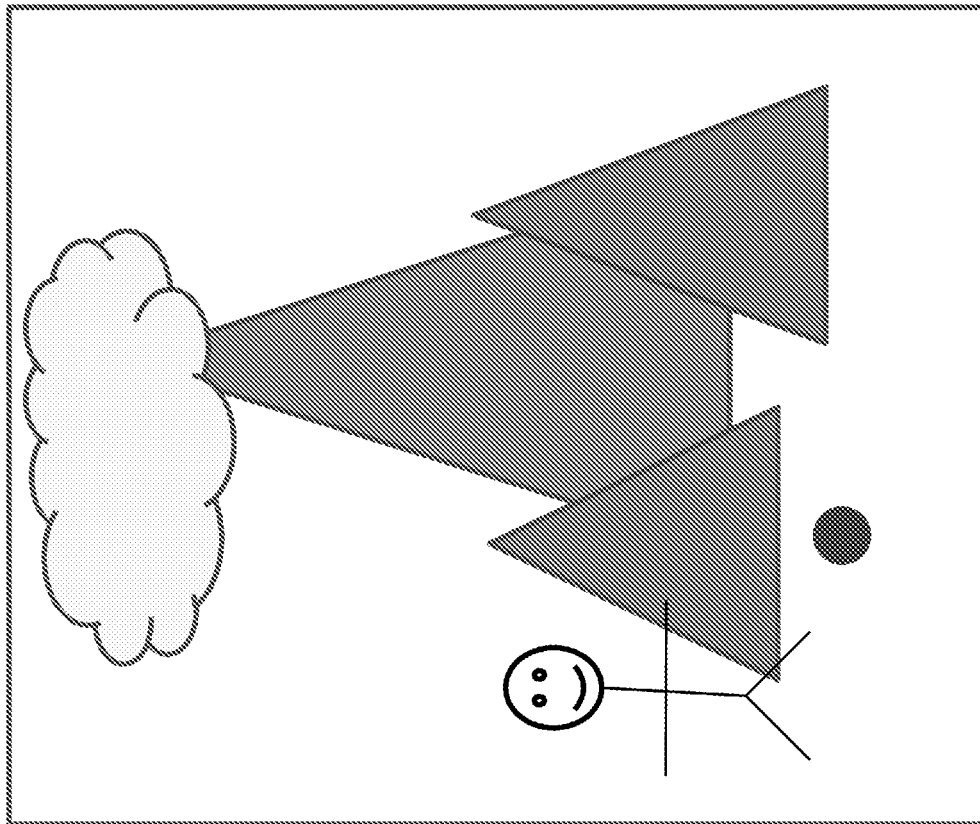


Fig. 33A

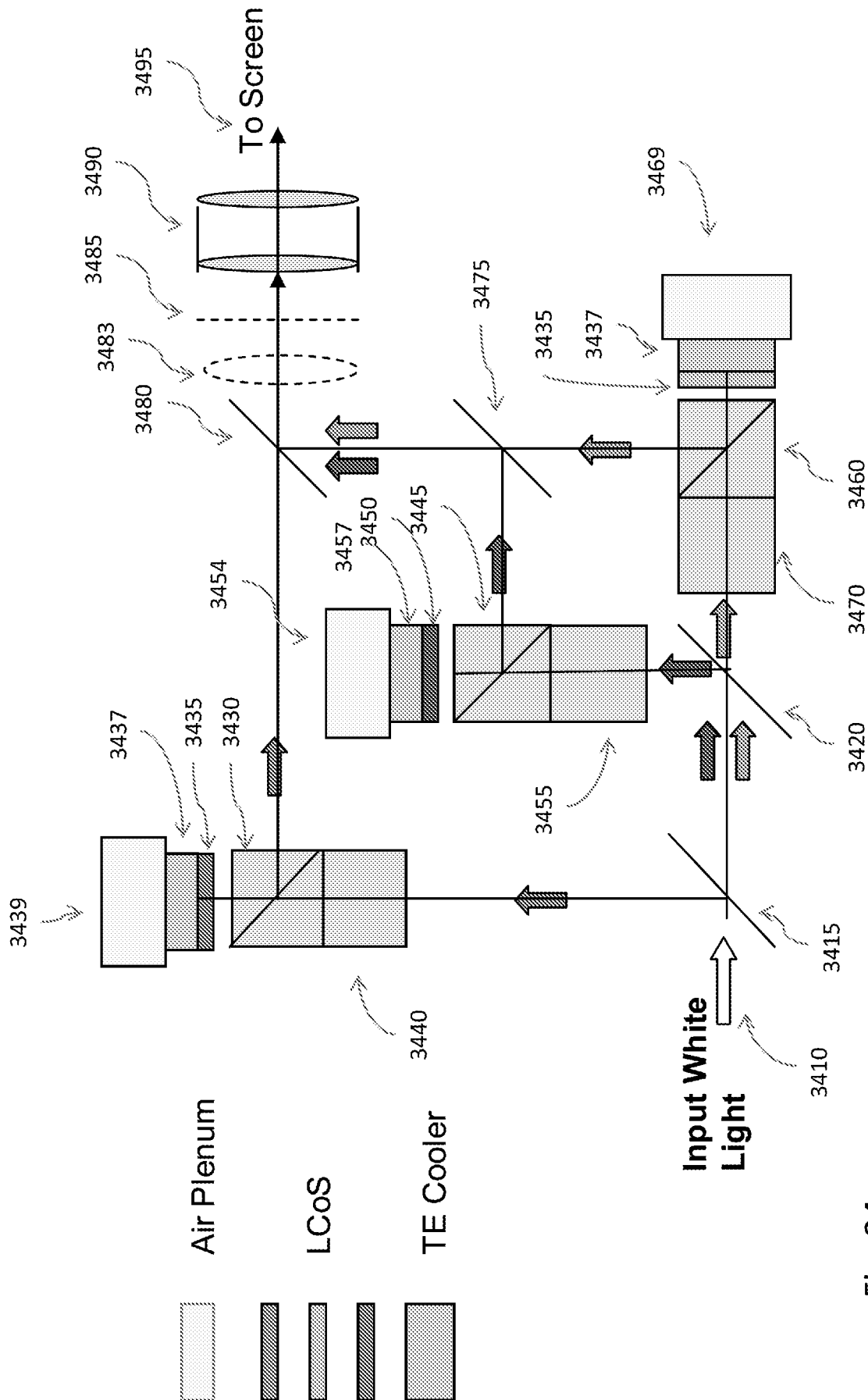


Fig. 34

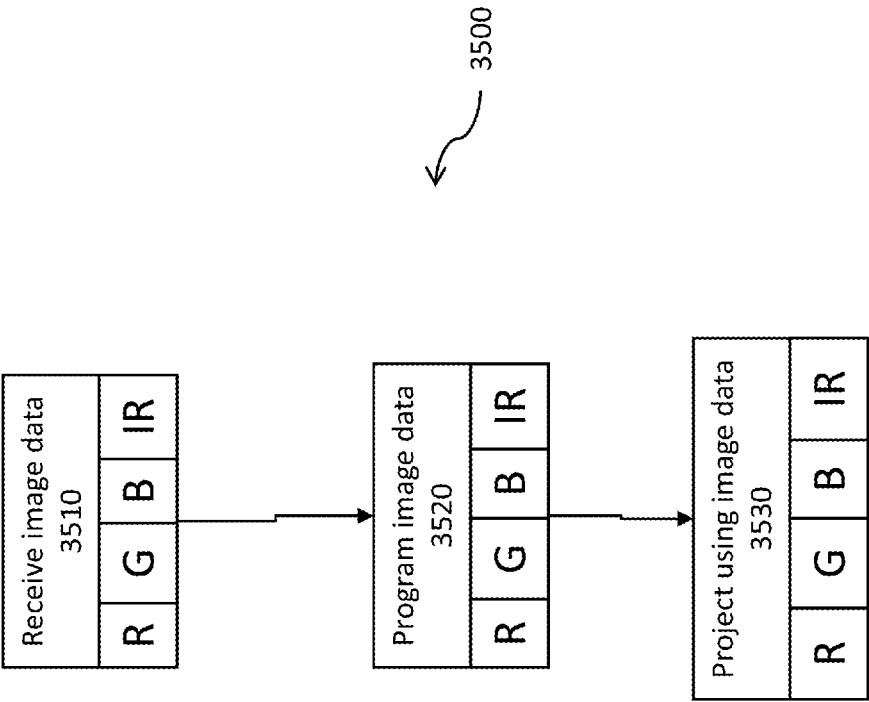


Fig. 35

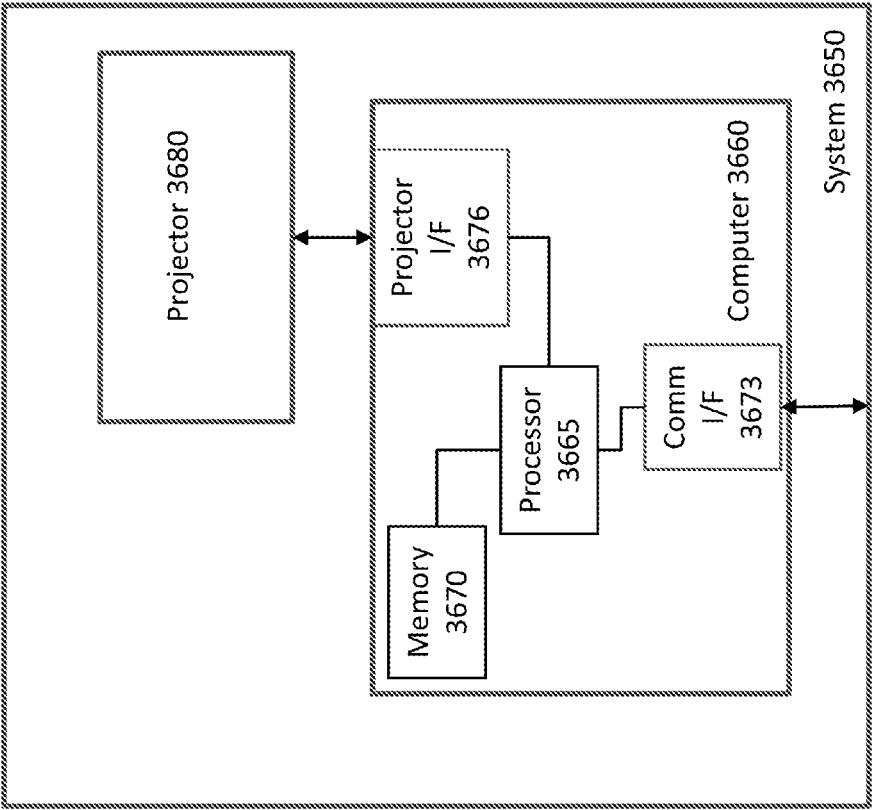


Fig. 36B

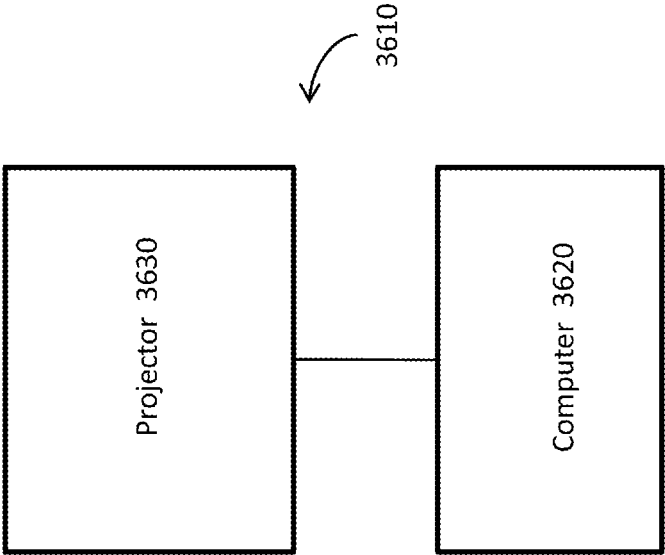


Fig. 36A

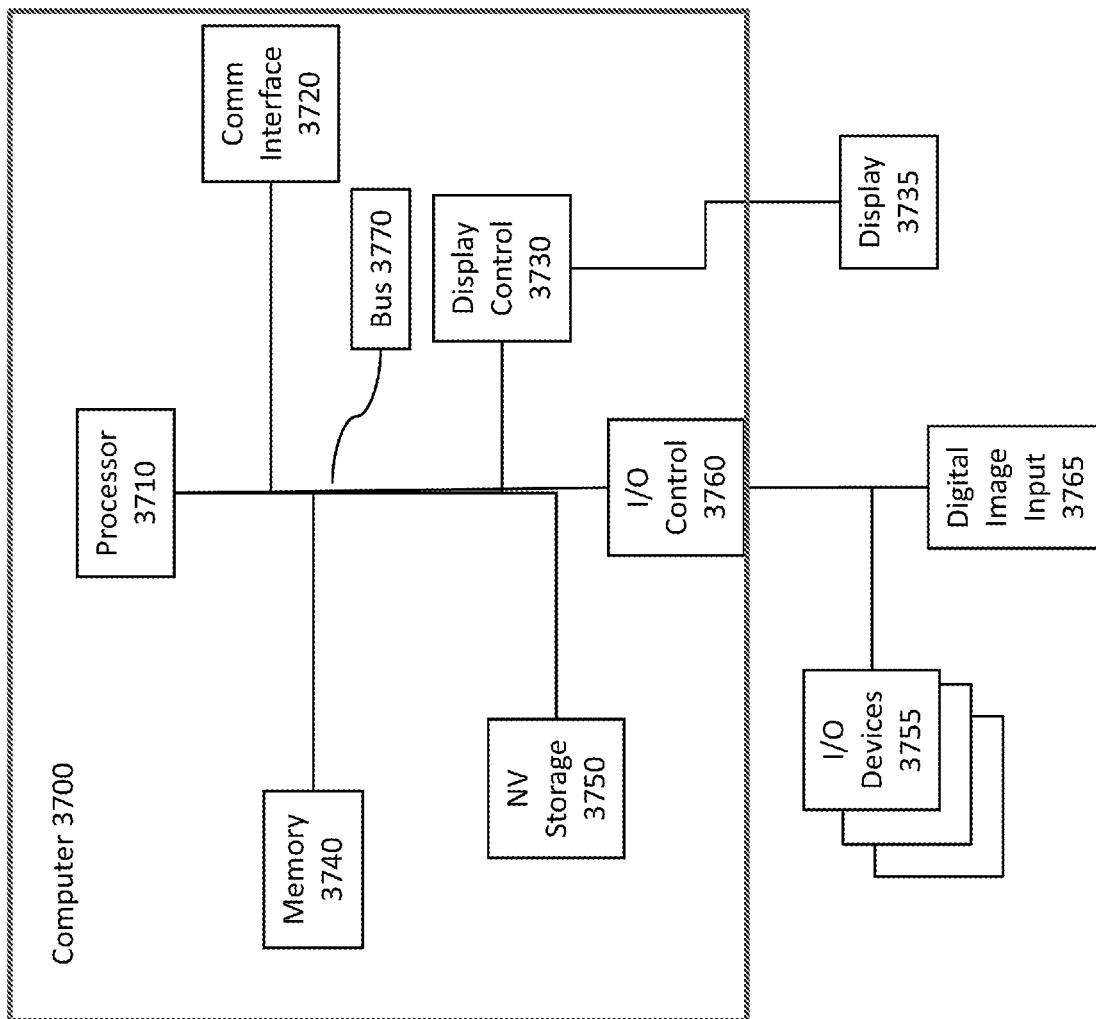


Fig. 37

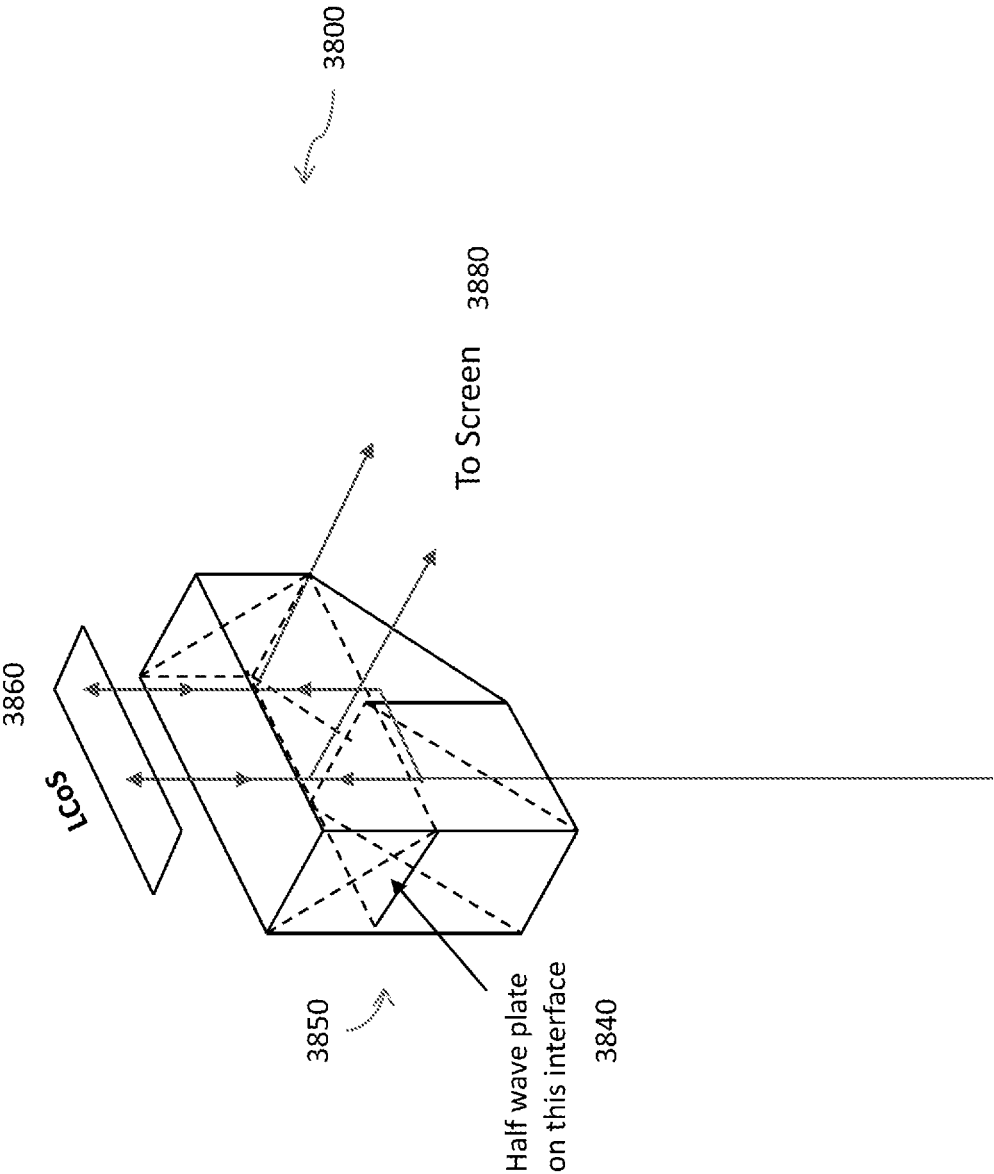


Fig. 38A

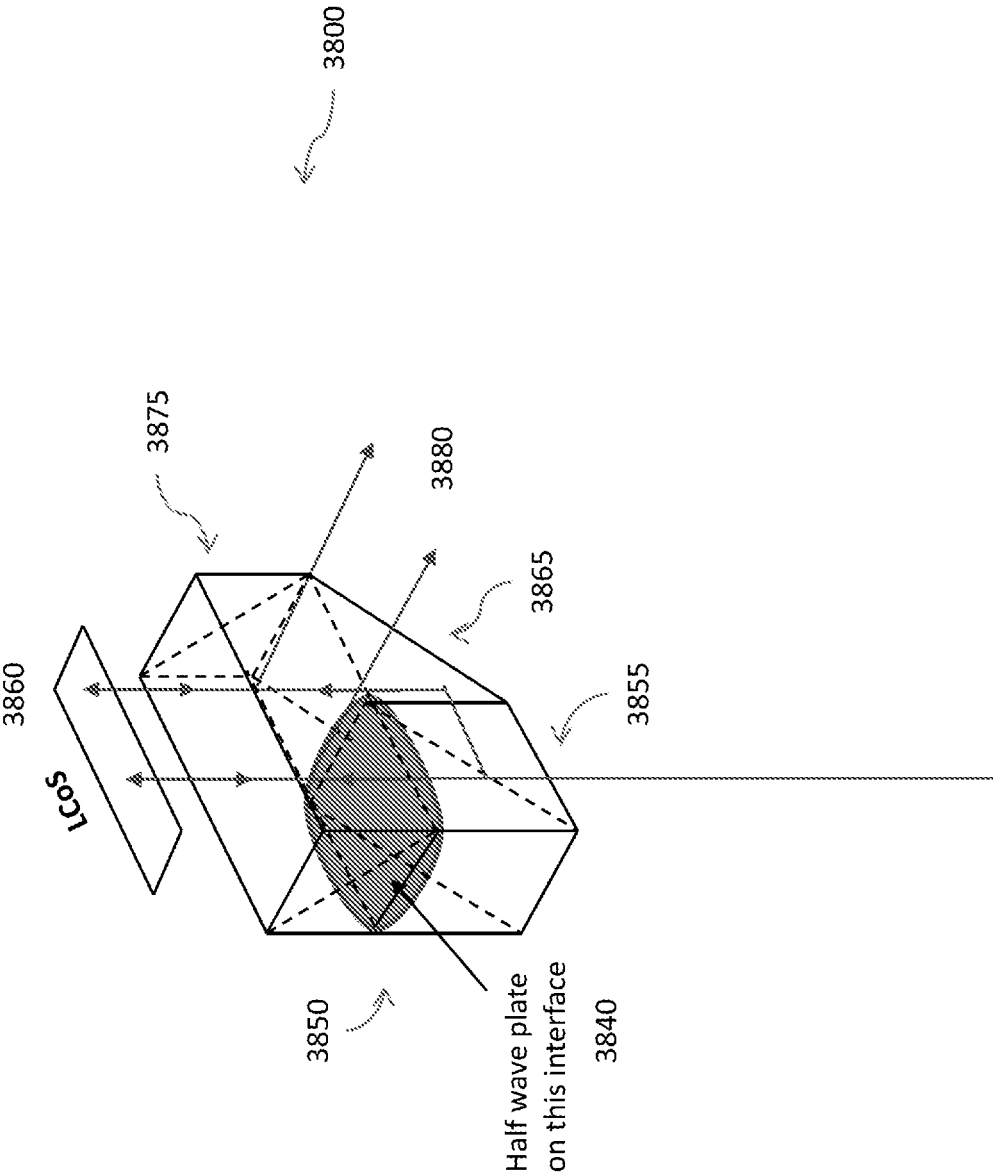


Fig. 38B

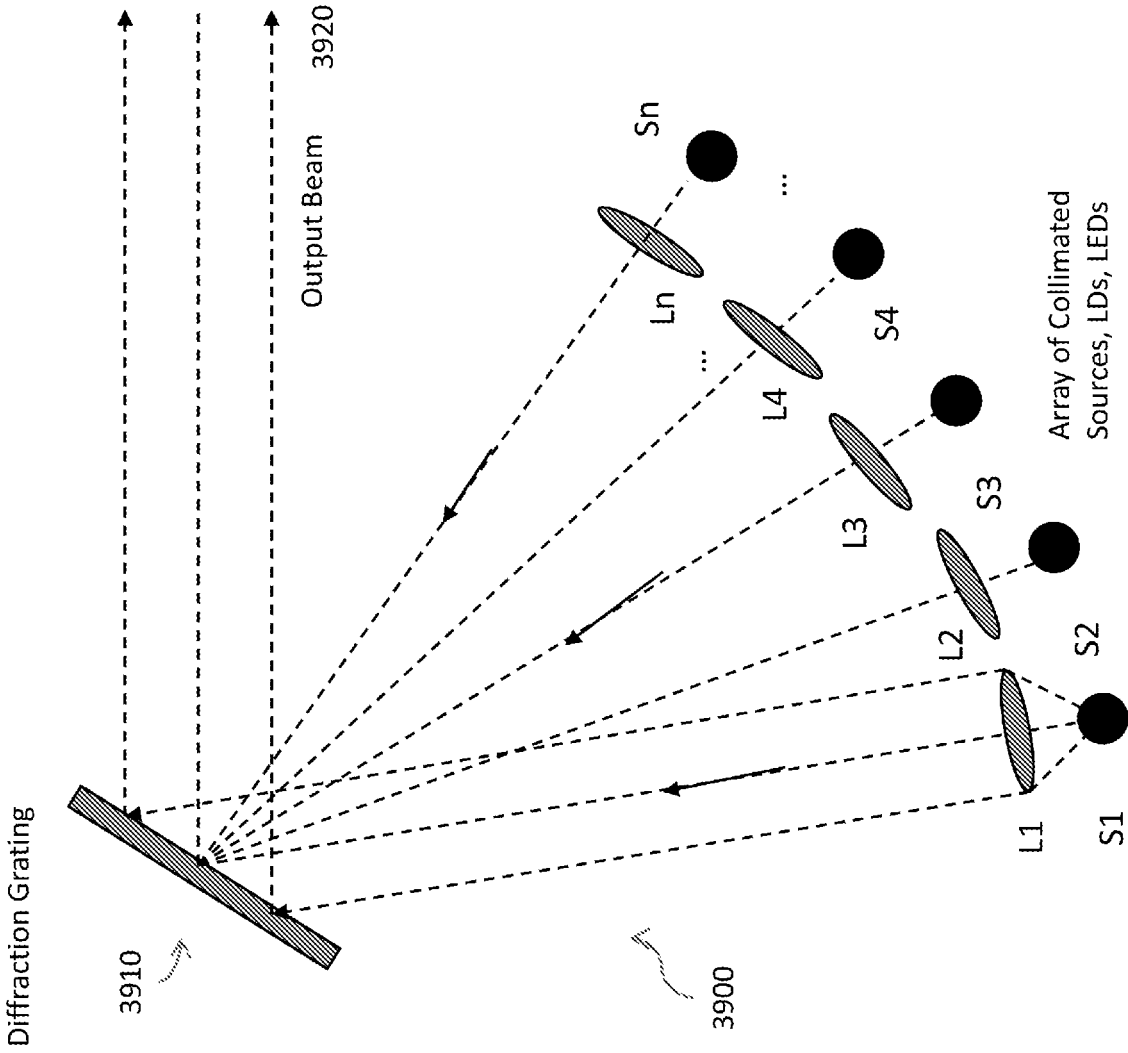


Fig. 39

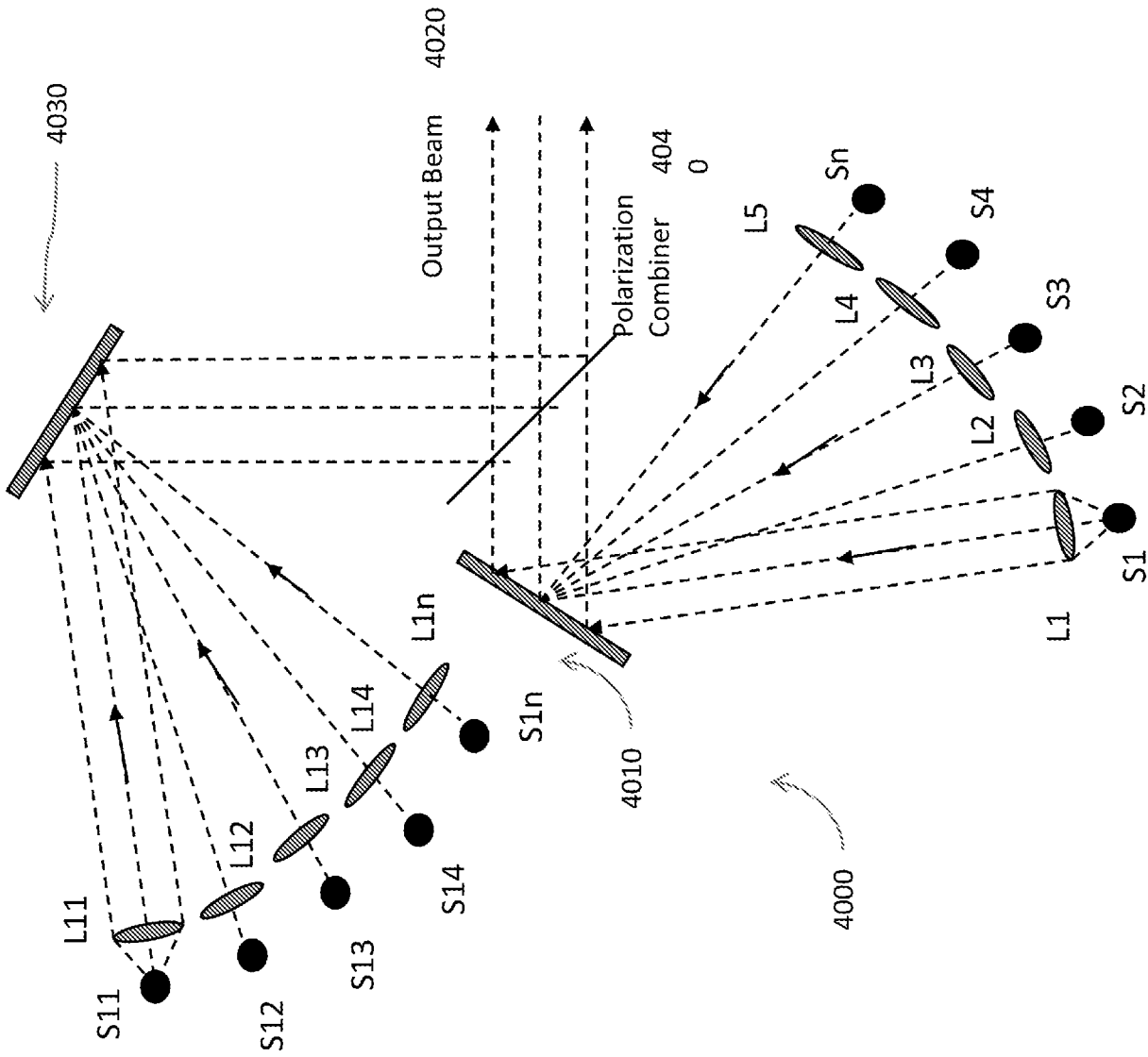


Fig. 40

Fig. 41

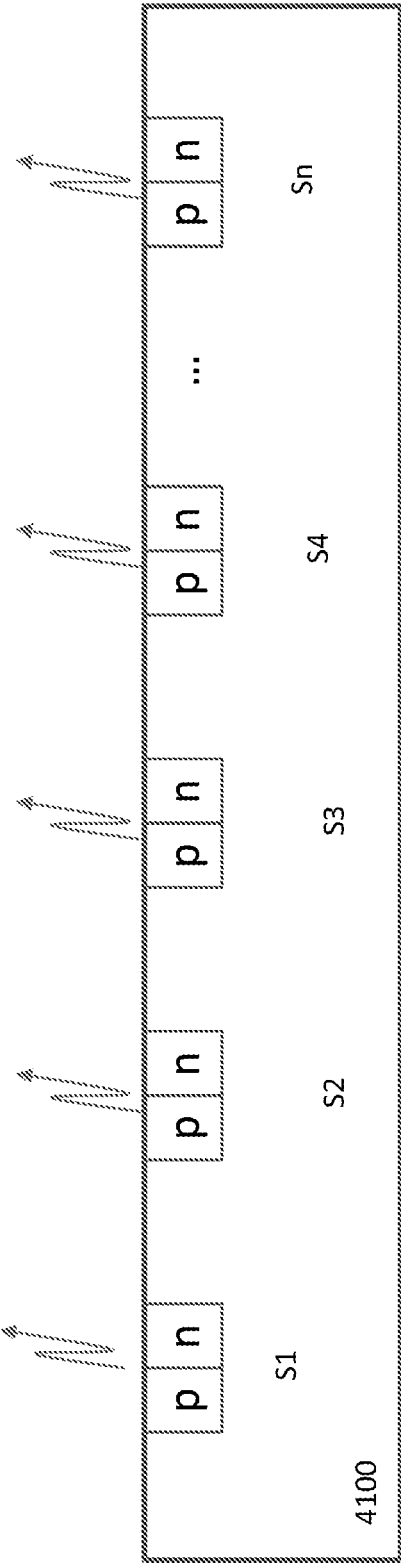
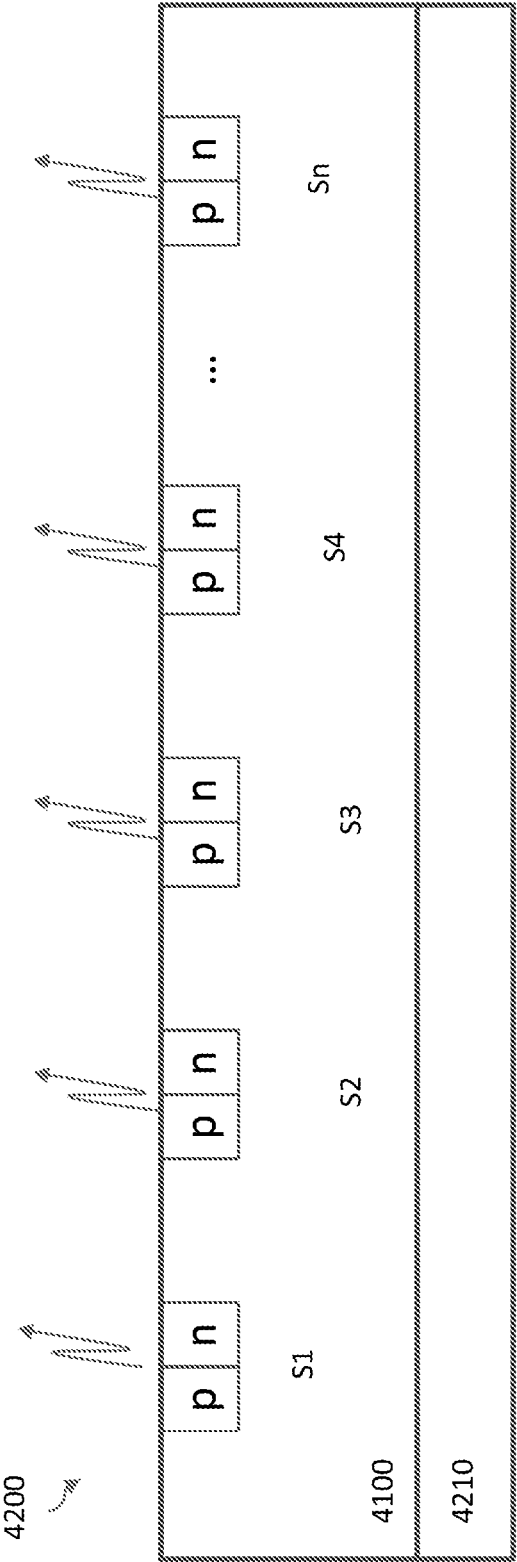


Fig. 42



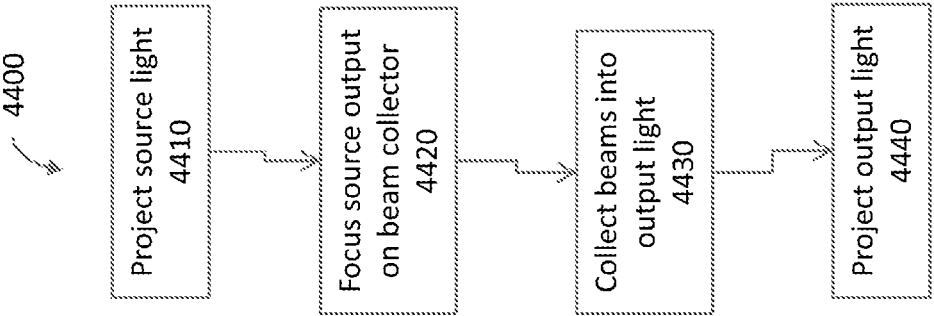


Fig. 44

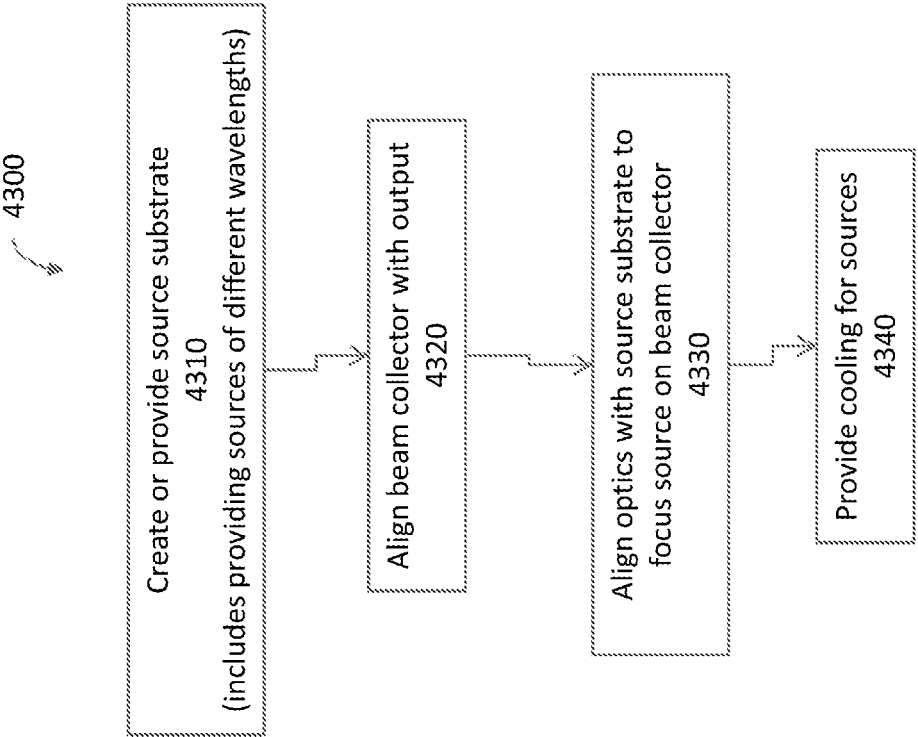


Fig. 43

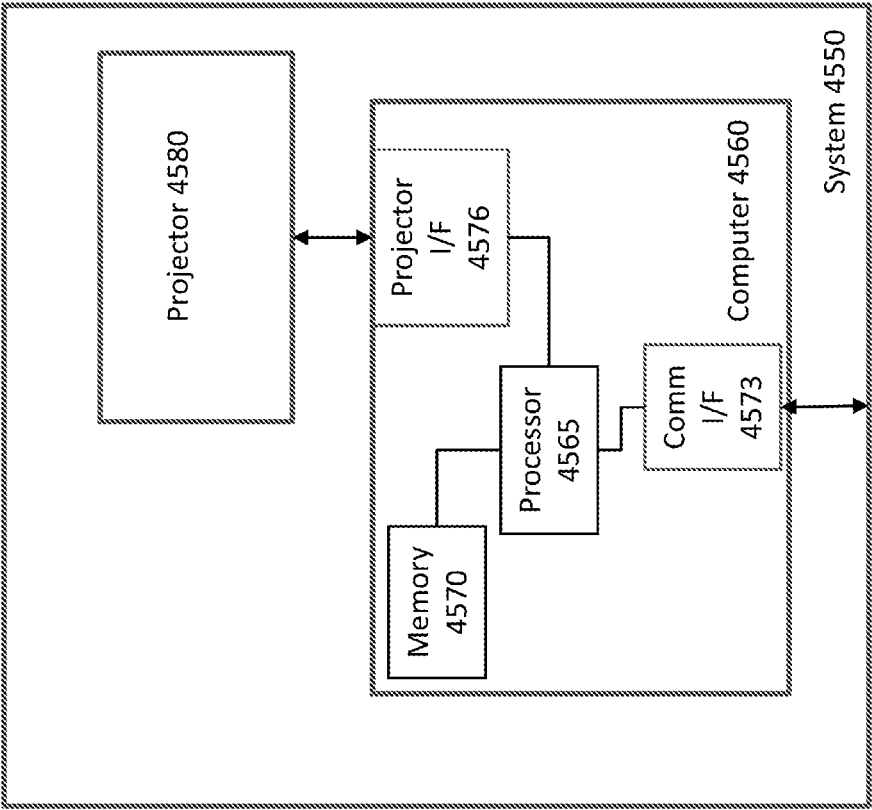


Fig. 45B

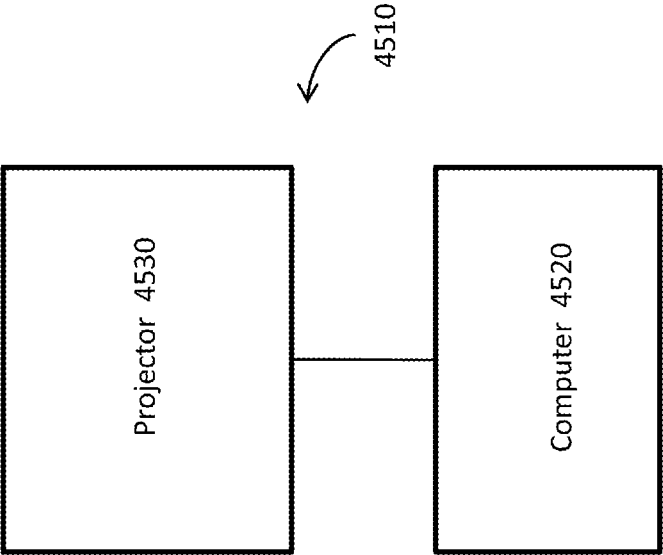


Fig. 45A

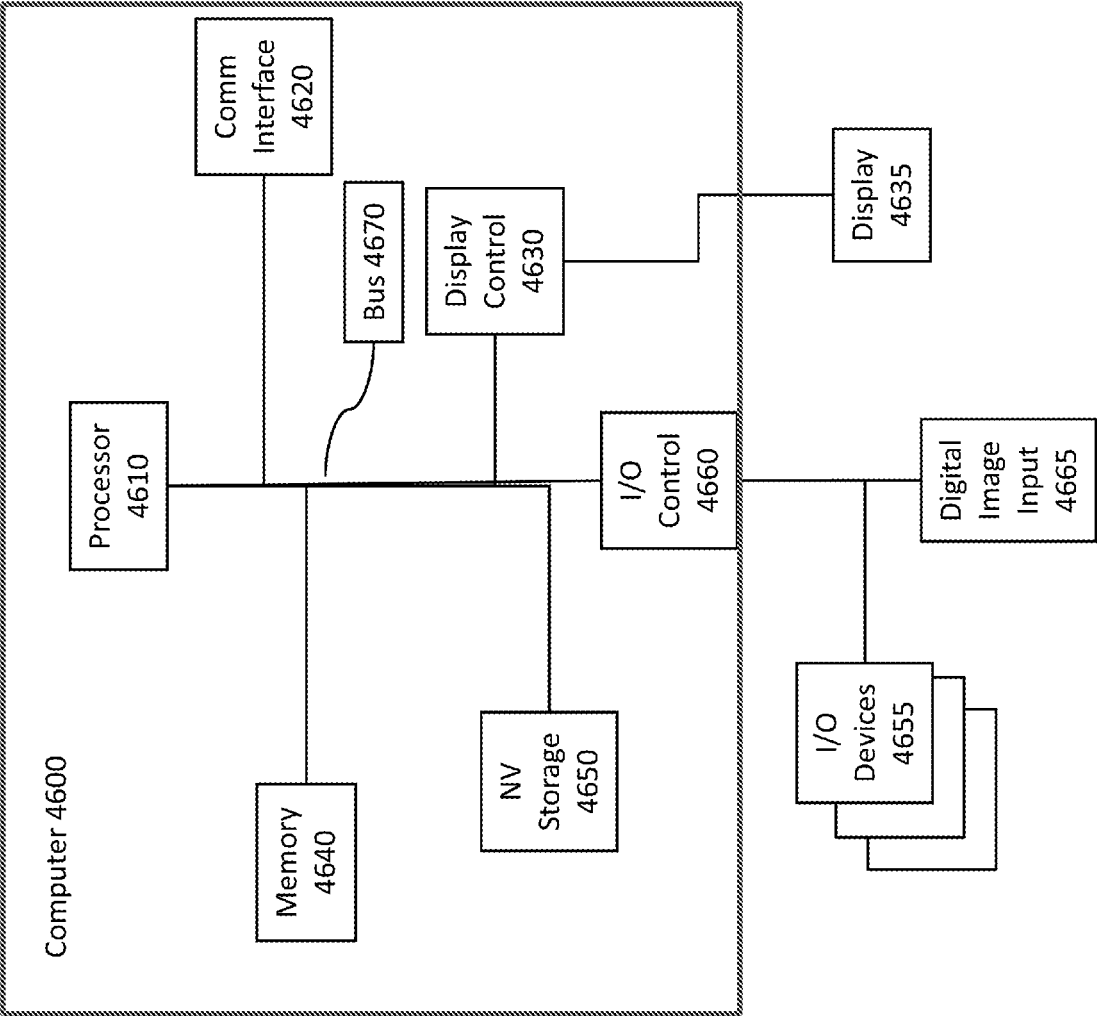


Fig. 46

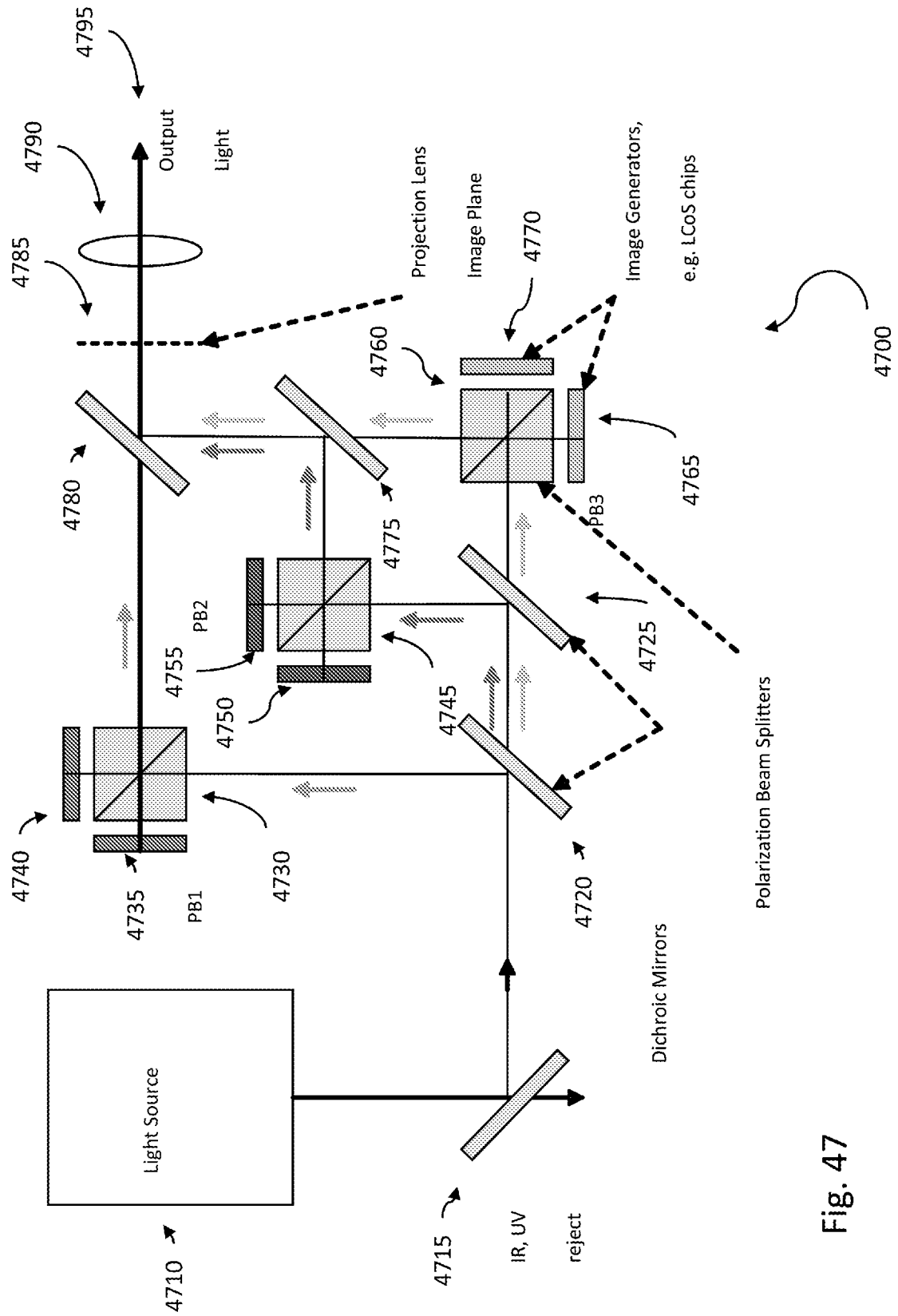


Fig. 47

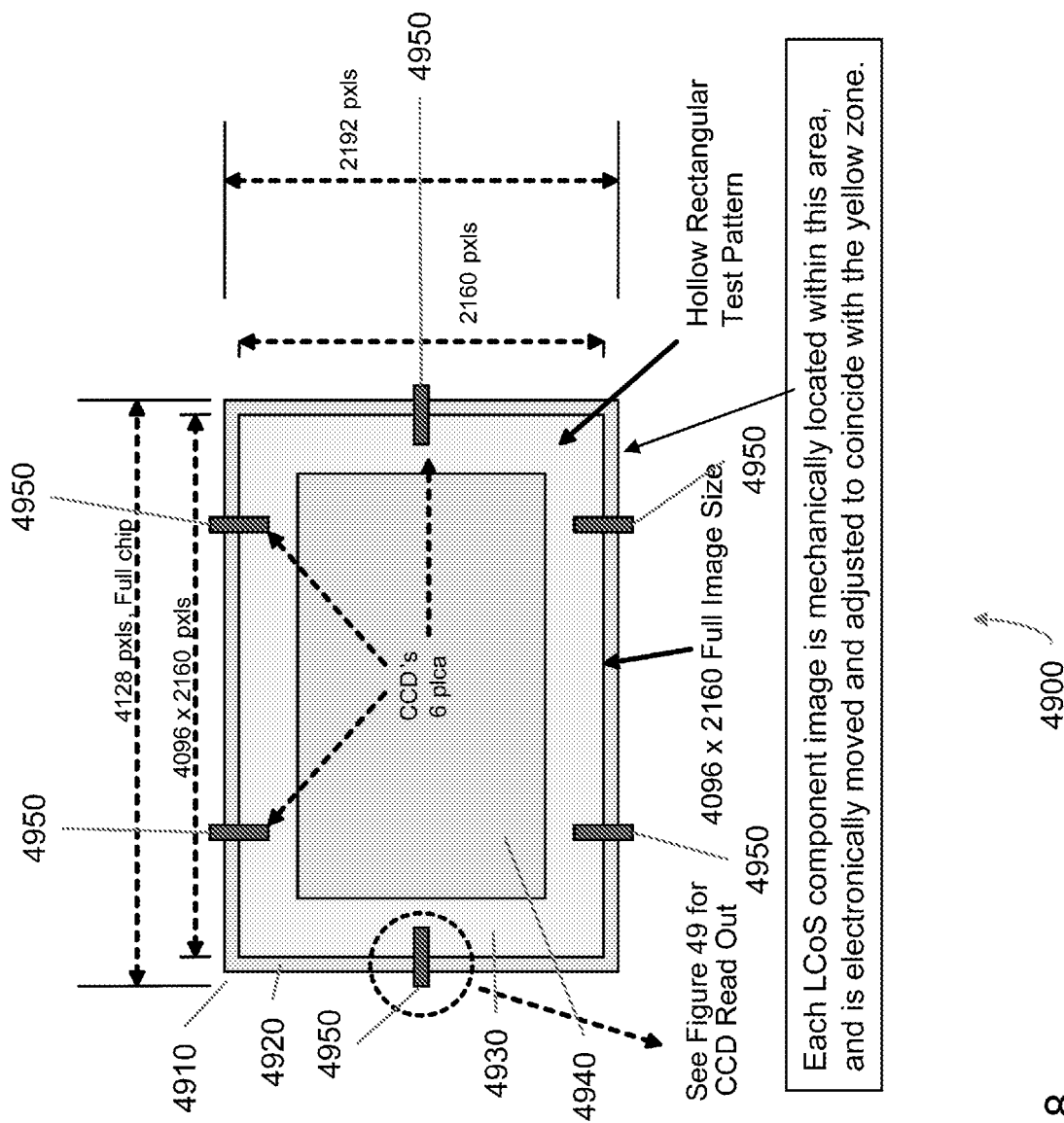


Fig. 48

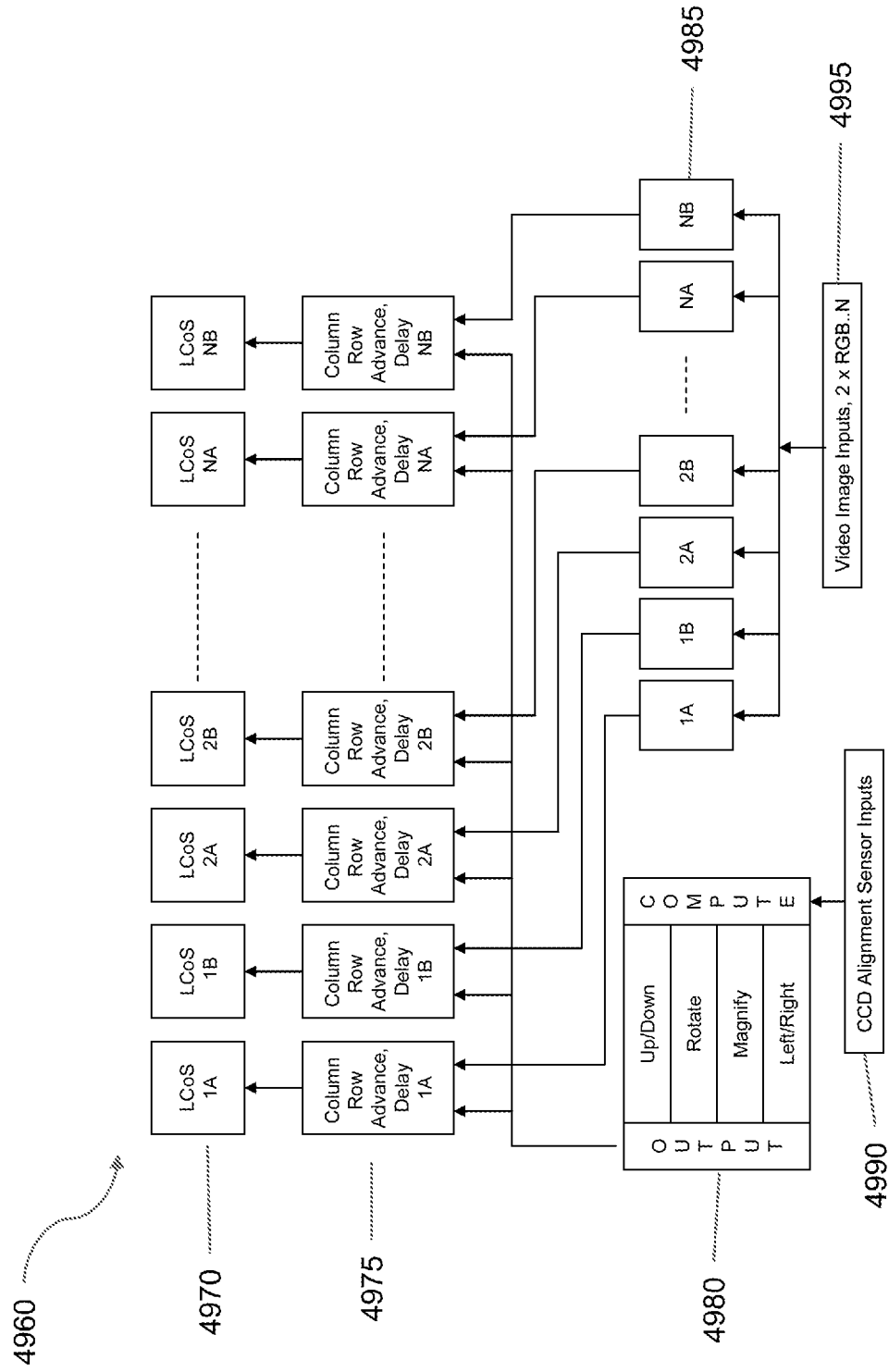


Fig. 49

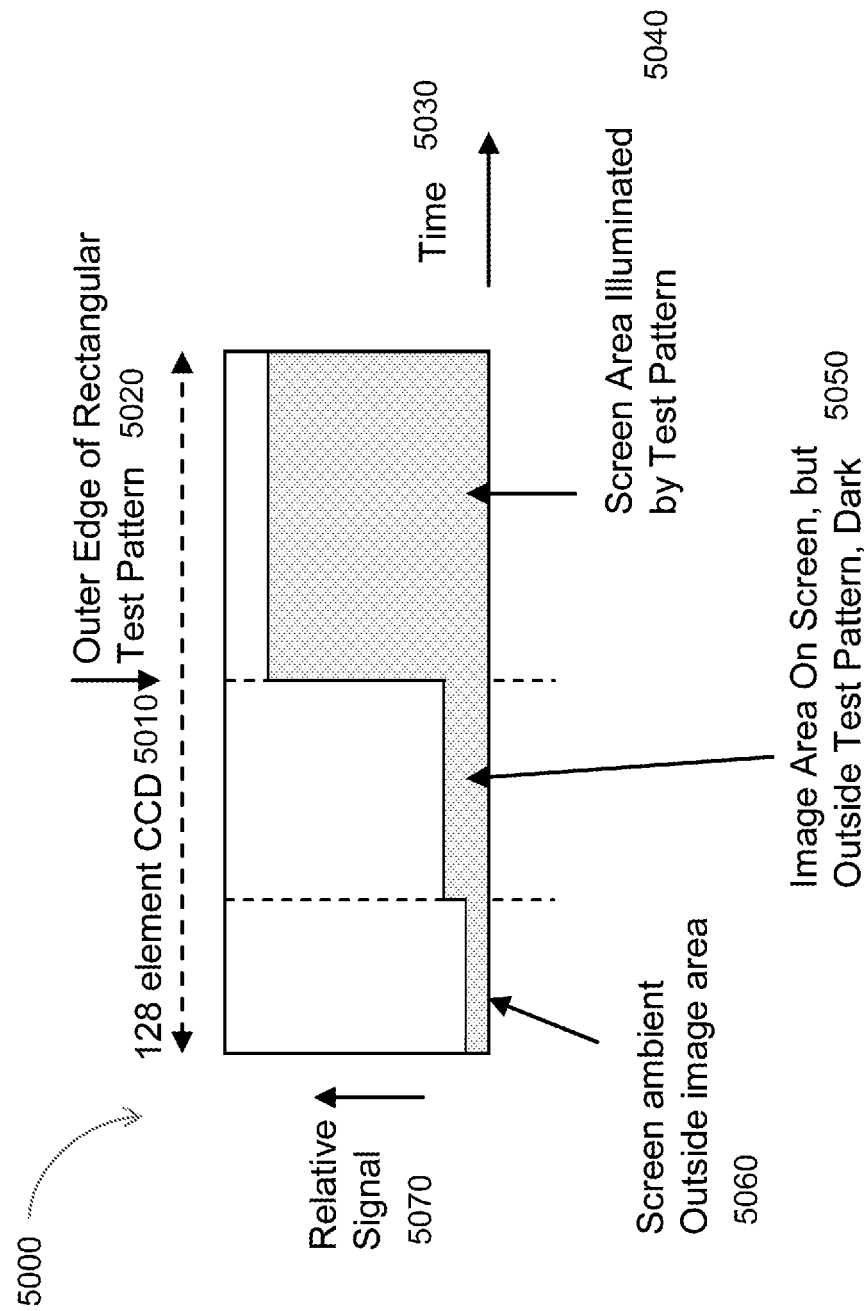


Fig. 50

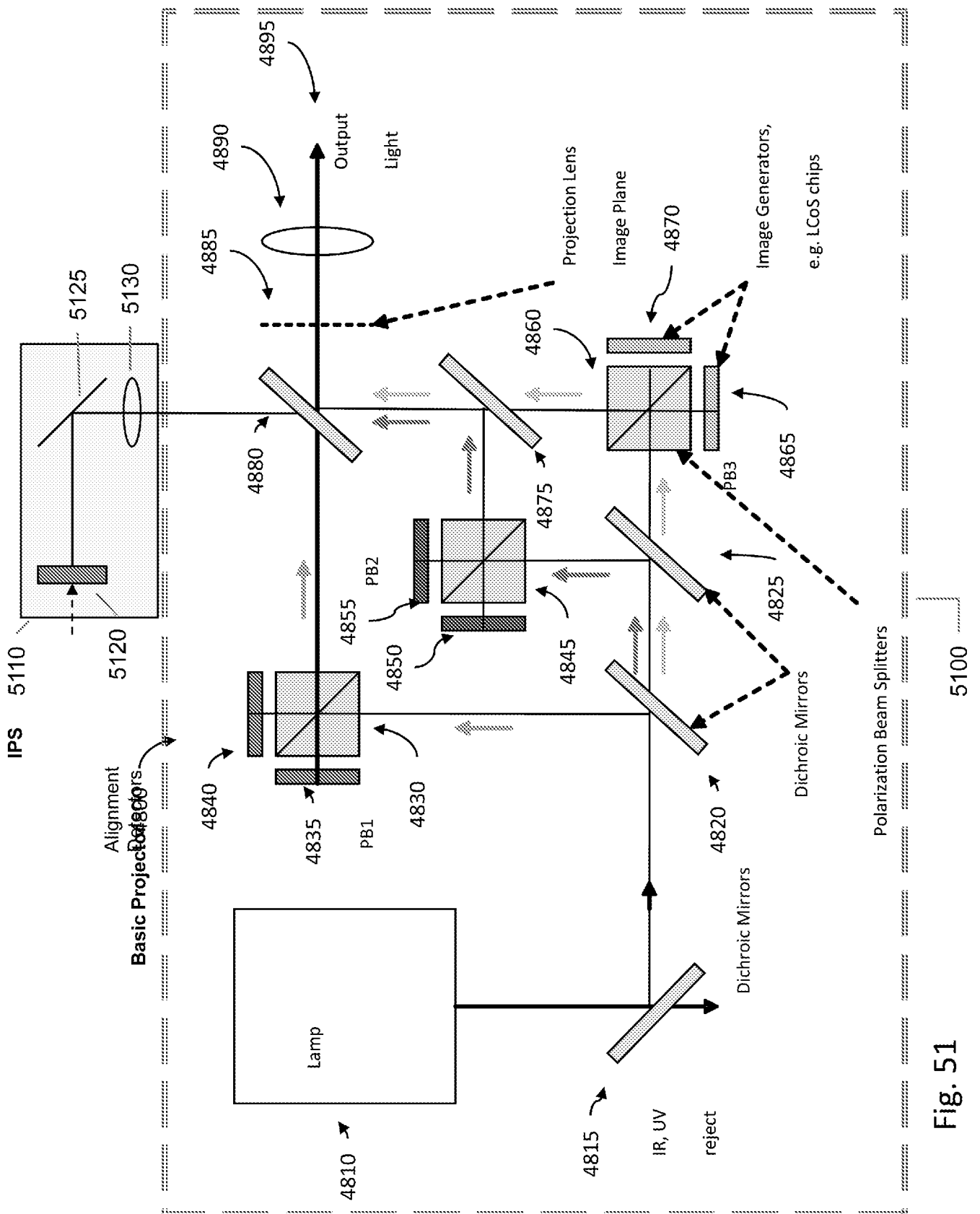


Fig. 51

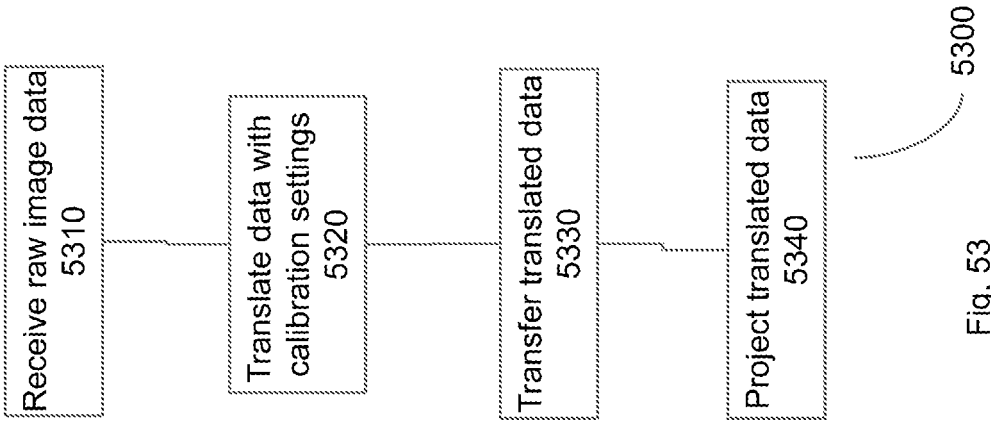


Fig. 53

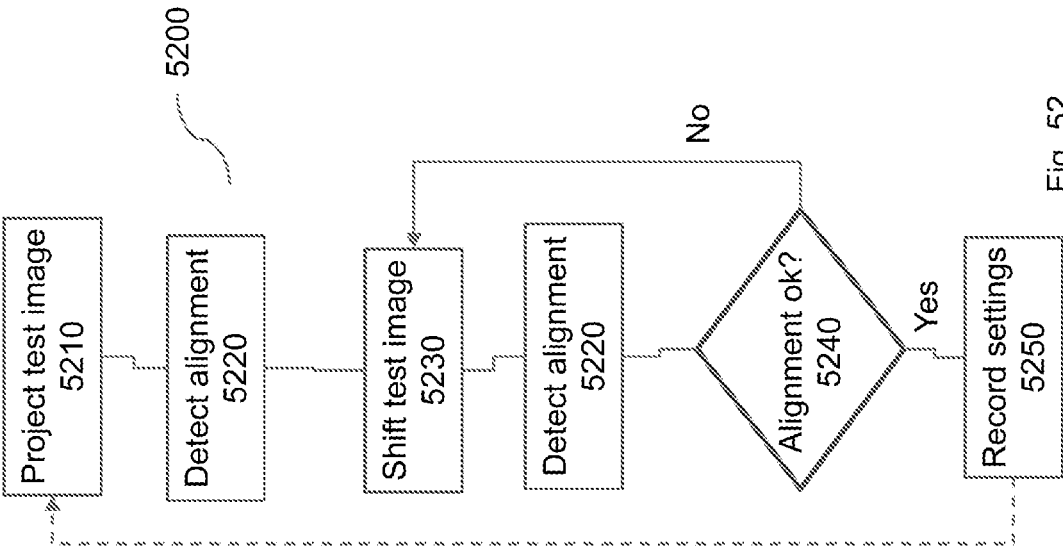


Fig. 52

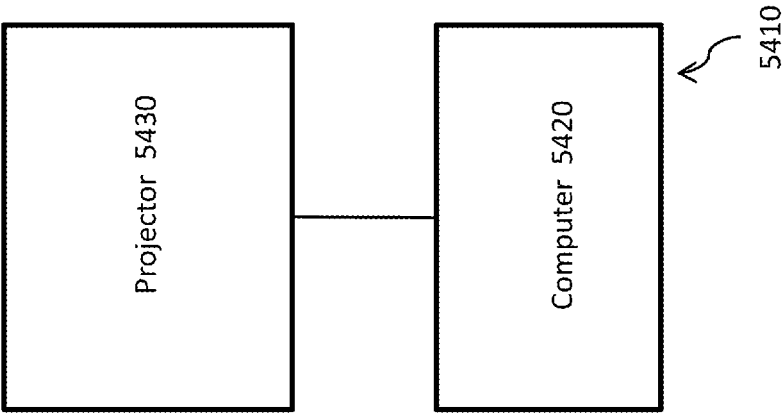


Fig. 54

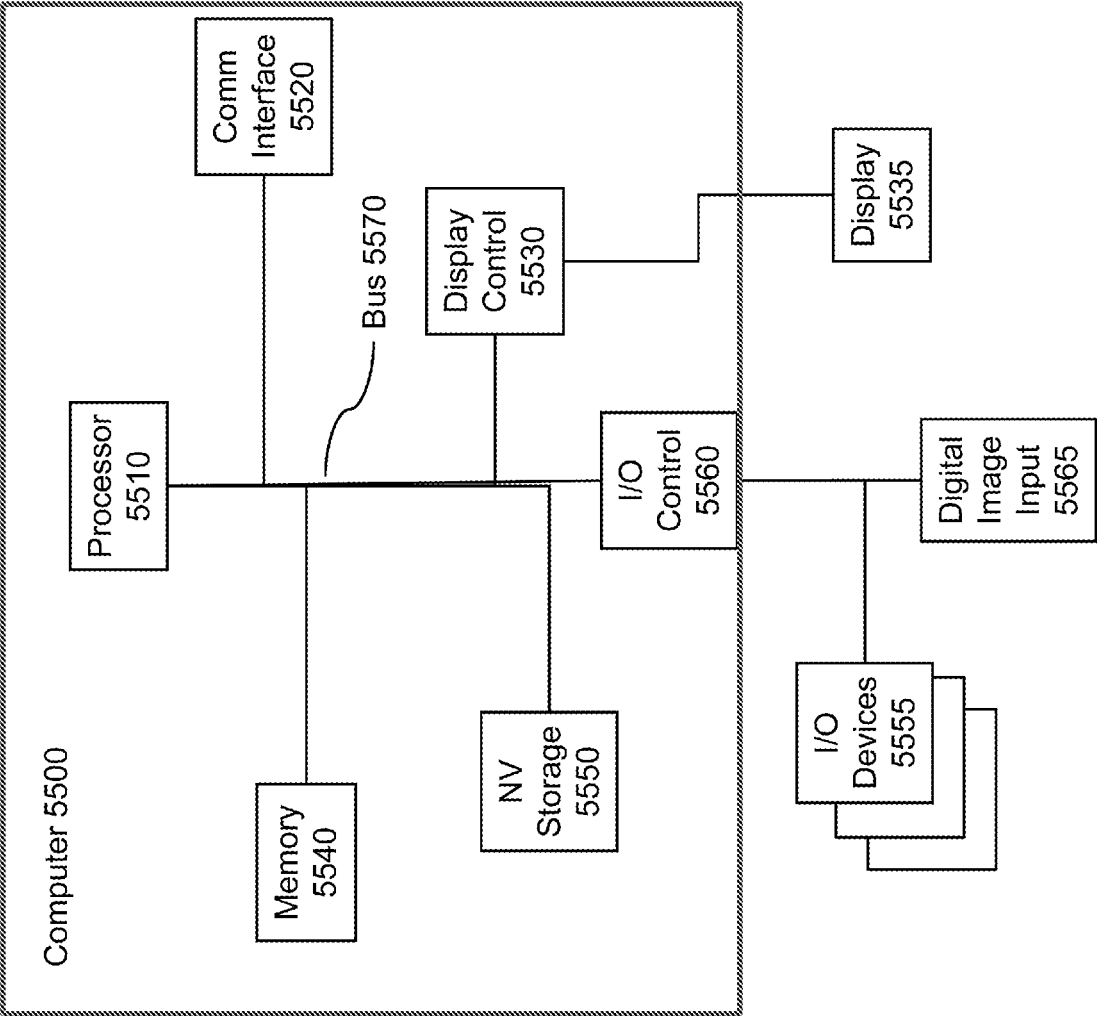


Fig. 55

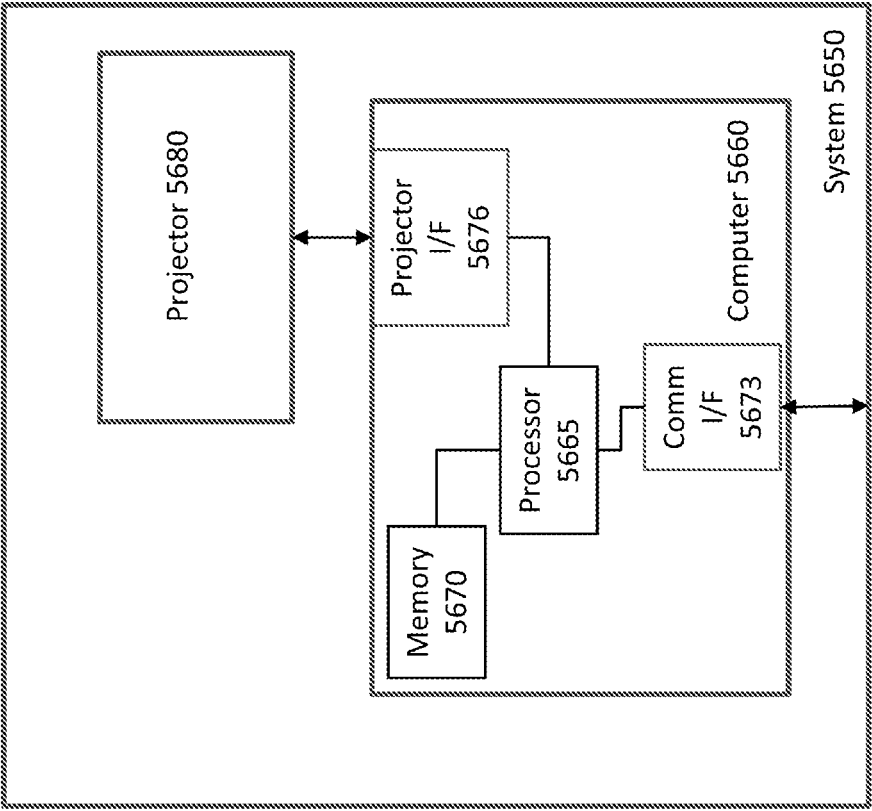


Fig. 56

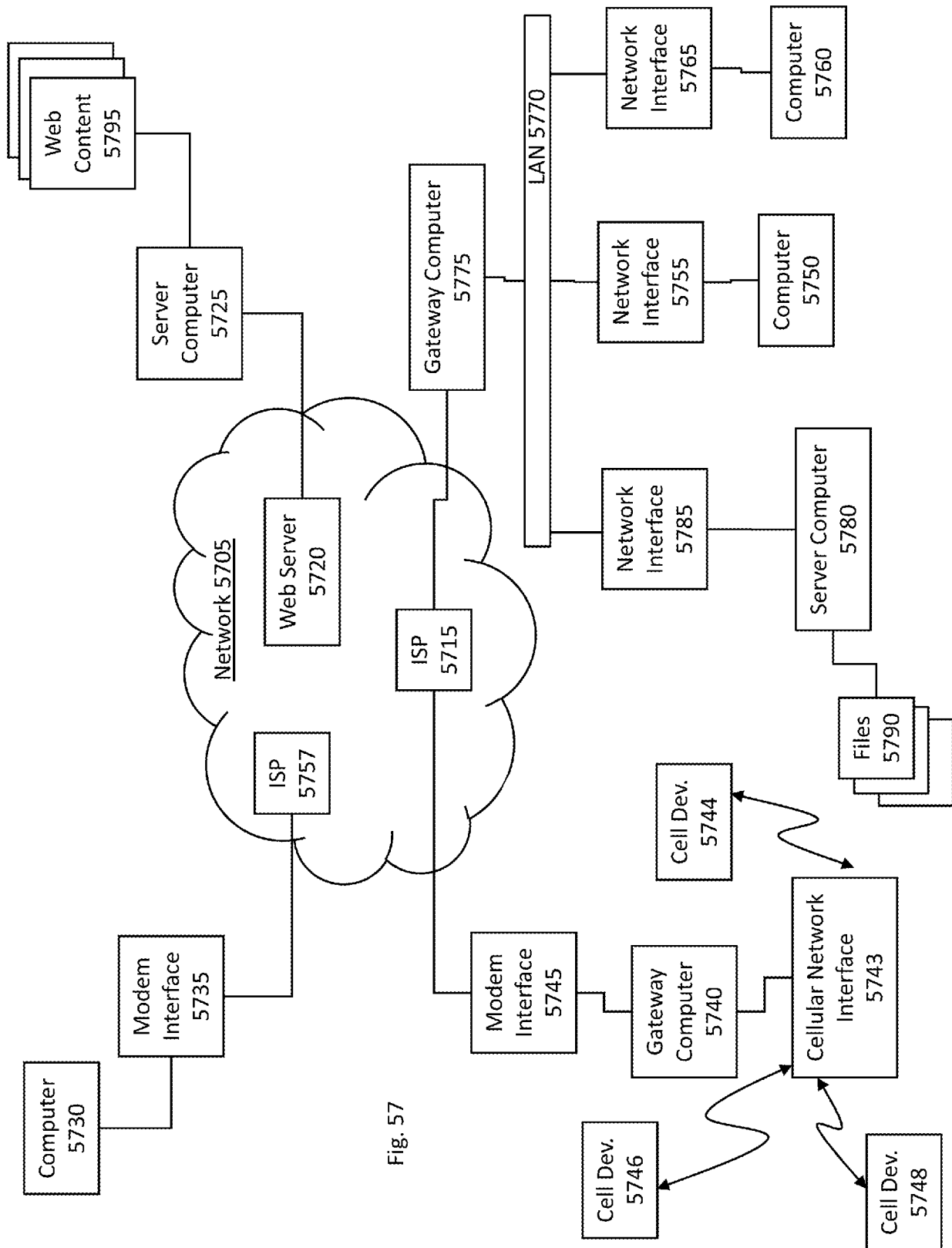


Fig. 57

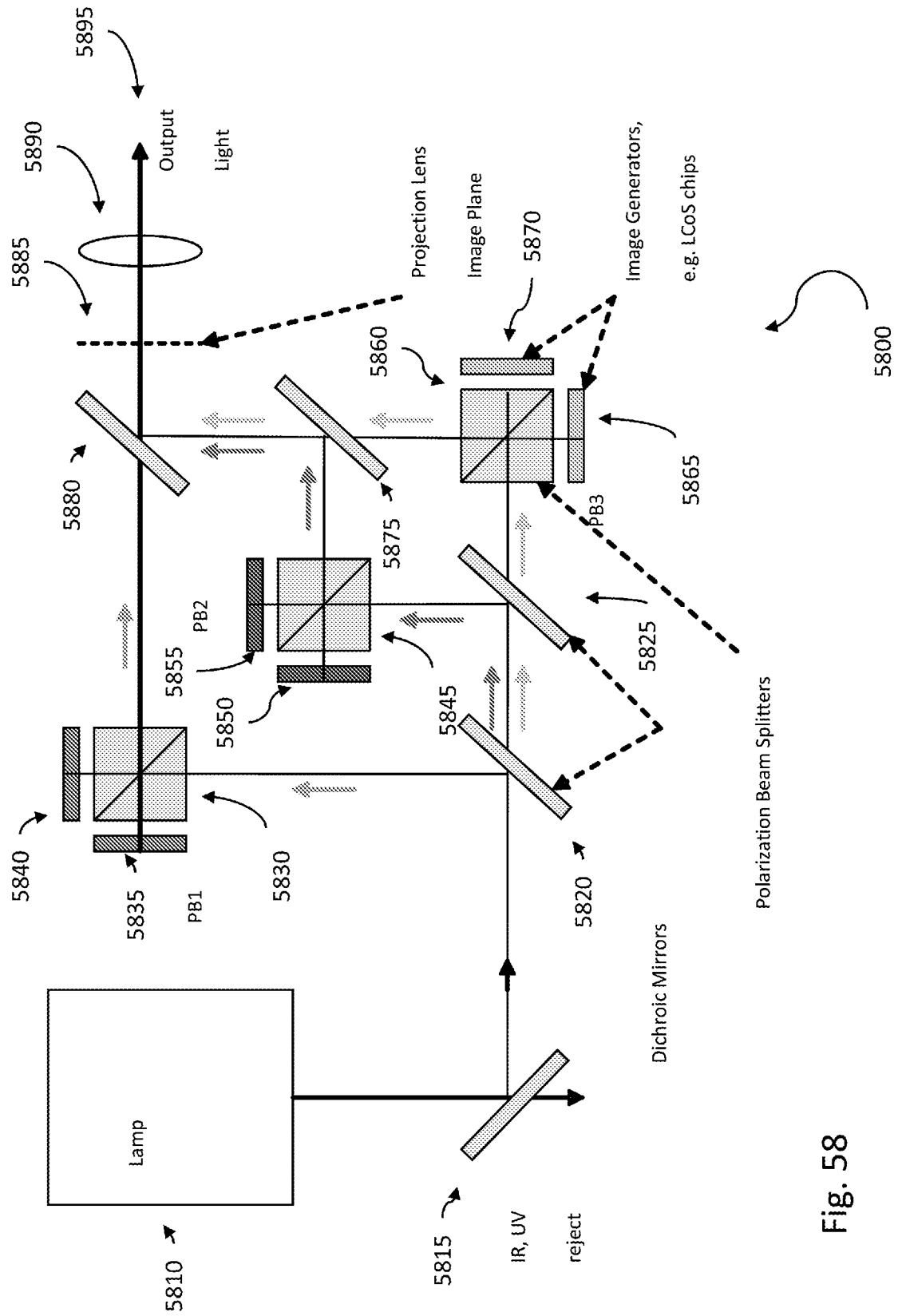


Fig. 58

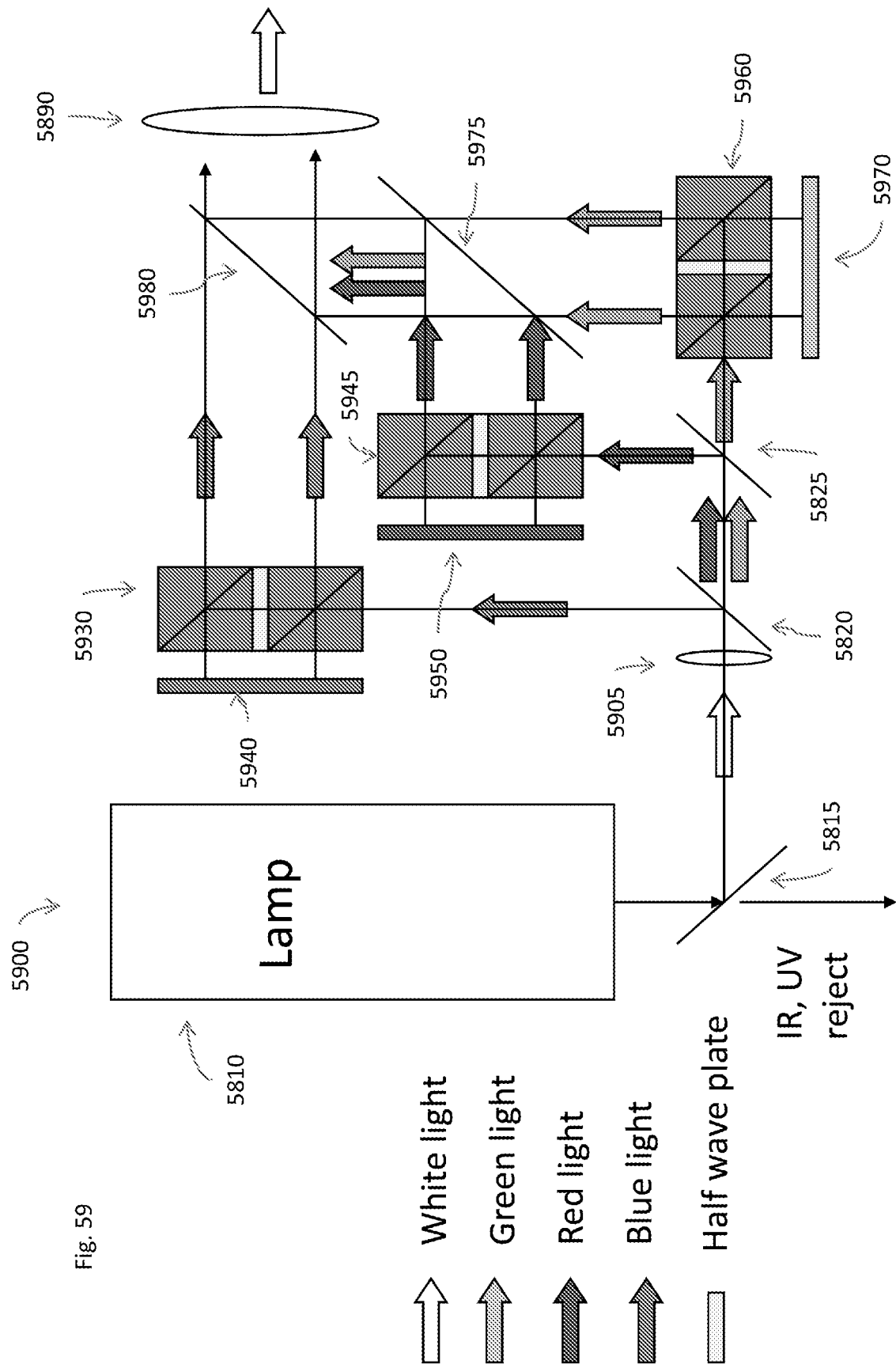


Fig. 59

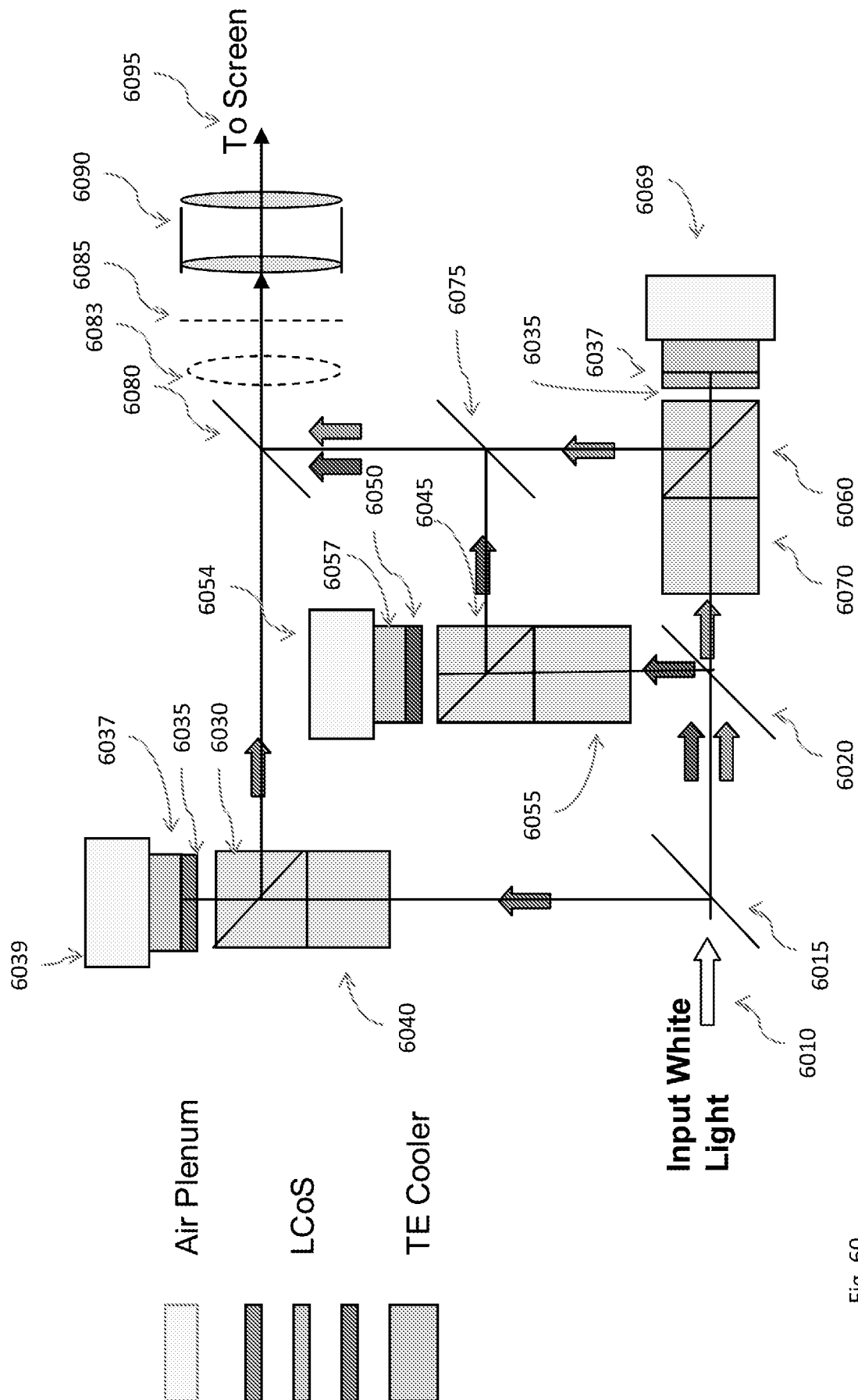


Fig. 60

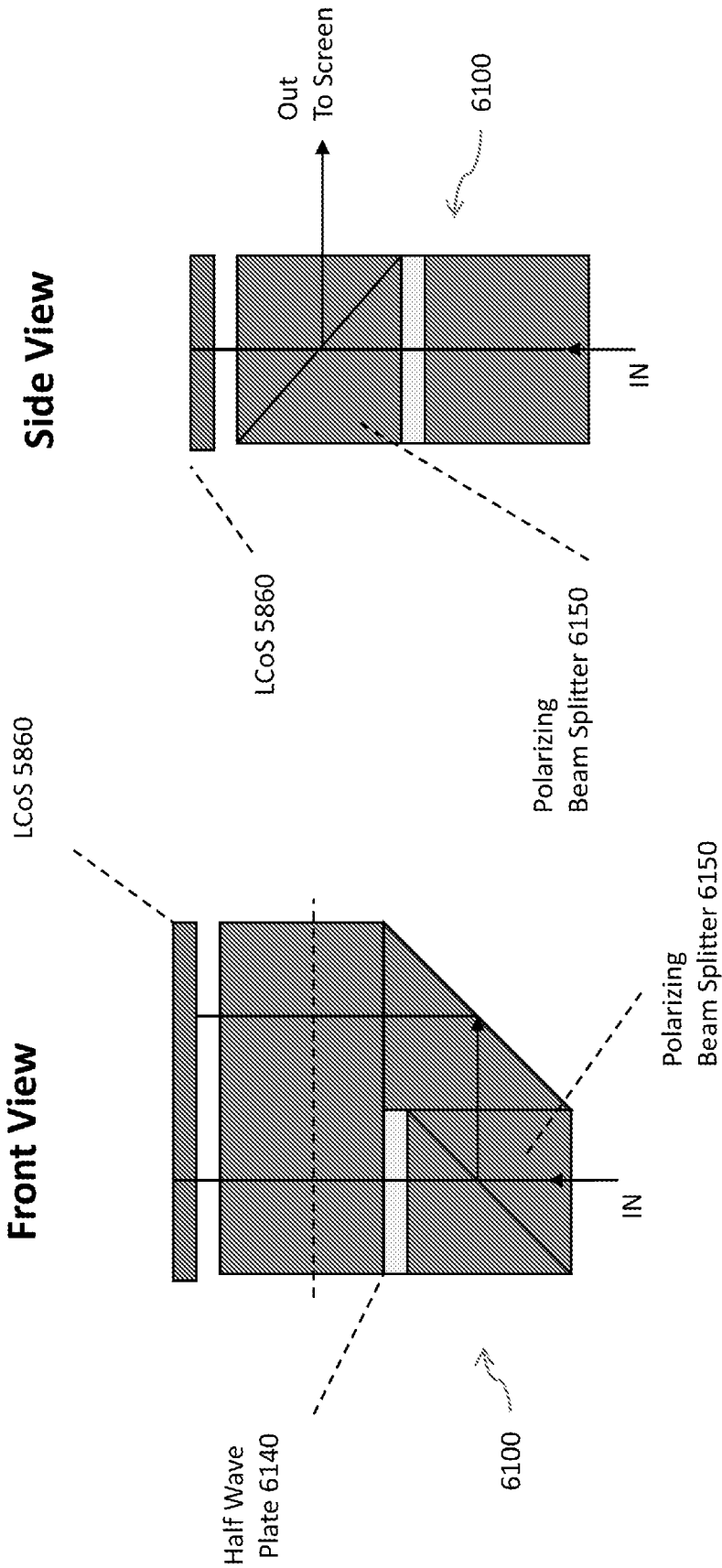


Fig. 61A

Fig. 61B

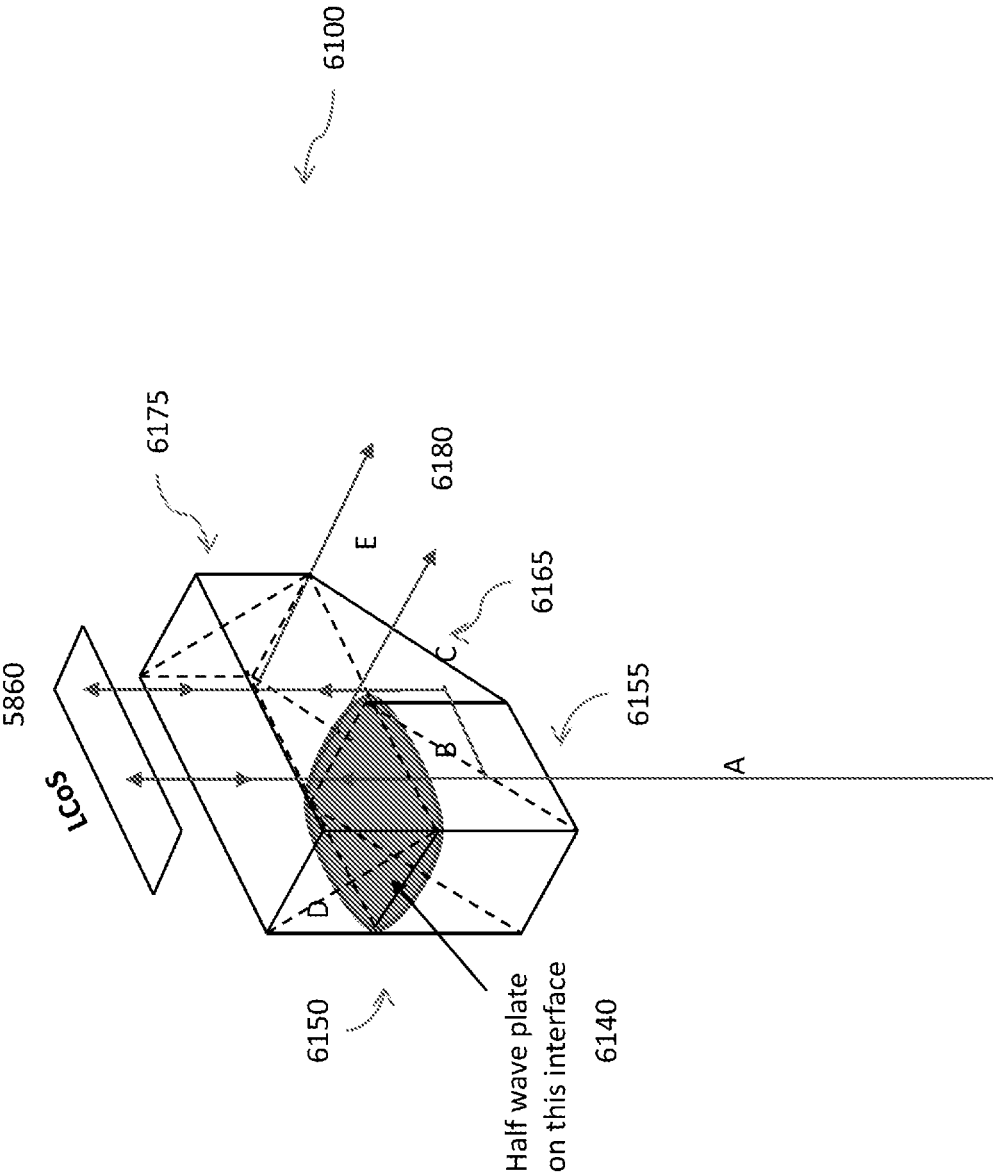


Fig. 61C

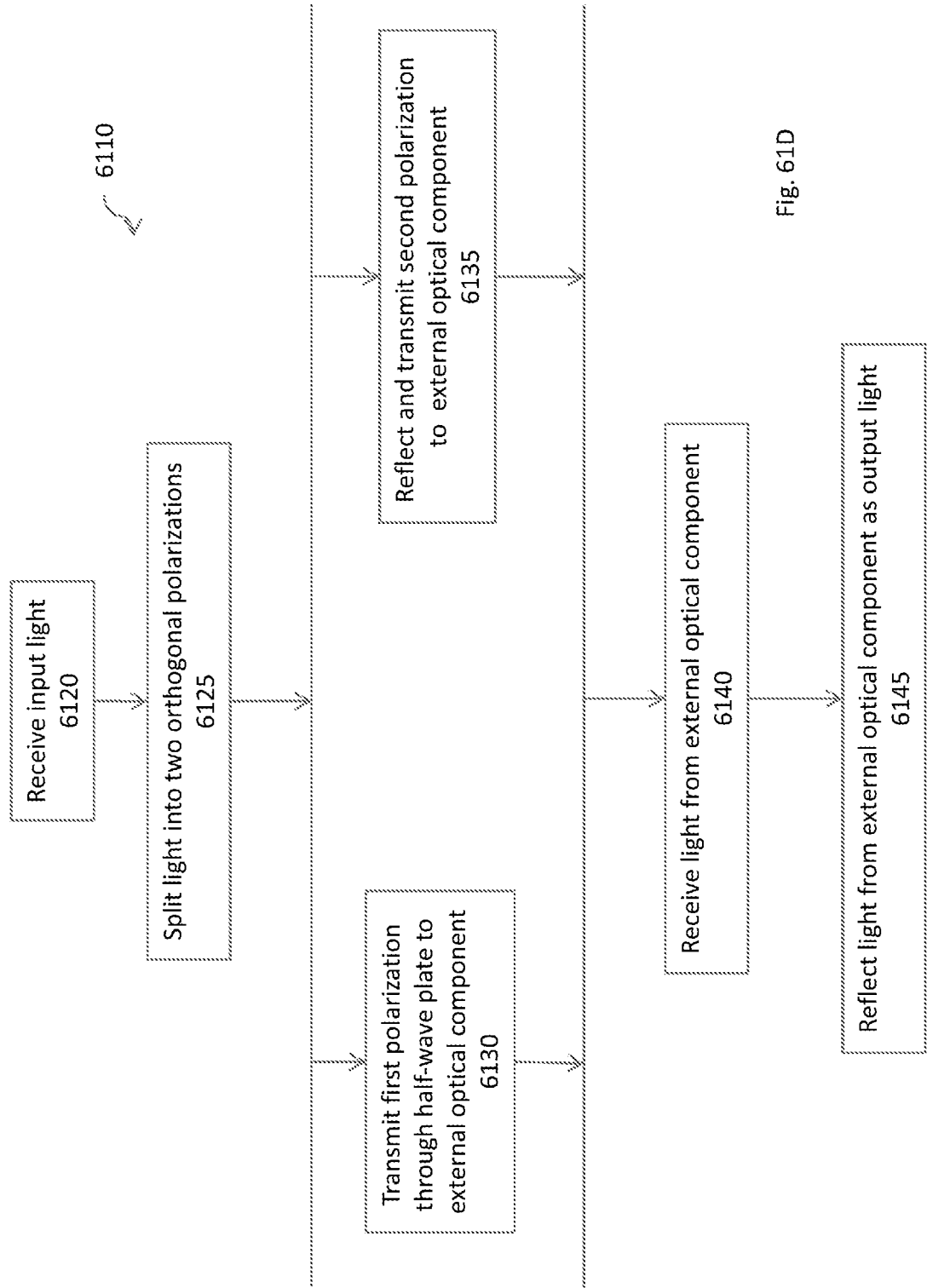


Fig. 61D

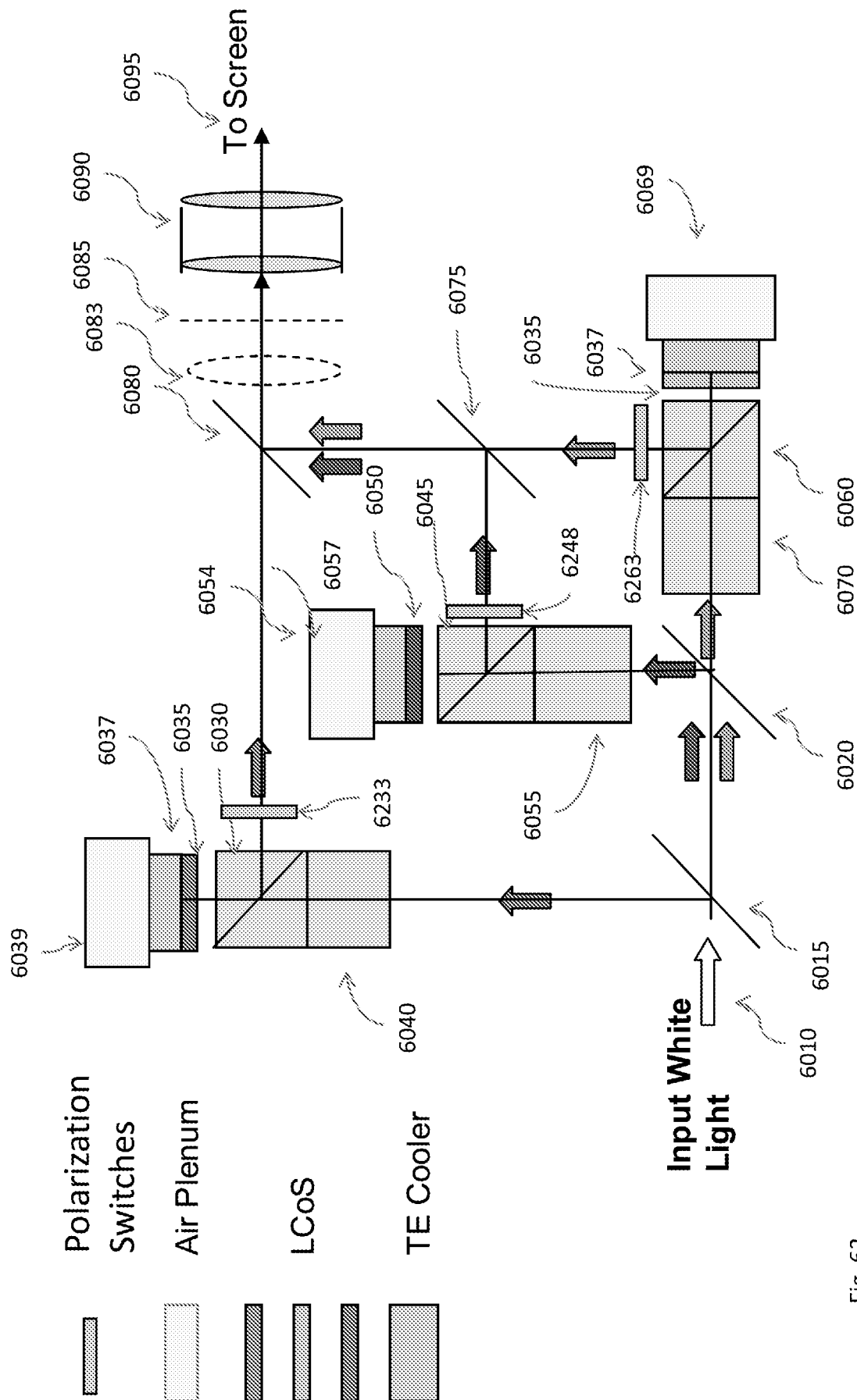


Fig. 62

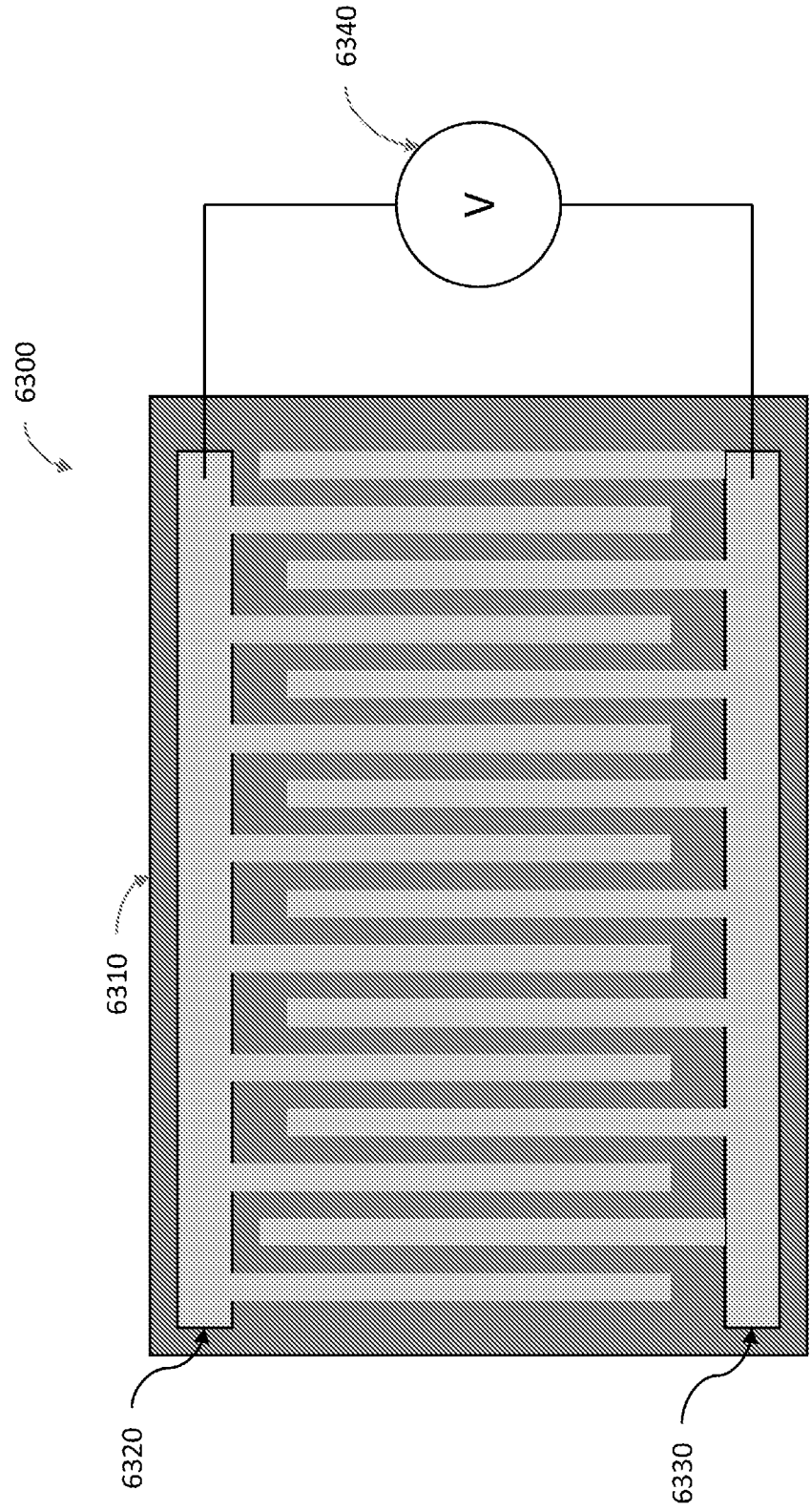
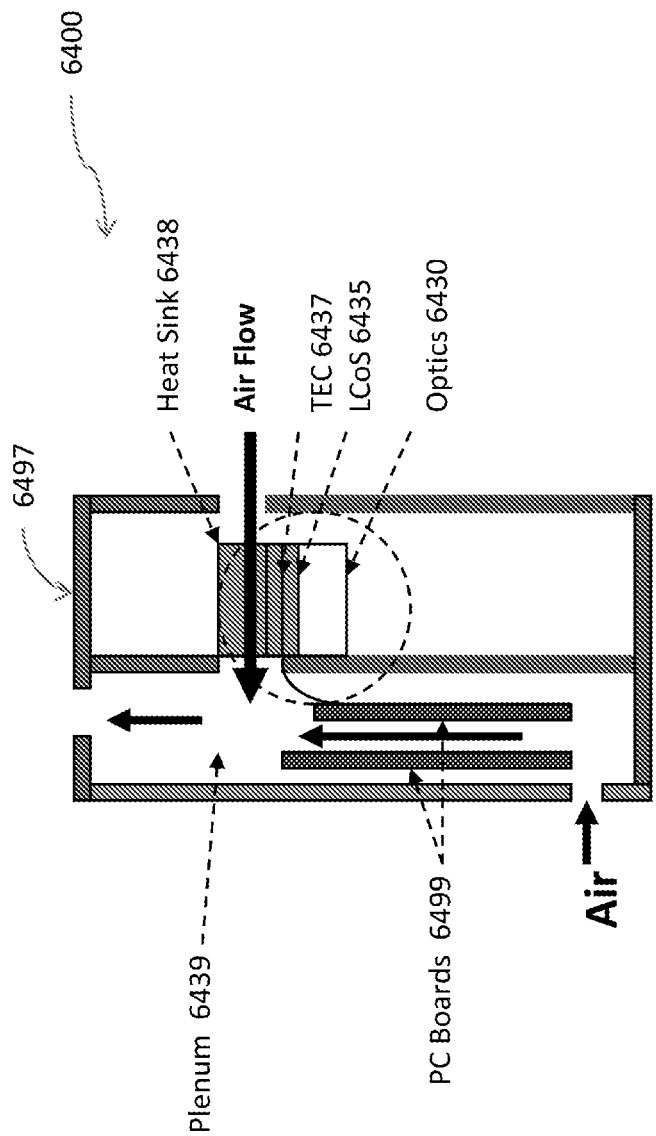


Fig. 63



Side View of Box showing Air Flow

Fig. 64

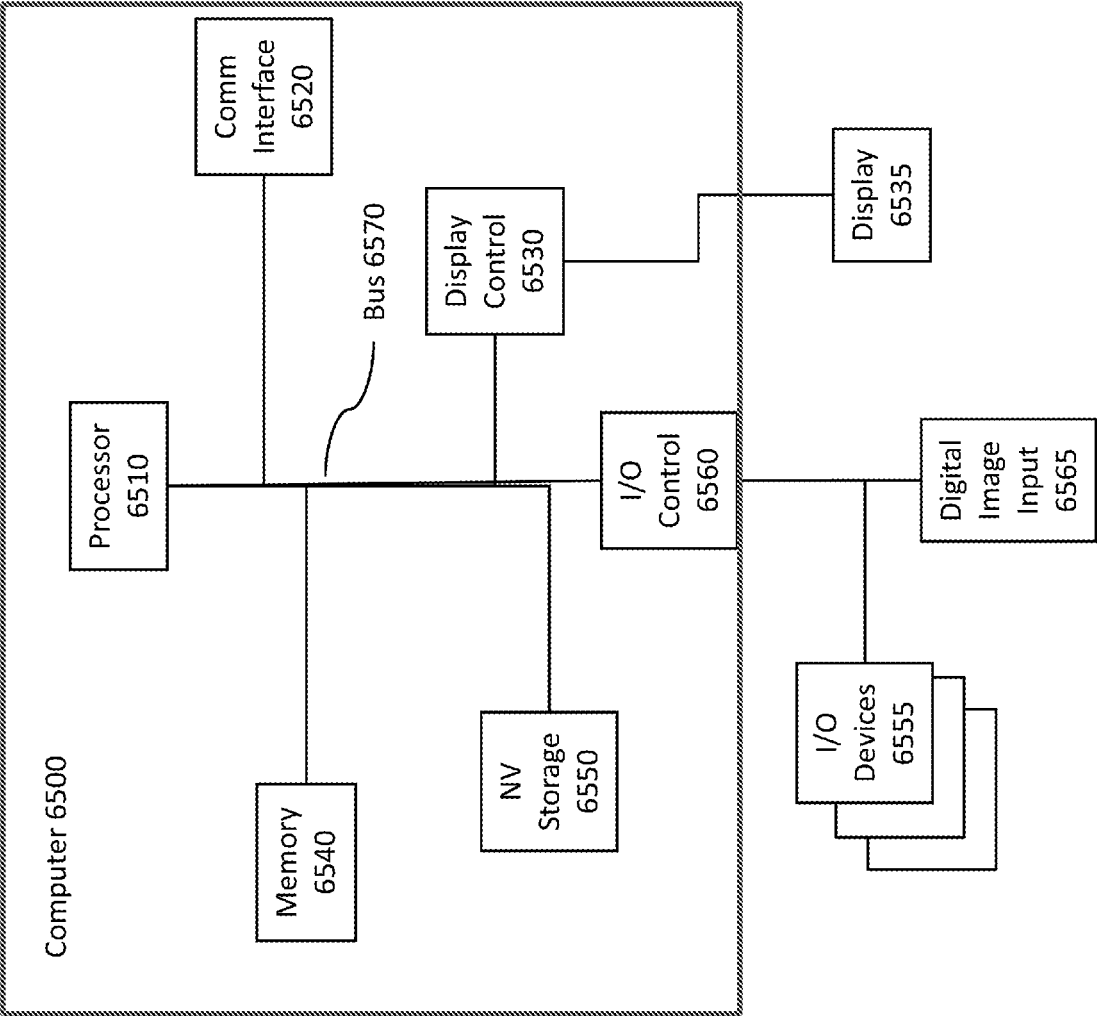


Fig. 65

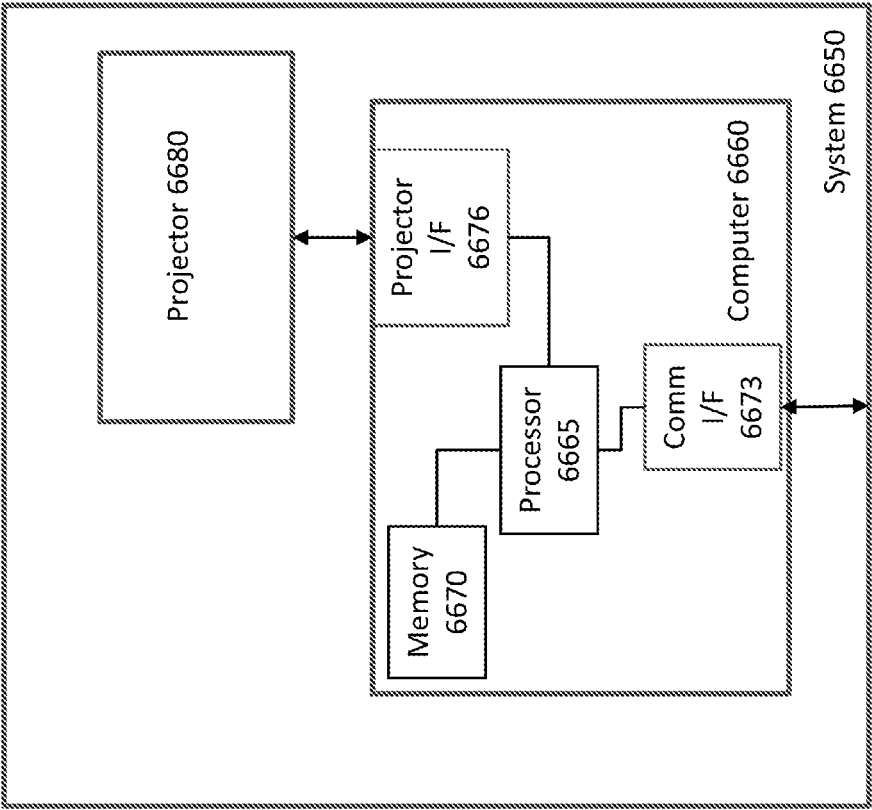


Fig. 66B

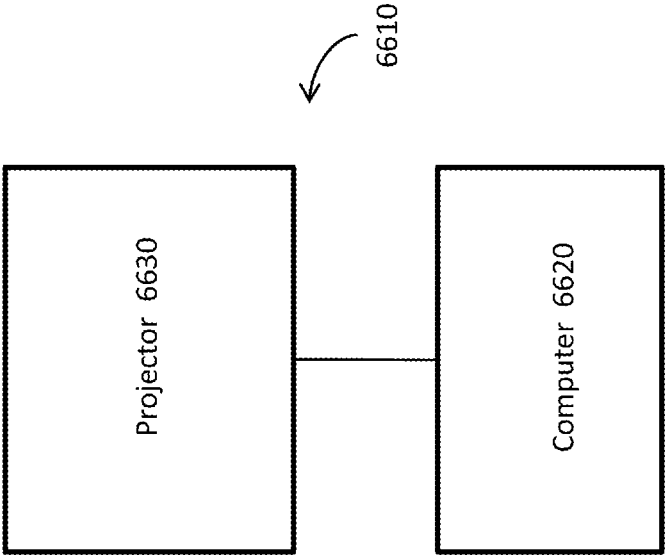


Fig. 66A