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Title: MODULATOR DEVICE AND APPARATUS FOR THREE DIMENSIONAL DISPLAY SYSTEM

Abstract: A modulator and apparatus comprising the modulator comprising a Tunable Diffraction Grating (TDG) component is arranged with a plurality of individual modulator sections, wherein a prism with appropriate chromatic and polarization filters provides at least two independent overlaid two dimensional images providing stereographic displays for three-dimensional images.
Modulator device and apparatus for three dimensional display system.

The present invention is related to line scanning projection display systems, and especially to a three dimensional image generating line scanning projection system comprising a modulator with Tunable Diffraction Grating (TDG) elements and a specially designed prism providing splitting, recombination, or both splitting/recombination of the different colors and/or polarization states of the light source embedded as one component.

In recent years, image projectors, and especially digital projectors, have found increased popularity as a tool for presenting a variety of information to an audience. Typically, these projectors are used to project a computer-generated image onto a viewing surface. Image projectors allow a user to easily present high-quality images to audiences of a wide range of sizes. As a result, these projectors are now often found as permanent fixtures in conference rooms and other meeting facilities.

Images projected by typical image projectors generally appear flat and two-dimensional to a viewer, without any representation of depth other than the depth of field of the image. Such a representation may be suitable for many types of applications. However, in some situations, it may be desirable to emphasize features such as depth or texture in an image to a higher degree than what is possible with an ordinary two-dimensional representation.

In prior art there are several schemes for generating three dimensional images. For example, a two-dimensional representation of an image may be given the appearance of depth by representing the image stereographically. These images comprise separate, superimposed left-eye and right-eye images configured to mimic the slight differences in the appearance of a three-dimensional object as viewed by the left and right human eyes due to the geometrical separation of the eyes on the human face. The left-eye and right-eye images, respectively, are presented such that the left-eye image is not perceived by the right eye of a viewer, and the right-eye image is not perceived by the left eye, typically provided for by optical filters worn by the viewer.

For example, a stereographic image may be presented in a meeting room environment by using separate image projecting systems to respectively project the left-eye image and the right-eye image. While such a system may be successfully in forming a
stereographic image, the cost and the weight of the system may be much higher than that of a single projector. Furthermore, the two projectors may require a relatively difficult and time-consuming optical alignment. Also, such a system may be particularly difficult to move between locations due to the weight and bulk of the two systems, as well as difficult image alignment problems when changing locations.

Another example of prior art 3D imaging systems uses a single projector with an active polarizing sheet positioned between the projector and the screen. The polarizing sheet circularly polarizes the alternating image frames in opposing directions. Viewers wearing the polarized eyewear see a stereo 3D image on the screen as alternating frames viewed by the right and left eye respectively. However, the polarizing sheet will absorb some light and thus yield a lower light efficiency. Furthermore, displaying alternating frames to different eyes can cause flickering and interlacing artifacts in the image. Also the response of the display modulator must be twice as fast as the response of a modulator used in a two-projector setup as the refresh rate of the single projector image must be twice as high.

A stereographic projector using lasers as light sources would provide a much larger color gamut than current projectors, and thus produce images with more natural and saturated colors. EP 021 1 596 A disclose an apparatus for producing stereoscopic images comprising a red laser (23) at 610nm, a green laser (24) at 514 nm, and a blue laser (25) at 476nm. Light from the lasers (23,24,25) are modulated in a first set of acoustic modulators (26,27,28) in a zero order, and two first orders light beams. The first set of modulators (26,27,28) are adjusted such that the first order light beams has an angle of departure relative to the zero order light beam that is equal for all primary colors. A first set of lenses (30,31,32) directs light from the first set of opto-acoustic modulators (26,27,28) towards a second set of lenses (36,37,38) in addition to a set of stoppers (33,34,35) for light that has not been diffracted. The second set of lenses (36,27,38) focus the light towards a point just in front of the beam scanner (52). The light beams (39,40) from second lens (36) are transmitted through a polarization rotor (41) before being transmitted through a polarization splitter (42). A first set of polarized light (43,44) is modulated in a second opto-electronic modulator (47), while a second set of polarized light (45,46), orthogonally polarized relative to the first set of polarized light, is reflected by a reflector (48) towards a third opto-electronic modulator (49). Mirrors (50,51,53) collects the light (43,44,45,46) and directs the collected light towards a first scanner (52), and further through a projection system, wherein a user can
view images through glass wear with different polarization filters for each respective eye, the polarization corresponds to the polarizations introduced in the apparatus.

GB 2 265 024 A disclose a modulator comprising a first transparent layer (1), a second deformable layer (5) in a distance (6) from an inner side of the first transparent layer (1). A prism (9) is located above the first transparent layer (1). The deformable layer (5) is deformed by applied signals.

US 2004/0008928 A disclose an apparatus (10) separating light (26') with different wavelengths from an incoming light beam (26). A substrate (12) have a layer structure (14), wherein members of the layer structure (14) have different optical features, providing separation and control of polarization of the light.

WO/ 90/03086 A disclose an apparatus (1) for reproducing stereoscopic pictures in a line scanning projection system. The apparatus comprises a multiple of viewing fields (5) with separation units (6) having polarization filters. In front of each separation unit, there is located a double sided display (14).

In summary, earlier known solutions to achieve stereographical images with projection displays typically involve either multiple light path systems with high complexity and cost, or single-chip solutions with low brightness performance and large response time requirements.

Therefore, there is a need for a simple low-cost stereographic projection system for displaying images that can produce flicker-free images with a large color gamut.

In prior art, 3D stereoscopic projection has been achieved with single-panel DMD (Digital Micro Mirror Device) systems, in which individual left/right frames for each eye is sequentially displayed. When the user is wearing glasses with a shutter function synchronized with the projector, only the left eye is allowed to see the displayed image when a "left eye frame" is displayed by the projector, and similar for the right eye, respectively.

However, such a solution requires more than the double bandwidth of the projector display modulator and electronics since the frame rate needs to be twice a "monoscopic" image rate to avoid flickering artifacts, and hence it is in practice with
current DMD component technology not possible to display for example full HDTV resolution with full 8 bits or higher grayscale resolution.

Other examples of prior art solutions uses anaglyphic left/right eye separation combined with single-panel DMD systems, where the viewer is wearing glasses with matching color bands. However, for white light sources the brightness efficiency is very low. The sequential operation mode of the system adds severe demands on the response speed of the display modulator and driving electronics, which implies a limited bit depth for the grayscale resolution.

Another example of prior art approach is to use two LCOS (Liquid Crystal On Silicon) displays, and providing the left/right eye separation respectively on the viewer's side of the system on glasses with passive polarization filters, and by matching the orientation of these filters with the left/right output from the projector since the polarization of the light incident on either LCOS modulator is orthogonally polarized.

In this case color and brightness uniformity and thermal stability is of great concern, as well as the split/recombination of polarized light from the two displays, which implies a complex optical system. Response speed is also an issue, since each LCOS modulator must display a full RGB color frame within the given frame rate.

According to an aspect of the present invention, a system providing single chip 3D imaging is proposed, with separation provided by polarization, color bands or a combination of these.

According to a preferred example of embodiment of the present invention, tunable diffraction gratings (TDG), particularly such gratings as described in the Norwegian patent application No. 20054834 are used. The working principle of this tunable diffraction grating is based on light diffraction due to surface modulation of a thin gel layer or a membrane with equal optical and functional characteristics. The basic principles of these modulators are well known and have been used for projection applications since the introduction of the Eidophor project over 60 years ago.

According to an example of embodiment of the present invention, a specially designed prism is used to split, recombine, or is used as a combined split/recombination element for the different colors and/or polarization states from the light source that is provided, wherein the solution is provided as a single component. The individual colors and/or
polarization states from the light source are guided towards individual modulator sections on a single TDG surface. By providing the prism as a part of the modulator, the necessary alignment adjustments are minimized as well as providing a very compact system solution.

According to an aspect of the present invention, this concept simplifies the optical system and reduces cost, effort, and investments in the production assembly process.

According to further aspects of the present invention, advantages are, but not limited to, reduced system complexity and cost compared to multi-chip solutions, reduced response speed requirements compared to current single-chip solutions, improved refresh rate etc.

Another aspect of the present invention is that it is possible to provide stereoscopic imaging by using a combination of polarization and color split. An effect of this property is that individual images may be presented to different groups of viewers, for example by providing a "presenter's mode" where the presenter has access to more image content than the audience.

Figure 1 illustrates an example of embodiment of a modulator device according to the present invention based on polarization split.

Figure 2 illustrates another example of embodiment of a modulator device according to the present invention based on polarization split.

Figure 3 illustrates an example of embodiment of a color projection system comprising a modulator design according to figure 2.

Figure 4 illustrates another example of embodiment of a modulator device according to the present invention based on chromatic split.

Figure 5 illustrates another example of embodiment of a modulator device according to the present invention based on chromatic and polarization split.

An aspect of the present invention is to use a TDG modulator comprising a set of electrodes located in a functional distance from a gel, membrane or polymer etc. such that a diffraction grid is formed on the surface of the gel or membrane etc. when appropriate voltages are applied on the electrodes. One of the features of such TDG
modulators is that several groups of independent electrodes can be incorporated in a functional distance from the gel or membrane, thereby providing individual diffraction of light incident on the different parts of the surface of the gel or membrane situated above the individual groups of electrodes, respectively. Therefore, according to an example of embodiment of the present invention, splitting and providing polarization of an incoming light beam, for example a laser, and then guiding the polarized light beams towards respective parts of the gel or membrane surface of a TDG component makes it possible to modulate images for left and right eyes, respectively. Optics for example arranged before the modulator and/or after the modulator provides the devices necessary to achieve a 3D projection system. According to an aspect of the present invention such modulators may be arranged as a single chip component.

Figure 1 illustrates an example of a single chip embodiment of a modulator device according to the present invention based on polarization split. Laser light, 1, is incident on the modulator prism. The light is reflected off a polarizing filter, 2, which divides the beam into two separate polarized beams, Is and Ip, with their individual polarization states orthogonal with respect to each other. Each beam is incident on separate modulating parts of the single TDG modulator surface, 4. Different grid patterns provided by voltages applied on the electrodes 3s and 3p makes it possible to control the angles of the diffracted laser light beams respectively, and the 3D effect can be obtained by viewing the diffracted light as known to a person skilled in the art through appropriate optics.

Figure 2 illustrates another example of embodiment of a single chip modulator device according to the present invention based on polarization split. Red, green, and blue laser light, 5, is incident on the modulator prism. The light is reflected off a stack of polarizing chromatic filters, 2. The effect of the reflection is that the incident light, 5, is divided into six separate beams, 4R₆₅ 4R₆₃ 4G₆₅ 4G₆₃ 4B₆₅ and 4B₆₃. Each beam is characterized by a unique combination of wavelength and polarization state. The polarization states of each wavelength are orthogonal with respect to each other. Each beam is then incident on separately modulating parts of the TDG modulator surface, 4. Different grid patterns provided by voltages applied on the electrodes 3R₆₃ 3R₆₅ 3G₆₅ 3G₆₃ 3B₆₅ and 3B₆₃ makes it possible to control the angles of the diffracted laser light beams respectively, as known to a person skilled in the art. Figure 3 depicts an example of a 3D display system according to the present invention comprising the modulator depicted in figure 2.
With reference to figure 3, the different laser colors, R, G, and B (red, green, and blue) are coaxially aligned with the aid of two dichroic filters (other components, e.g., an X-prism can also be used to perform this alignment), 9R and 9G and guided through beam-shaping relay optics (common to all colors), 10, to the modulator, 11, which splits the beam into its color and polarization components and modulates the different beams individually and then guides them towards the projection optics. 12. A schlieren stop, 13, is used to filter out unwanted diffraction orders and a scanning mirror, 14, is used to generate an overlay of two 2D-images with orthogonal polarization properties on a polarization maintaining screen, 15. A 3D-image is produced with the aid of passive polarizing spectacles worn by the viewer. The individual glasses of the spectacles polarize the passed light orthogonally with respect to each other and are configured with reference to the polarizing stack in the modulator so that light from one of the projected images reaches only the viewer's left eye, while light from the other projected image reaches only the viewer's right eye. The stereographic effect when the left eye sees a different image than the right eye produces a three-dimensional image, as known to a person skilled in the art.

Figure 4 illustrates another example of embodiment of a modulator device according to the present invention based on chromatic split. Six coaxially aligned laser beams with different wavelengths (two red, two green, and two blue), 7, are incident on the modulator prism. The light is reflected off a stack of chromatic filters, 8. The effect of the reflection is that the incident light, 7, is divided into six separate beams, 7R₁, 7R₂, 7G₁, 7G₂, 7B₁, and 7B₂ with different wavelengths. Each beam is then incident on separately modulating parts of the single TDG modulator surface, 4. Different grid patterns provided by applied voltages on the electrodes 3R₁, 3R₂, 3G₁, 3G₂, 3B₁, and 3B₂ make it possible to control the angles of the diffracted laser light beams of separate (or different) wavelengths. Two overlaid 2D images are projected on a screen using similar projection optics as in the projection system depicted in figure 3. A 3D-image is produced with the aid of passive filtering spectacles worn by the viewer. The individual glasses of the spectacles passes different wavelengths so that the right eye (for example) sees the image produced with the colors 7R₁, 7G₁, and 7B₁, while the left eye (for example) sees the image produced with the colors 7R₂, 7G₂, and 7B₂. The stereographic effect when the left eye sees a different image than the right eye produces a three-dimensional image, as known to a person skilled in the art.

Figure 5 illustrates another example of embodiment of a modulator device according to the present invention based on chromatic and polarization split. Six coaxially aligned
laser beams with different wavelengths (two red, two green, and two blue), 16, are incident on the modulator prism. The light is reflected off a stack of chromatic and polarizing filters, 17. The effect of said reflection is that the incident light, 16, is divided into twelve separate beams, 16R_{1s}, 16R_{1p}, 16G_{1s}, 16G_{1p}, 16B_{1s}, 16B_{1p}, 16R_{2s}, 16R_{2p}, 16G_{2s}, 16G_{2p}, 16B_{2s}, and 16B_{2p}. Each beam has a unique combination of wavelength and polarization state. The polarization states of each wavelength are orthogonal with respect to each other. Each beam is characterized by a unique combination of wavelength and polarization state. The polarization states of each wavelength are orthogonal with respect to each other. Each beam is then incident on separately modulating parts of the single TDG modulator surface, 4. Different grid patterns provided by applied voltages on the electrodes 3R_{1s}, 3R_{1p}, 3G_{1s}, 3G_{1p}, 3B_{1s}, 3B_{1p}, 3R_{2s}, 3R_{2p}, 3G_{2s}, 3G_{2p}, 3B_{2s}, and 3B_{1p} makes it possible to control the angles of the diffracted laser light beams, respectively. Four overlaid 2D images are projected on a polarization maintaining screen using similar projection optics as in the projection system depicted in figure 3. A 3D-image is produced with the aid of passive filtering spectacles worn by the viewer. The individual glasses of the spectacles pass different wavelengths in combination with different polarization states. The right eye of one viewer, for example, sees the image produced with the color and polarization combinations, for example 16R_{1s}, 16G_{1s}, and 16B_{1s}, while the left eye sees the image produced with the color and polarization combinations, for example 16R_{2s}, 16G_{2s}, and 16B_{2s}. The right eye of another viewer wearing different spectacles sees the image produced with the color and polarization combinations, for example 16R_{1p}, 16G_{1p}, and 16B_{1p}, while the left eye sees the image produced with the color and polarization combinations, for example 16R_{2p}, 16G_{2p}, and 16B_{2p}. The stereographic effect when the left eye sees a different image than the right eye produces a three-dimensional image for each viewer. Since four different 2D images are overlaid, two different 3D images can be presented to viewers wearing different spectacles. This could have numerous applications, e.g., multitask-use where individual images comprising information is presented to different groups of viewers, for example a "presenter's mode" where the presenter has access to more image content than the audience.

An aspect of the present invention is to utilize the properties of the TDG modulator to provide at least two groups of electrodes related to each state of the light constituting the image to be displayed, by applying appropriate voltages on the electrode groups, respectively, for controlling the angle of each diffracted laser light beam before being passed through display optics and a scanning mirror arrangement, for example. According to another example of embodiment of the present invention, the angle of
each diffracted light beam is controlled by the geometry of the electrode pattern related to that diffracted light beam, respectively.
Claims:

1. Modulator device for providing three dimensional images in a line scanning projection system, wherein images are viewed by a user through optical filters, comprising a Tunable Diffraction Grating (TDG) component (4) with a plurality of individual electrode groupings providing a plurality of individual modulator sections in the TDG component, wherein the modulator device further comprises:

   a prism guiding incident light (1, 5, 7, 16) towards a reflecting arrangement (2, 6, 8, 17) that provides a split into components of the incident light, wherein each respective component from the split of the incident light is guided by the prism towards corresponding modulating parts of the TDG component (4), wherein the angle of each diffracted light beam guided out of the modulator device through the prism is controlled by voltages applied on the respective electrodes in each respective electrode groupings providing polarization split or a chromatic split, or a combination of both polarizations split and chromatic split.

2. Modulator according to claim 1, wherein the split is provided by a stack of polarization filters.

3. Modulator according to claim 1, wherein the split is provided by a stack of chromatic filters.

4. Modulator according to claim 1, wherein the split is provided by a stack of chromatic and polarization filters.

5. Modulator device according to claim 1, wherein the modulator device is arranged with one polarization filter (2) reflecting and splitting incident light (1) from one laser light source into two separate polarized beams (Is, Ip), wherein the polarized states of each beam (Is, Ip) is orthogonal with respect to each other, wherein the reflected beams (Is, Ip) are guided by the prism towards the modulator component (4) comprising a modulator section (3s) modulating one of the reflected beams (Is) and another
modulator section (3p) modulating the other reflected beam (Ip), and wherein voltages applied on the corresponding respective electrode groups for each modulator section (3s, 3p) control the angle of the diffracted light beams guided out of the modulator device through the prism.

6. Modulator device according to claim 1, wherein the modulator device is arranged with a stack of chromatic polarizing filters (6) reflecting and splitting the incident light (5) from one red, one green and one blue laser light source, wherein the red laser light is split into two separate polarized beams (5Rs, 5Rp) with orthogonal polarized states relative to each other, the green laser light is split into two separate polarized beams (5Gs, 5Gp) with orthogonal polarized states relative to each other, the blue laser light is split into two separate polarized beams (5Bs, 5Bp) with orthogonal polarized states relative to each other, wherein the reflected beams (5Rs, 5Rp, 5Gs, 5Gp, 5Bs, 5Bp) is guided by the prism towards the modulator component (4) comprising 6 modulator sections (3Rs, 3Rp, 3Gs, 3Gp, 3Bs, 3Bp) each respectively modulating the corresponding reflected light beams, wherein the prism is guiding the respective diffracted light beams out of the modulator device through the prism at angles controlled by voltages applied on electrodes in each respective modulator section (3Rs, 3Rp, 3Gs, 3Gp, 3Bs, 3Bp).

7. Modulator device according to claim 1, wherein the modulator device is arranged with a stack of chromatic filters (8) reflecting and splitting the incident light (7) from six coaxially aligned lasers with different wavelengths, wherein the incident light (7) comprises two red, two green and two blue laser light sources, and the stack of chromatic filters (8) provides six reflected light beams (7R₁, 7R₂, 7G₁, 7G₂, 7B₁, 7B₂) with different wavelengths, wherein the prism is guiding the six reflected light beams towards six independent modulator sections in the TDG modulator component (4), wherein applied voltages on electrodes in each of the respective modulator sections in the TDG modulator component controls the angles of the diffracted light beams out of the modulator device through the prism, wherein the diffracted light beams can be arranged by optics as two separate overlaid two dimensional images.

8. Modulator device according to claim 1, wherein the modulator device is arranged with a stack of chromatic and polarization filters (17) providing a reflection of six coaxially
aligned laser beams with different wavelengths, two red, two green and two blue, wherein the filter stack (17) provides twelve separate beams, wherein each respective beam has a unique combination of wavelength and polarization state, wherein the prism is guiding the twelve reflected beams towards the TDG modulator device (4) comprising twelve independent modulator sections, wherein voltages on electrodes in each of the respective twelve modulator sections controls the angles of the diffracted light beams out of the modulator device through the prism, and wherein the diffracted light beams can be arranged by optics as four separate overlaid two dimensional images comprising two different three dimensional images.

9. Modulator device according to any of the claims 1 to 5, wherein the angles of the diffracted light beams out of the modulator device is controlled by the geometry of the electrodes in each respective modulator section.

10. Modulator device according to any of the foregoing claims, wherein the modulator device is provides as a single integrated electronic component.

11. Apparatus for providing three dimensional images in a line scanning projection system comprising a modulator device (11) according to claim 5, 6, 7 or 8, wherein the apparatus comprises two dichroic filters (9R, 9B), aligning coaxially the three different laser colors red, green and blue, which is then guided through beam shaping relay optics (10) towards the modulator device (11), which splits the beam into its color and polarization components and modulates the different beams individually, and then guiding the beams towards projection optics (12), wherein a schlieren stop (13) after the projection optics (12) filters out unwanted diffraction orders from the modulator sections in the modulator device (11) before the light beams via a scanning mirror (14) is providing an overlay of a plurality of two dimensional images with orthogonal polarization properties on a polarization maintaining screen (15).

12. Apparatus according to claim 11, wherein the coaxial alignment is provided by an X prism.
Figure 1
Figure 4
A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04N, G02B, G03B

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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D. Further documents are listed in the continuation of Box C.

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