(54) Title: A LINE SCANNING PROJECTION DISPLAY SYSTEM COMPRISING A DOUBLE PIXEL ARRAY LIGHT MODULATOR

![Graph showing light intensity over time]

(57) Abstract: A method and system is disclosed providing improved response time in a Tuneable Diffraction Grating (TDG) component based line scanning projection system by alternating incident light between at least two parallel pixel arrays in said TDG component and said incident light. By synchronously controlling the movement of the incident light between the at least two pixel arrays according to which of said two pixel arrays comprising a steady state of an image line to be displayed while the other pixel array is being loaded, the "on" time of a pixel is prolonged to significantly improving the light efficiency of the display system.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
A line scanning projection display system comprising a double pixel array light modulator.

The present invention is generally related to line scanning projection display systems, and more specifically to a line scanning display system comprising a double pixel array light modulator, and deflecting means of incident light on said modulator, in accordance with the independent claims 1 and 13.

Projection display systems have recently become increasingly popular for a multitude of applications, ranging from e.g., rear projection consumer TV's to front projector products for presentation purposes. Several different light modulator technologies exist for projection displays, and the light modulator are currently typically being based on DMD, LCOS, or LCD technology.

There exist several new technologies for projection display systems that have recently been proposed, e.g., GLV, GEMS, and Tunable Diffraction Grating based light modulators. In contrast to the previously mentioned technologies, which are based on two-dimensional modulators, these technologies are based on one-dimensional light modulator arrays for line scanned projection using laser illumination. A one dimensional modulator has the advantage that the modulator size does not grow as fast as with increasing resolution in older two dimensional technologies. The fact that one dimensional modulators are smaller than two dimensional modulators provides the possibility to also decrease modulator component costs, and also to be able to use smaller, simpler, and cheaper optics, which in the end provides a cheaper and yet reliable projection display system.

Especially, the Tunable Diffraction Grating (TDG) based light modulator is a promising candidate as technology for providing the cheapest and most reliable and versatile possible scanning line projection systems. However, a general drawback with line scanning projection systems is the response time of the modulator. This is especially a challenge with respect to higher demand on pixel resolution, as seen for example in the new high definition television standard (HDTV) which requires a format of up to 1080x1920 pixels in each image frame. If for example the HDTV signal is updated at 100Hz, the “on” time in a two dimensional light modulator would be 10 ms, while a one dimensional light modulator must support an “on” time of merely 5.2 μs. This figure is even worse since practical experience suggest that the actual “on” time demand of a one dimensional modulator should be ten times lower to insure correct switching of the
pixels, providing an image without any form of artifacts due to switching conditions of said pixels. In order for no light to leak into a following or preceding pixel, the rising and falling of a pixel signal setting must be well inside the "on" time of a pixel.

Figure 1 illustrates a typical curve of the response time of a TDG based modulator. The "on" time is defined as Δt. When using analog driving techniques for the TDG modulator, the efficiency of the modulator is lower since the total light output of a pixel is the area under the response curve. If the driving technique of the TDG based modulator is digital, and by employing a pulse-width modulation to provide generation of gray scale intensities, a slow response time limits the number of equivalent grey scale bits the modulator can support.

Therefore, there is a need for a TDG modulator based projection display system comprising fast enough response time, while still maintaining the cost, reliability and versatile aspects of TDG technology.

According to an aspect of the present invention, an improved response time is achievable by providing two parallel pixel arrays used such that while a first one of said two pixel arrays is modulating a current image line of an image, a next image line providing a correct setting of the second one of said two pixel arrays is arranged, and when the projection of the first pixel array is finished a deflection means moves the incident light from the first pixel array to the second pixel array thereby providing a possibility to start arranging a further new image line into said first pixel array while the second pixel array is projected, and so on.

According to this aspect of the present invention, each modulator pixel line can then use the time during which the other pixel line provides image information to settle into its next state. This means that a pixel can be at the same state during the entire pixel time slot and thus provide a high light efficiency.

According to an example of embodiment of the present invention, the response time is improved by arranging two parallel arrays of pixels to each other, and by providing beam deflection means between the light source and the modulator such that the beam deflection means is moving the incident light alternating between the two pixel arrays. According to this example of embodiment, each image frame to be displayed in said display system is divided in two sections in a memory, a first section comprising all even image lines for example, while the other section comprise all odd image lines, for
example. The displaying of the image is then provided by loading alternating even and odd image lines from said memory into said two pixel arrays, respectively, and synchronously with said loading, alternating moving the incident light between said two pixel arrays. The sections of the memory may be provided by loading images into said memory by using even memory addresses for even image lines, while odd addresses are used for odd image lines. The loading of image lines into said two parallel pixel arrays is performed by addressing the memory with odd and even addresses, respectively.

According to an example of embodiment of the present invention, the deflection means comprise a piezo-electrically controlled mirror, whereby oscillations of said crystal controlled by an applied electrical signal makes the attached mirror to deflect incident light alternating between said two pixel arrays. The applied control signal on said crystal is synchronized with the loading from said memory of said alternating image lines.

According to another example of embodiment of the present invention, the deflection means comprise an acousto-optic deflection device, whereby variations of an acoustic wave in said acousto-optic deflection device, provides deflection of incident light alternating between said two pixel arrays. An applied control signal on said acousto-optic deflection device is synchronized with the loading from said memory of said alternating image lines.

According to another example of embodiment of the present invention, said deflection means comprise two laser light sources switched “on-off” or being modulated to provide the correct “on” time of a pixel, wherein a first laser illuminates a first of said two pixel arrays, while the other of said two lasers illuminates the second of said two pixel arrays. The alternating illumination of said two pixel arrays according to the present invention may be provided by controlling each separate laser to be in anti-phase. That is, the “on-off” setting is in ant-phase, or the separate modulation signals to each laser are in ant-phase. An alternative embodiment may use electronic shutter devices or mechanical devices (such as a rotating wheel with holes) to block or pass the light, respectively, as known to a person skilled in the art.

According to yet another example of embodiment of the present invention, a TDG based modulator may be configured to act as a light switch as known to a person skilled in the art. A dual light switch configuration based on TDG modulators may then be
inserted as said deflection means by alternating passing or blocking said two laser beams as described above.

Figure 1 illustrates a typical response of a TDG based modulator.

Figure 2 illustrates an example of embodiment of a modulator according to the present invention.

Figure 3 illustrates the projection of an image in a projection system according to the present invention.

Figure 4 illustrates an example of improved response time in a light modulator according to the present invention.

Figure 5 depicts a display system according to an example of embodiment of the present invention.

Figure 6 depicts a block diagram illustrating functional blocks and interconnections between functional blocks in a system according to the present invention.

Embodiments according to the present invention comprise a modulator design having at least two parallel pixel arrays. In a preferred embodiment of the present invention, a TDG based modulator is used. As known to a person skilled in the art, a pixel definition in such a TDG based modulator is provided for by an electrode structure on a substrate defining a diffraction grid in the component. Figure 2 illustrates an example of an electrode structure in TDG based modulator according to the present invention. Two parallel rows of electrode patterns define the two pixel arrays 1a and 1b. An important aspect of this embodiment is that the two electrode patterns are aligned such that there is no offset between the two pixel arrays.

Figure 3 illustrates an example of embodiment of the present invention, wherein an image has been divided into even and odd image lines in a memory. A display system comprising a TDG component according to the present invention, such as depicted in figure 5 (described below), may then projects the odd and even image lines onto a screen. Figure 3 illustrates how even image lines (vertical lines in this example) are modulated and displayed via pixel array 1b illustrated in figure 2. The odd image lines
(also vertical lines in this example) are projected via pixel array 1a in fig. 2, for example.

The effect of the arrangement of the two pixel arrays as depicted in figure 2 and which is used in a system as depicted in figure 5 is illustrated in figure 4. The response behavior of a pixel array, for example 1a in figure 2 according to the present invention, is illustrated in figure 4. The modulator is driven to a desired state during the time period Δt1. During this time the image information is loaded onto the other modulator row, 1b, which is illuminated. At the end of Δt1, the illumination is switched to modulator row 1a, which loads image information during the time period Δt2 after which the illumination is switched back to the modulator row 1b. The modulator row 1b is driven to a desired state during the time period Δt2, wherein image information may be loaded during the time period Δt3, during which the modulator row 1a is driven to a desired state making it ready to load image information in a succeeding time period.

Figure 5 is an illustration of an embodiment of the present invention used in a projection system. A light source, 2, directs light via beam deflection means, 3, through a system of source optics, 4 onto a light modulator, 1. Projection optics, 5, images the modulator rows throw a filter plane, 6, which removes unwanted diffraction orders, onto a single line on the screen and a scanning device, 7 (mirror for example), projects the line across the screen creating a two dimensional image, 8.

Figure 6 is a block diagram illustrating functional elements and physical and logical interconnections between said functional elements according to an example of embodiment of an image display system according to the present invention. A light source, 2, directs light via beam deflecting means, 3, through a system of source optics, 4 onto a light modulator, 1. The modulation is achieved via an image signal, 11, fed through an image processing unit, 9, which processes the image and directs control signals to two driving electronic units, one for each pixel row in the modulator, 12a and 12b respectively. The driving electronic signals pass through a synchronization unit, 10, which synchronizes the beam deflecting means 3 and scanning device 7 according to the image information sent to the two pixel rows 12a and 1b, from a memory for example (not shown). Projection optics, 5, images the modulator rows onto a single line on the screen and a scanning device, 7, scans the line across the screen creating a two dimensional image 8.
As can be understood by a person skilled in the art, a main requirement for any embodiment according to the present invention is to provide means for a method according to the present invention wherein loading of image lines corresponding to image lines of an image to be displayed are controllably loaded alternating into at least two parallel pixel arrays, for example one pixel array for even image lines, and the other pixel array for example for odd image lines. The actual projection of an image is then performed by synchronously with said loading, alternating incident light between said two pixel arrays, and via optics project the light onto a screen. Therefore, it is evident that any deflecting means providing shifting of incident light between said at least two pixel arrays are inside the scope and spirit of the present invention. Examples of deflections means, but not limited to, are a piezo-electric crystal with an attached mirror, acousto-optic device wherein an acoustic wave provides the deflection means controlled by the frequency of the acoustic wave, two separate laser operated in anti-phase wherein each laser is arranged to illuminate one of each pixel arrays only, electronic shutter means, mechanical rotating wheel with holes blocking or passing light, or a TDG component arranged as a light switch.

As can be understood by a person skilled in the art, a major aspect with the present invention is to provide means for a method according to the present invention for synchronously driving each of said at least two parallel pixel arrays with a light deflecting means. Such synchronic operation may be provided by software program executed in for example an image processor comprised in a display system according to the present invention. An image source, for example an image memory, a network connection, DVD, etc. may be in communication with said image processor executing said software providing synchronic operation. According to an example of embodiment of the present invention, a first image line may be regarded as being an even image line loaded by said software into a first pixel array from said image source. A second image line to be loaded from said image source is then regarded as being an odd image line to be loaded into a second pixel array, and so on. When said software is executing such a loading scheme, at the same time, controlling signals may be issued from said image processor controlling a deflecting means as required according to the present invention. Digital controlling of examples of deflecting means as those described above is known to a person skilled in the art.
Claims:

1. Method for improving response time in a line scanning projection display system comprising a Tuneable Diffraction Grating (TDG) optical component, wherein said method comprise the steps of:

arranging at least two parallel pixel arrays in said TDG component with no offset in pixel direction between said at least two pixel arrays,

providing driving of said at least two pixel arrays such that when one of said at least two pixel arrays comprise a steady state of an image line to be displayed, the other of said two pixel arrays is settling to a state representing a next image line to be displayed,

performing projection of content of said at least two pixel arrays by synchronously with respect to the driving of said at least two pixel arrays, moving incident light onto said TDG component alternating between said at least two pixel arrays such that said incident light at any time falls onto one of said of at least two pixel arrays that at the moment comprise a steady state representing an image line to be displayed.

2. Method according to claim 1, wherein said step of performing projection further comprise:

a) transferring image lines one by one from an image source comprising at least one image frame to be displayed in said display system, such that content of a first of said image lines drives a first of said at least two pixel arrays, while content of a second pixel line drives a second of said at least two pixel lines,

b) repeating step a) until all image lines constituting said at least one image frame is displayed in said display system.

3. Method according to claim 1 and 2, wherein synchronously moving of incident light is provided for by synchronising said transfer of image lines one by one with moving a deflecting means arranged in the light path between said at least two pixel arrays and said incident light such that incident light at any time falls onto one of said at
least two pixel arrays that at the moment comprise a steady state representing one of said image lines to be displayed.

4. Method according to claim 3, wherein said transfer of image lines and movement of said deflecting means is coordinated by an image processor executing a controlling program issuing controlling signals of said display system.

5. Method according to claim 3, wherein said deflecting means comprise a piezo-electric crystal with an attached mirror.

6. Method according to claim 3, wherein said deflecting means comprise an acousto-optic device.

7. Method according to claim 3, wherein said deflecting means comprise at least two lasers operated in anti-phase.

8. Method according to claim 3, wherein said deflecting means comprise at least two electronic shutter devices each blocking or passing light from a light source in anti-phase.

9. Method according to claim 3, wherein said deflecting means comprise at least two mechanical rotating wheels comprising holes each blocking or passing light from a light source in anti-phase.

10. Method according to claim 3, wherein said deflecting means comprise a TDG component configured with two light switches.
11. Method according to claim 1, wherein said image lines are transferred from an image source such as an image memory, DVD, CD, network connection, or similar source.

12. Line scanning projection system including a Tuneable Diffraction Grating (TDG) component, comprising:

a TDG component arranged with at least two parallel pixel arrays in optical contact with a deflecting means arranged in the light path between said at least two parallel pixel arrays and a light source of said system,

a controlling device issuing controlling signals two said deflecting means thereby controlling said deflecting means such that said light from said light source falls onto each of said at least two pixel arrays in an alternating manner.

13. System according to claim 12, comprising a controllable input port in said system for image lines transferred from an image source.

14. System according to claim 12, wherein said controlling device is a processor device comprising a program executing steps of a method according to claim 1.

15. System according to claim 14, wherein said image source is one of an image memory, DVD, CD, network connection, or similar source.

16. Method according to claim 12, wherein said deflecting means comprise a piezo-electric crystal with an attached mirror.

17. Method according to claim 12, wherein said deflecting means comprise an acousto-optic device.
18. Method according to claim 12, wherein said deflecting means comprise at least two lasers operated in anti-phase.

19. Method according to claim 12, wherein said deflecting means comprise at least two electronic shutter devices each blocking or passing light from a light source in anti-phase.

20. Method according to claim 12, wherein said deflecting means comprise at least two mechanical rotating wheels comprising holes each blocking or passing light from a light source in anti-phase.

21. Method according to claim 12, wherein said deflecting means comprise a TDG component configured with two light switches.
Fig. 1
Relative light intensity (%)

Δt1  Δt2  Δt3

Fig. 4
Fig. 6
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC:** see extra sheet

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, G02F

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

SE, DK, FI, NO classes as above

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

**EPO-INTERNAL, WPI DATA, PAJ, INSPEC, COMPENDEX**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Further documents are listed in the continuation of Box C.

See patent family annex.

Date of the actual completion of the international search: 8 May 2007

Date of mailing of the international search report: 11-05-2007

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Form PCT/ISA/210 (second sheet) (April 2007)
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International patent classification (IPC)

G02B 5/18 (2006.01)
H04N 9/31 (2006.01)

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