Projection architectures with light emitting diodes and reflective liquid crystal light modulators

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We present an overview of our work on projection system architectures using light emitting diodes and liquid crystal on silicon light valves. This covers the overall design challenges of illumination systems with high power light emitting diodes and our work on LED projectors with two and four liquid crystal on silicon light modulators.

Introduction

Projection displays are used in a wide variety of applications such as consumer television, digital cinema, multimedia business presentations and also recently in mobile devices [1] and displays for cars and airplanes [2].
The two key-parts to build a projection display are the illumination system and the image modulator. In the illumination system a light beam is generated that uniformly illuminates the image modulator that contains the information of each pixel of the image. This light beam consists of the primary colors that are necessary to form a full-color image. Traditionally this is realized by using a discharge lamp emitting white light in combination with a color wheel. More recently, light emitting diodes (LED) have become a viable alternative as light sources for projection systems. LEDs are small light sources with a low operating voltage that are available in the necessary primary colors with a relatively narrow spectral emission band. This enables projection systems with a large color gamut, but a major drawback of LEDs is their limited brightness.

Image modulation

Several light modulation technologies are used to encode the light beam with the image content [3]. A first approach is to use a matrix of micro-mirrors on a semiconductor chip (Digital Micromirror Device™). These are individually addressed and represent the pixels of the image [4]. Another approach is to represent the pixels by liquid crystal cells. These can rotate the state of polarization of incident linear polarized light. There are two classes of devices that use this concept. Transmissive Liquid Crystal Devices (LCD) change the state of polarization of light while while it is propagating through the light modulator. For this, the liquid crystal cells are placed between two transparent electrodes. When one of these transparent electrodes is replaced by a reflective electrode, a reflective LCD is created. These light modulators are called Liquid Crystal On Silicon (LCOS) micro displays [5, 6].

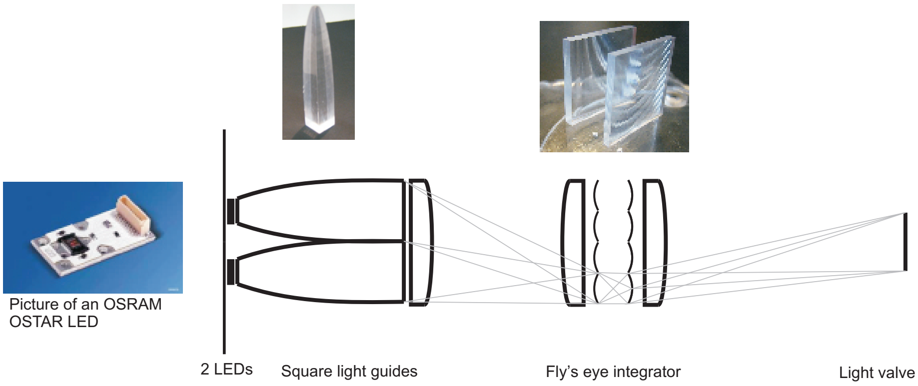

Figure 1: Using a fly's eye integrator to combine two LED into one light source for projection applications

Illumination systems with high power LEDs

LEDs emit their light over a quite large solid angle. This light should be collimated before it can be used in a projection system. We designed a system that collimates the LED light and that combines several LED light sources into one primary color light source for projection systems. It consists of square polymer lightguides with an optimized conic profile and a fly's eye integrator (fig. 1). Both components are optimized using a non-imaging approach. The merit function of the optimization is the light flux transfer in the system. This is contrary to imaging systems, where the aberrations are reduced. Our design enables a full and uniform illumination of the light valve, even if one of the LEDs would fail. [7]

Two LCOS panel projection system

Commercially available LCOS projection systems use one or three LCOS panels. When one LCOS panel is used, each image frame is split into three subframes that convey the information content of the three primary colors. The LCOS panel is then color sequentially illuminated. When three LCOS panels are used, the primary colors can be simultaneously imaged onto the screen. This has the advantage that the light output can be higher and that color break-up does not occur at cost of a larger system.

To obtain a white light output, a certain ratio of the primary colors needs to be respected. When LEDs are used more green light is necessary than red or blue. Because of this, it is interesting to use one LCOS panel strictly for the modulation of the green image while a second is used to modulate both the red and blue image. Such a system thus uses two LCOS panels and thereby approaches the compactness of a single LCOS panel system [8] and the light output of a three LCOS panel system when the LCOS panels are sufficiently fast [9].

A LCOS panel changes the state of polarization of the ON-state pixels. Therefore a polarizing beam splitter (PBS) is needed to separate the light beam illuminating the light valve and the image that is modulated through reflection at the light valve. Figure 2

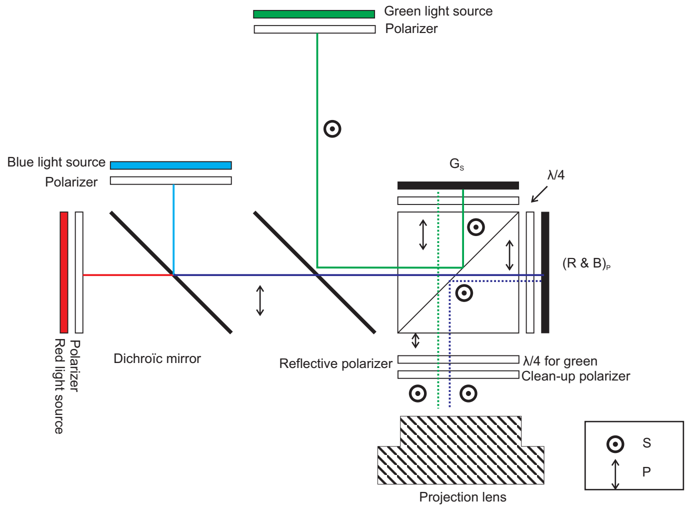

Figure 2: Our color management system for a two LCOS projector with LED light sources

gives a schematic overview of our two LCOS system. The blue and red collimated light beam are combined using a dichroïc mirror. This beam is transmitted by the wire-grid polarizer and is thereby linearly polarized. The green LED light is reflected by the wire-grid polarizer and is also linearly polarized with a state of polarization orthogonal to the transmitted beam. The alternating red/blue light beam is redirected by the cube PBS to (R & B)$_P$, the green one to G_S. The PBS redirects the reflected image beam to the projection lens. A clean-up mechanism with a polarizer and a selective half wave retarder for green wavelengths is provided to ensure a sufficient contrast of this system. [8]

Four LCOS panel projection system

A four LCOS panel projection system can be seen as an extension of a two LCOS panel approach. Two sets of two LCOS panels are used to create two linear orthogonally polarized images (figures 3(a) and 3(b)). To illuminate all LCOS panels and to combine all images towards one projection lens an optical architecture is necessary consisting of four PBSs that are positioned such that their polarization splitting surfaces form a cross shape [10]. This system can be used for stereoscopic 3-D viewing when the observer wears polarization sensitive eyeglasses or as a 2-D system when no eyeglasses are used. When used for 2D image creation, this system is more efficient than the two LCOS system since both linear states of polarization of the sources are used.

Conclusion

We have overviewed our work on LCOS projection displays with LEDs as light source. Our two LCOS approach enables a system that is compact and that emits more light than a single color design. This was extended to a four LCOS approach that is more optically efficient and that can be used to generate 3D images.

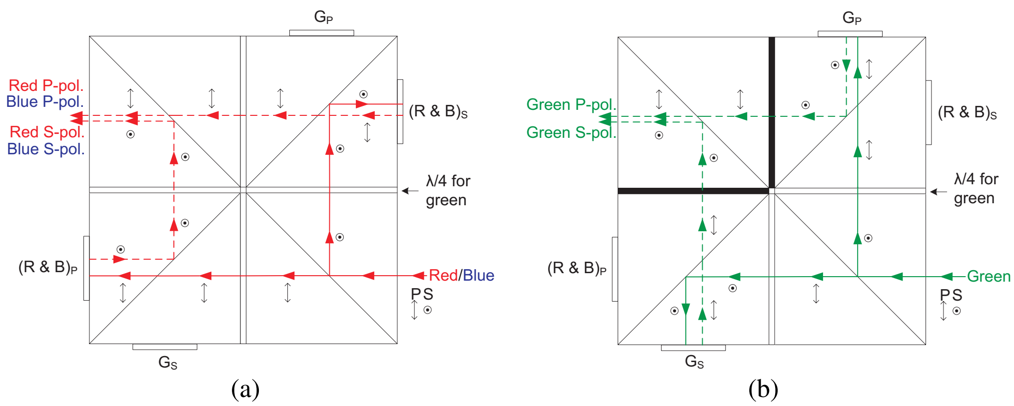

Figure 3: Our color management system for a four LCOS projector with LED light sources

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