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Spatial Light Modulators in Digital Projectors

By Michael Pate, President, OSCI

The spatial light modulator is what creates the spatial array of picture elements or pixels that are used to create the images that we see projected onto the screen for our viewing pleasure. These very small pixels in the spatial light modulator are turned on and off or modulated to create the grey levels or color levels in an image. The spatial light modulator is part of the illumination system and also part of the imaging system. Some say that the spatial light modulator is the heart of the digital projector light engine. Let's take a deeper look at what we need from a spatial light modulator and how we will use it

in a digital projector light engine with other components to create digital images on the screen.

Spatial Light Modulator in the Illumination System

Over the last several issues we have been learning about the illumination system parts and their functions. We kept hearing about the function of the whole illumination system was to capture light from the source and transform the spatial distribution of this illumination so that it will uniformly illumination the illumination plane. The illumination plane is where the spatial light modulator is located and to project a uniform image we need to start with uniform illumination on this illumination plane or spatial light modulator.

Plasma light sources with their round cylindrical cathode and anode typically produce cylindrical shaped plasmas as we learned about in the early editions of In The Box. Cylindrical plasmas are easily coupled using round shaped elliptical mirror surfaces. Everything is nice and rotationally symmetric until we get to the spatial light modulator which is rectangular. The two popular height:width:diagonal ratios are 3:4:5 or 9:16.

In transforming the light from rotationally symmetric lamp reflectors to rectangular spatial light modulators some light is lost. Luckily we can change from round to rectangular configurations and perform the spatial uniformity using components like fly's eye arrays and integrating rods, see previous edition of In The Box. We often need to slightly over fill the spatial light modulator so that we are always illumination the full array of pixels. This gives the opto-mechanical tolerances and optical assembly and alignment operations some leeway in the precision that they need to work to in the light engine fabrication and alignment. This over fill also wastes light as it cannot be used if it doesn't fall upon the modulating pixels of the spatial light modulator.

Spatial Light Modulator in the Imaging System

The spatial light modulator is the object in the imaging system. You may have learned that an imaging system has an object and an imaging system produces a high fidelity image of the object in the image plane. The object is either illuminated by an external source or is self luminous. A digital camera is and imaging system where the person is illuminated by the sun and the lens on the camera creates and image of the object (person) in the image plane (CCD detector).

Since the features in the object or spatial light modulator that we want to image onto the screen with high fidelity are relatively low spatial frequency this imaging should be fairly easy it appears. The pixels of the spatial light modulator all lie in a flat object plane which makes their imaging onto the screen easier. All of the pixels should have equal transmission, reflection, scatter, or diffraction of the light from each of the pixels in the object to the image plane when illuminated with uniform illumination from the illumination system.

Spatial Light Modulator in the Color System

In most digital projector light engines there are either one spatial light modulator and a sequential color system or three spatial light modulators and an x-cube color combiner. This means either sequential color from a color wheel spinning in front of the lamp or parallel color in three channels which are recombined before projection.

In the sequential color system there is typically a spinning color filter wheel located between the lamp and the rest of the illumination system. The spinning color filter wheel sequentially passes in time the red, green, blue, and white color segments. The sequential pulse segments of color in time are sequenced to the corresponding color frames of the digital signal. During the time that the red light hits the spatial light modulator the red frame is loaded onto the spatial light modulator and the red pixels are modulated according to the amount of red light needed on the pixels for that frame. The green, blue, and white frames are sequentially loaded onto the spatial light modulator and imaged onto the screen for viewing.

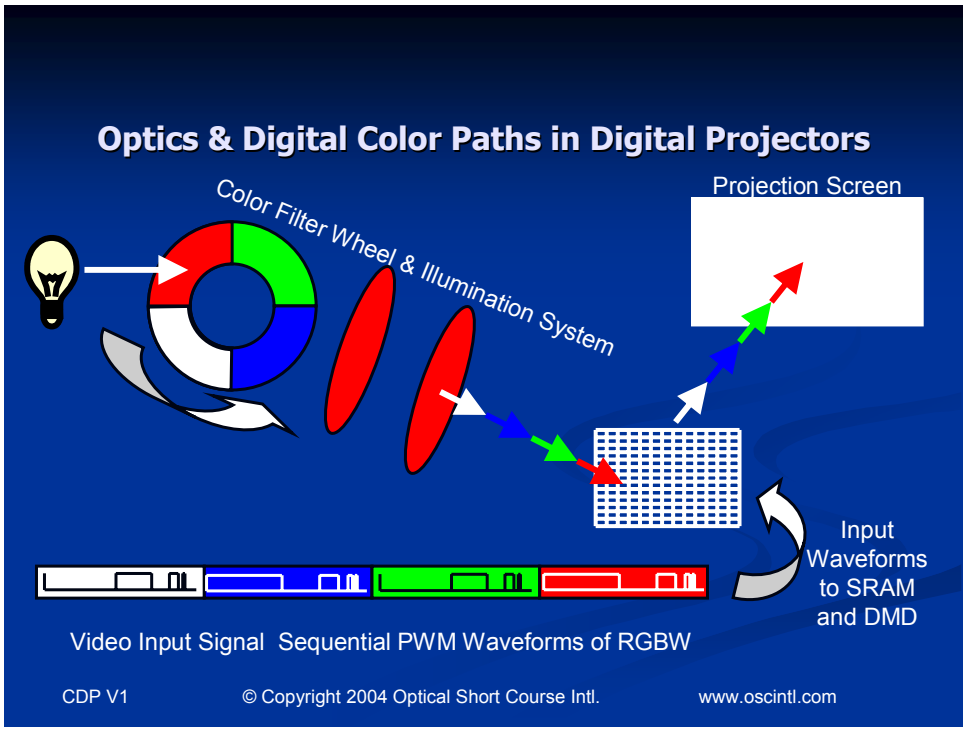

Figure 1. Sequential Color System
From OSCI's Color In Digital Projectors DVD Course
http://www.oscintl.com/prod03.htm

In the parallel color system each of the digital signals for each color red, green, and blue is split and sent to the corresponding spatial light modulator panel. The white light from the source is split into the different red, green, and blue optical paths by dichroic filters. Each of these colors illuminates a spatial light modulator in parallel and this illuminated spatial light modulator object is image by a single projection lens onto the screen. The

single projection lens looks spectrally into three different optical paths that are separated by color in an x-cube color combining prism.

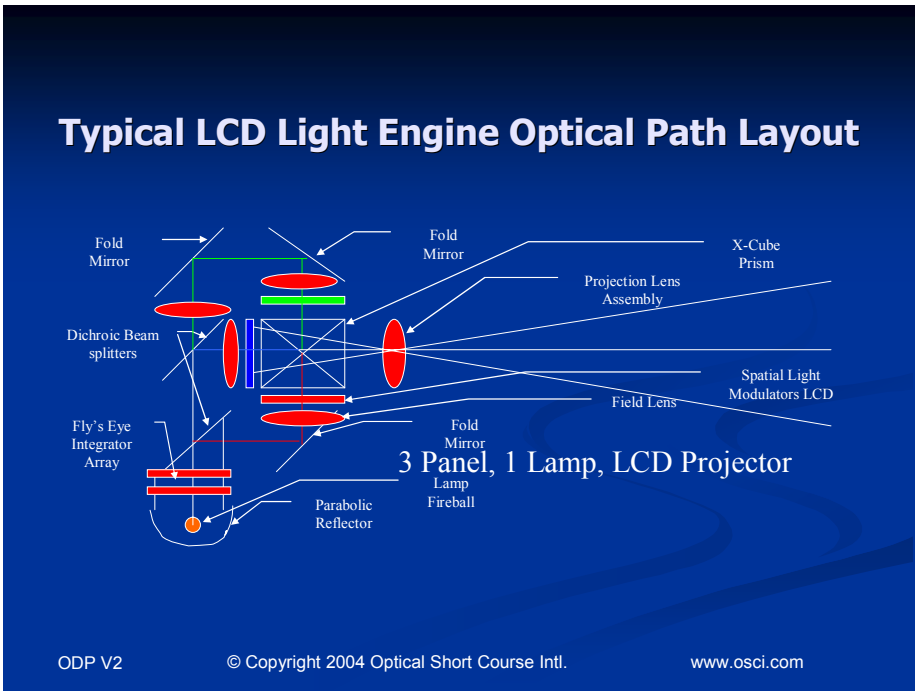

Figure 2. Parallel Color System – LCD Light Engine
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

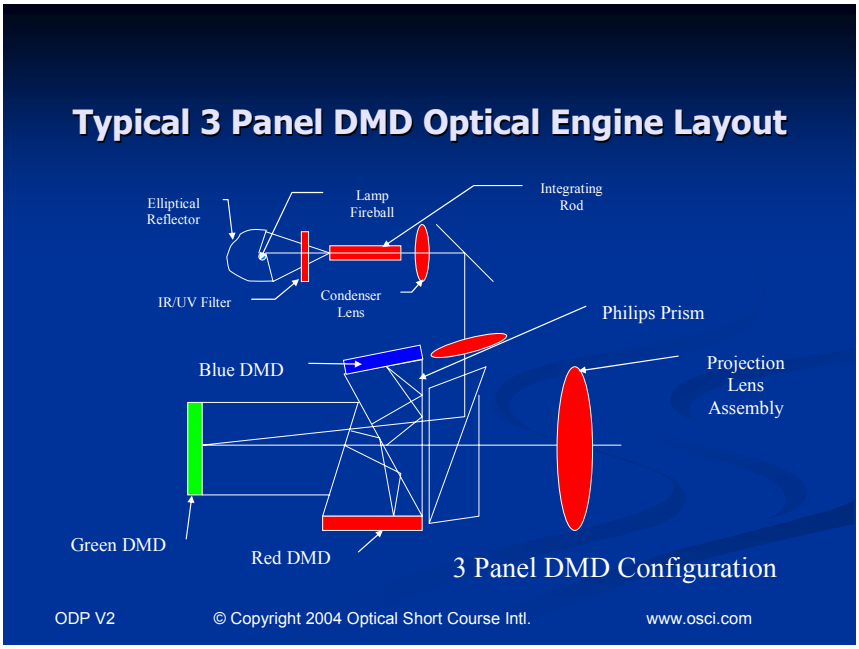

Figure 3. Parallel Color System – 3 Panel DMD Light Engine
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

Spatial Light Modulator is the Light Source
If we think about the combined function of the illumination system and the spatial light modulator panel, it is to uniformly illumination the pixels of the panel and for the pixels to modulate the light to the appropriate level required to reproduce the frame of the digital object. If we synthesize these devices and functions we arrive at an interesting idea. The modulator is the light source!

Instead of illuminated pixels turning on and off we have and array of closely packed light sources that are modulated on and off. If a particular source panel array can emit all color then we would need some color filtering. If a particular source panel array can emit one of the three primaries red, green, or blue then we can have a parallel color imaging system.

Arrays of LED's come to mind but the thermal cooling problem arises again. It seems to me that thermodynamic engineers will soon rule the design world as they have built in job security with all of the challenging problems that lie ahead. The other newer technologies for source panel arrays are OLED or organic light emitting diodes and other solid state lighting technologies.

The modulator is the light source! Think about it!

Spatial Light Modulator is the King of Cost – The Entrepreneurs Dream
It seems that when you take a look at where the bulk of the cost in digital projector light engine components are attributed to two main components: spatial light modulator and the light source. In many digital projector light engines the rest of the components are becoming commodities where every nickel is beat out of the cost of these components. Because it takes tens of years historically to develop spatial light modulators and there are large barriers to entry because they typically require lithography processes and equipment on a few of the large companies can leverage their production equipment for a few R&D runs. Once these silicon or lithography processes are developed then yield becomes and issue like many other fabrication processes involving millions of small features on these parts.

Developing a new spatial light modulator with disruptive technology where one could quickly demonstrate a low cost and high yield process with good process parameters would be very valuable and would endear you to many venture capitalists who love easy home runs. Maybe something like printable organic light source arrays using inkjet printing or self assembling periodic structures will enable this disruptive technology to replace our costly spatial light modulators in digital projector light engines.

Entrepreneurs look at the previous section, Think About It!

Thinking is the hardest work I ever did – Thomas Edison
Think with the few and speak with the many – Baltasar Gracian

Summary

We have looked at some of the basic functions of the spatial light modulator in digital projector light engines. The spatial light modulator is located at the illumination plane and needs to be uniformly illuminated to provide a uniform irradiance image on the viewing screen. The spatial light modulator is the object for the projection lens to image onto the screen with high fidelity to create and image for the viewers to see. We have seen how the spatial light modulators function in a sequential or parallel color system in a digital projector. We have come to understand what a huge value it would be if someone could create a spatial light modulator is synthesized with a light source where the modulator is the light source. Think about it!

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