Optical Short Course International

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What's "Inside The Box"?

Optics of Digital Projectors Weekly Newsletter

Liquid Crystal Displays in Digital Projectors

By Michael Pate, President, OSCI

The transmissive liquid crystal display (LCD) panel is a very competitive spatial light modulator in the digital projector market. This article takes a look at the structure of how they are put together along with some of their performance parameters and limitations. We also compare some properties of the transmissive LCD panel to the other modulator types. We also take a look at some of the industry structure and why these panels are here to stay for a while and compete with some of the new modulators technologies.

Liquid Crystal Display Panels

The transmissive LCD panels are used in about 70 percent of the digital front projectors in the 1500 screen lumen class of digital projectors and almost all of the current sub US$900 front projectors. These LCD panels typically have one panel for each of the colors red, green, and blue. A cross section of these panels is shown in Figure 1 below. We see that there is a glass window substrate on each side of the LCD panel. Each of these windows is coated with an indium tin oxide or ITO coating. ITO is an optically transparent but electrically conductive material that is vacuum deposited onto the windows just like typical antireflection coatings on optical surfaces.

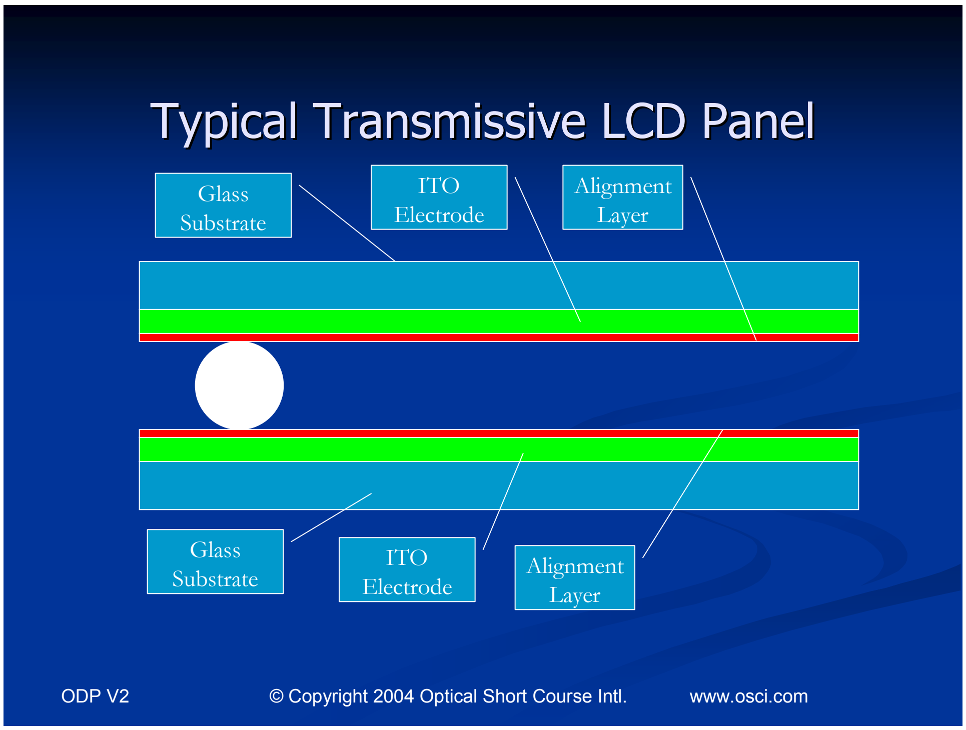

Figure 1. LCD Panel Cross Section View
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

On one side of the LCD panel the ITO is put down as one large electrode which is known as the common electrode. On the opposite side of the panel each ITO is patterned as an individual pixel. On the side with individual pixels there is also room for the row and column matrix wires so that each individual pixel can be addressed. These address lines take up valuable real estate on the panel see Figure 2. Where ever the address lines are a pixel cannot be and this causes distinct rows and columns between the pixels to be visible in the image from these projectors. This is often called the screen door effect as it has the visual appearance of viewing something through a screen.

There is an alignment layer deposited onto the ITO electrode layer for the purpose of prealigning the large molecules of the liquid crystal material. This alignment layer is often an organic layer and is deposited onto the surface and a special procedure called rubbing is performed to cause alignment grooves to appear in the surface of the alignment layer. The purpose of these surface reliefs's is to preferentially align the liquid crystal material into a particular orientation to these surface relief's. In many LCD panels these surface reliefs or grooves are aligned orthogonal to each other or at some angle depending upon the LC material, LC layer thickness, and material properties. The two halves of the LCD sandwich are precisely spaced using glass spheres, rods, or lithographically deposited structures. These spacers set the precise thickness of the LCD material within the panel.

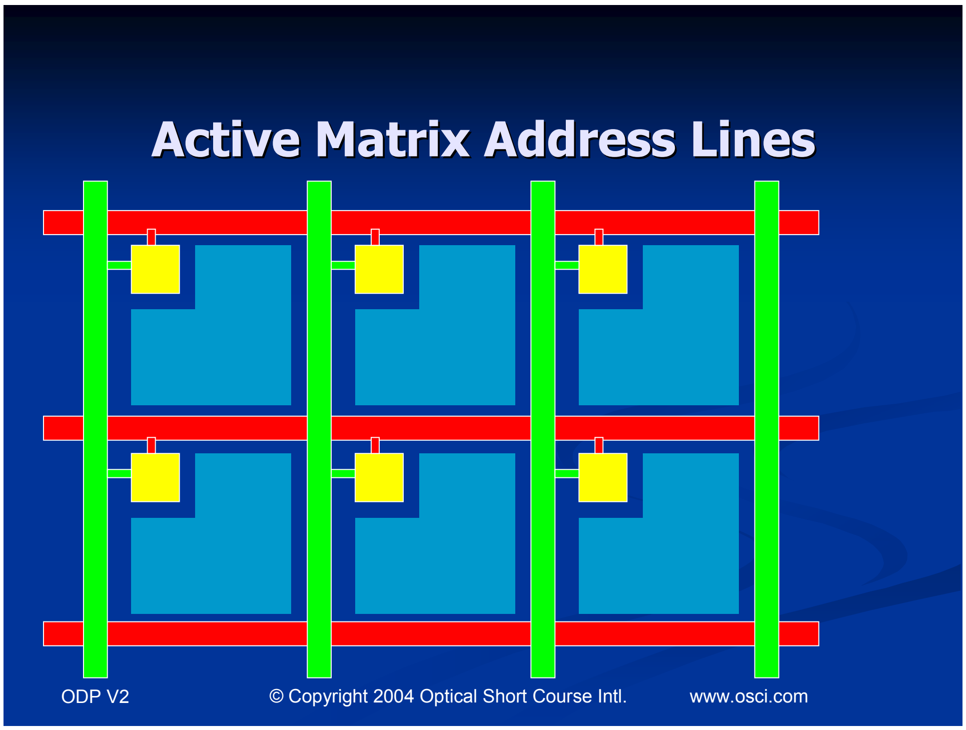

Figure 2. Active Matrix Address Lines Create Screen Door Effect
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http://www.oscintl.com/prod01.htm

The alignment layer is often the lifetime limiting item in the LCD panel sandwich. The UV photons in the blue panel are absorbed in the organic layer material and cause degradation in the lifetime and optical performance of the panel. There have been studies on this problem and how it affects lifetime and color fastness of the display. The panel manufacturers have been working hard to find a replacement for this limiting organic alignment layer. I have no doubt that a suitable replacement with a better optical lifetime performance will be found.

We can see a view of an LCD pixel in a panel in Figure 3 below. We see that on the input side of the panel that there is a linear polarizer. We also can see that if no electric field is applied to this pixel that the liquid crystal material is oriented by the alignment layers on the top and bottom windows. These two alignment layers are oriented in an orthogonal orientation with respect to each other. This makes the liquid crystal material particles rotate as they progress from the top to the bottom alignment layers. This twist in the orientation of the liquid crystal polymers is what optically interacts with the electric field of the incident linearly polarized light. The long molecules of the polymer interact and rotate the light from the top to the bottom of the LCD panel so that the e-field of the light is oriented to the analyzer and it will pass through indicating an ON state pixel. If the electric field is applied between the common and the active matrix pixel then the liquid crystal polymers are affected by the electric field and become oriented like dipoles to the positive and negative sides of the panel. If these liquid crystal polymers are oriented in the long direction then they will not interact with the incident light e-field and thus will be blocked by the analyzer.

It should be noted that the pixels can be on with no e-field applied to the pixel, as shown, or on with an e-field applied. The switching speed of LCD panels is typically in the tens of milliseconds. The optical transmission of an LCD panel is about 25%. This means that is you put in 100 units of unpolarized light you will get 25 units of polarized light out the opposite side of the panel if all of the pixels are turned on. So this accounts for optical efficiency of the polarizers and coatings, the fill factor, and absorption in the panel.

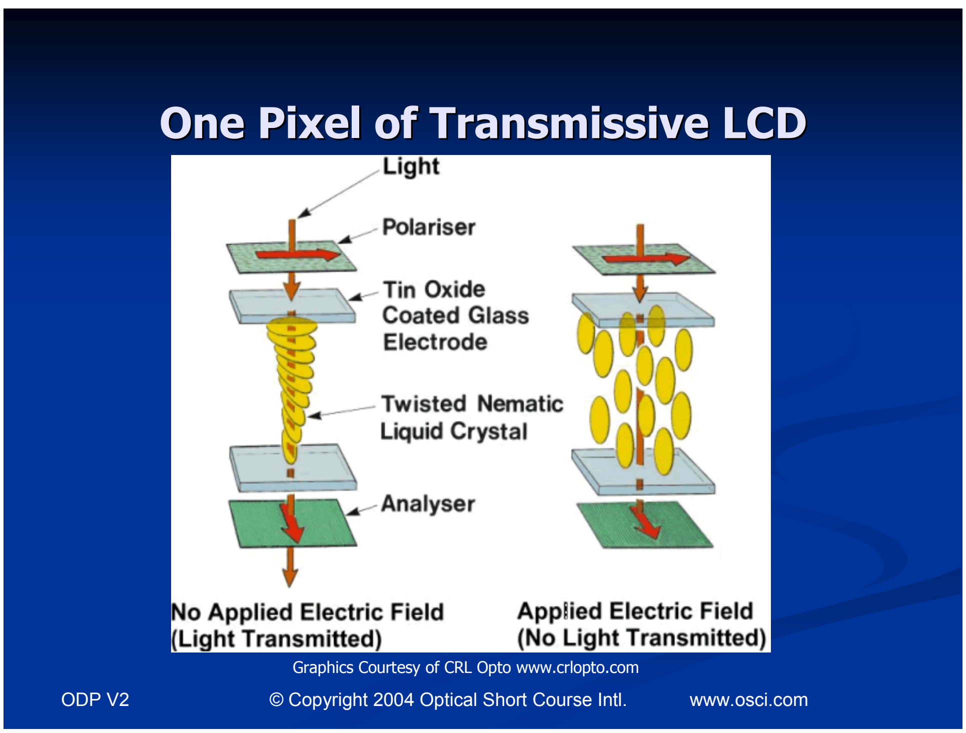

Figure 4. LCD Panel Principle of Operation
From OSCI's Optics of Digital Projectors DVD Course
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As we can see in Figure 5 below the fill factor is about 75% for transmissive LCD panels so this means that we are wasting 25% of the light due to active matrix address lines and the gate switch.

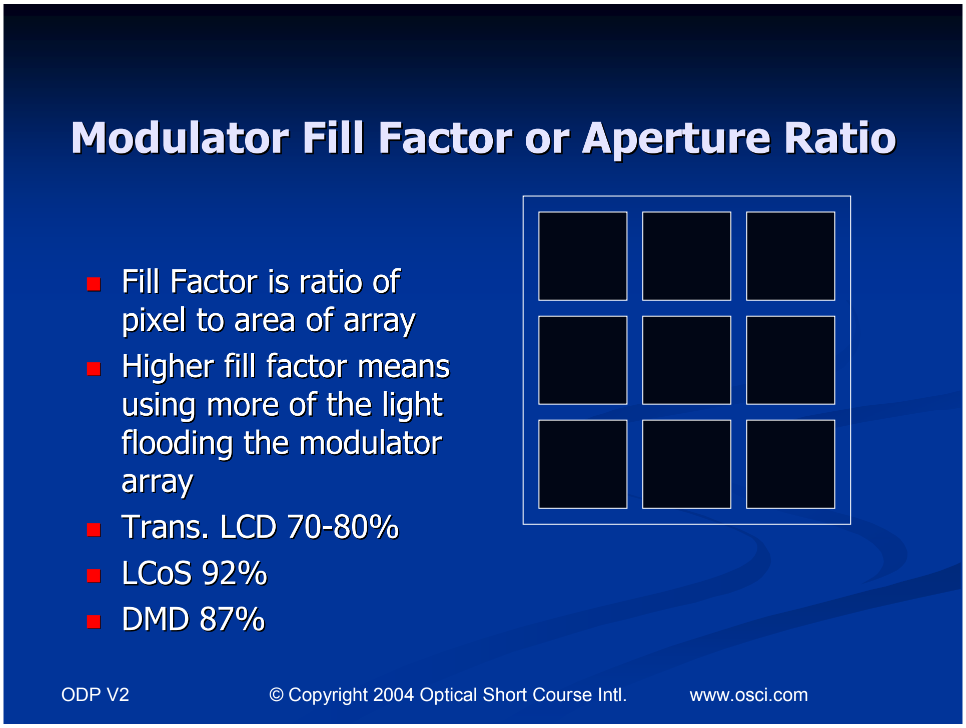

Figure 5. Modulator Fill Factor
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Transmissive LCD panel projectors are limited in the amount of optical power they can transmit in each panel. In the market we see that most transmissive LCD panel digital projectors are limited to about 3500 lumens and less, which means that there are about 1166 lumens per panel if each of the red green and blue channels had equal energy, which they don't.

I do like the fact that the transmissive LCD panel technology is leveraged with the same or similar technology as the LCD flat panel displays used in personal computers. The technology, training, personnel, capital equipment, testing, characterization, etc are all leveraged between the two similar industries. There are also two manufacturers of these panels the first is Sharp which has been doing R&D since 1982 and started production in 1990 and their competitor Seiko-Epson also manufacturer's panels. Their individual competition is a great thing for consumers and is also great to compete against the other panels' technologies such as LCoS and DLP. Finally I also like transmissive LCD panels because METI the Japanese technology ministry has declared LCD technology a long term strategic interest to Japan and their high tech oriented economy. This means that they have developed a long term technology policy towards funding and development of this technology and are serious about executing this long term technology policy.

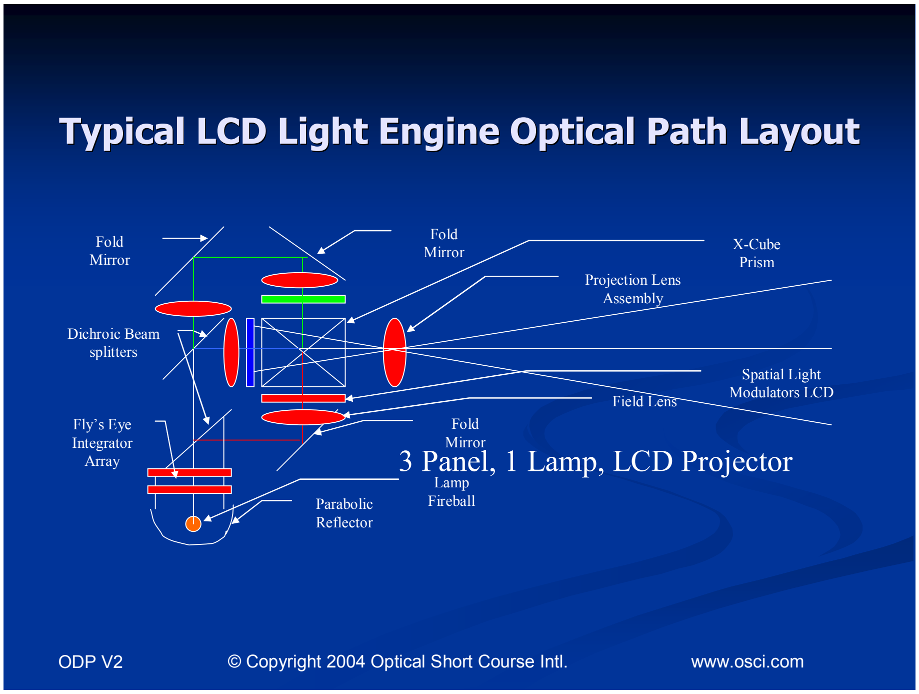

Figure 6. Parallel Color System – LCD Light Engine
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We can see how the three panels are used in this LCD light engine. Each of the three LCD panels is oriented around the X-cube combining prism. The projection lens concurrently images all three panels onto the projection screen for viewing.

Summary

We have looked at the individual parts and subsystems of digital projector light engines. We investigated the light sources and the illumination system design to properly illuminate these spatial light modulator panels. Now we have taken a look at the details of the structure of the transmissive LCD panel to understand how a pixel is formed and modulated from on to off. We have also looked at some of the operation parameters of these panels to better understand how they affect system performance. We have also looked at some of the business related parameters surrounding the LCD industry and hopefully have a better understanding of how and why this type of panel can compete well in the front projection industry segment.

Stay tuned and keep looking for your weekly dose of "In The Box" to understand the optics of digital projectors. If you enjoy increasing your knowledge about digital projector optics please tell a friend about this e-newletter, your referral is the kindest compliment we can get to show your appreciation.