Optical Short Course International

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What's "In The Box"?

Optics of Digital Projectors Weekly Newsletter

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Reflective Liquid Crystal Displays in Digital Projectors

By Michael Pate, President, OSCI

LCoS™ and D-ILA™ are one of the newest and highest resolution spatial light modulators being used today in digital light projectors. They are used with high frequency in RPTV light engines and increasingly in front projection applications. They use two of the common optical methods of optical modulation together, namely reflection and liquid crystal polarization extinction. As the competition increases and RPTV replacement continues to occur to take advantage of the HDTV programming LCoS™

and D-ILA™ will become a dominant force in the display market place. If this logical business reasoning doesn't capture your interest in this technology then let me appeal to your emotions. Go out and see one of these displays and you will be impressed.

LCoS™ and D-ILA™ History

The term liquid crystal on silicon or LCoS™ is trademarked by Brillian Corp of Tempe Arizona. The history of Brillian starts with National Semiconductor creating a spin off in 1985 called Three Five Systems. In 1997 Three Five and National Semiconductor developed a miniature flat panel display for projection. They were the first company to have combined high volume silicon fabrication and liquid crystal manufacturing together in one company. In 2000 they shipped the first LCoS™ SXGA projection light engine. In 2002 Three Five acquired the IP of Colorado Microdisplay and invests in Color Link to help solidify their IP and also to drive into near to eye displays. In 2003 Three Five decides to spin off the LCoS™ business in a new company called Brillian Corporation. In 2003 Brillian Corp. enters the RPTV market with an LCoS™ solution.

Hughes Research in 1985 invented the first liquid crystal light valve for military applications. In 1987 JVC started R&D on liquid crystal technology. Also in 1987 Hughes had developed a display that could present video and graphics. By 1992 Hughes and JVC created a joint venture to develop display technology. The joint venture developed the liquid crystal technology based ILA™ or Image Light Amplification technology which is the predecessor today's D-ILA™. In 1995 JVC had a controlling interest in the joint venture and their R&D teams in Japan by 1997 had developed the Direct Drive Image Light Amplification.

Some of the other leading companies that offer LCoS™ panels are Aurora Systems, CRL Opto, eLCOS, Sony, Hana Microdisplay Technology and Varitronix. Many of these companies are leveraging their experience and capital equipment, and personnel in the area of liquid crystal technology into the LCoS™ technology arena.

It should also be noted that several companies have abandoned the LCoS™ technology development in the last several months, after many years of R&D and investment such as Intel and Philips.

LCoS™ and D-ILA® Panels

The LCoS™ and D-ILA™ devices are liquid crystal polarization based reflective spatial light modulators. They are partially based upon liquid crystal technology and partially based upon the reflective mirror technology that we have seen in the last two week's issues of In The Box. The LCoS™ and D-ILA™ panels are illuminated and imaged on axis or normal to the panel. These reflective panels require that the illumination and imaging are on the same sides of the panel. The incident illumination is linearly polarized and split by color in the correct red, green, or blue panel. Once the linearly polarized light is incident on the panel and after traversing the liquid crystal material thickness of the device or pixel and reflecting from the metal mirror and propagating back out the LC thickness the polarization has been rotated from the incident orientation through ninety degrees. This ninety degrees rotation is one of the key methods to making the LCoS™ and D-ILA™ light engines work properly.

We need to take a look at how these panels work first and then we can come back to how they are used in a digital projector light engine. LCoS™ and D-ILA™ panels typically have small pixels on the order of 8 to 12 microns square with 0.35 to 0.4 micron gaps between the pixels. The current vintage LCoS™ panels have high resolution such as 1280 x 720, 1900 x 1080, and 1920 x 1080 pixels.

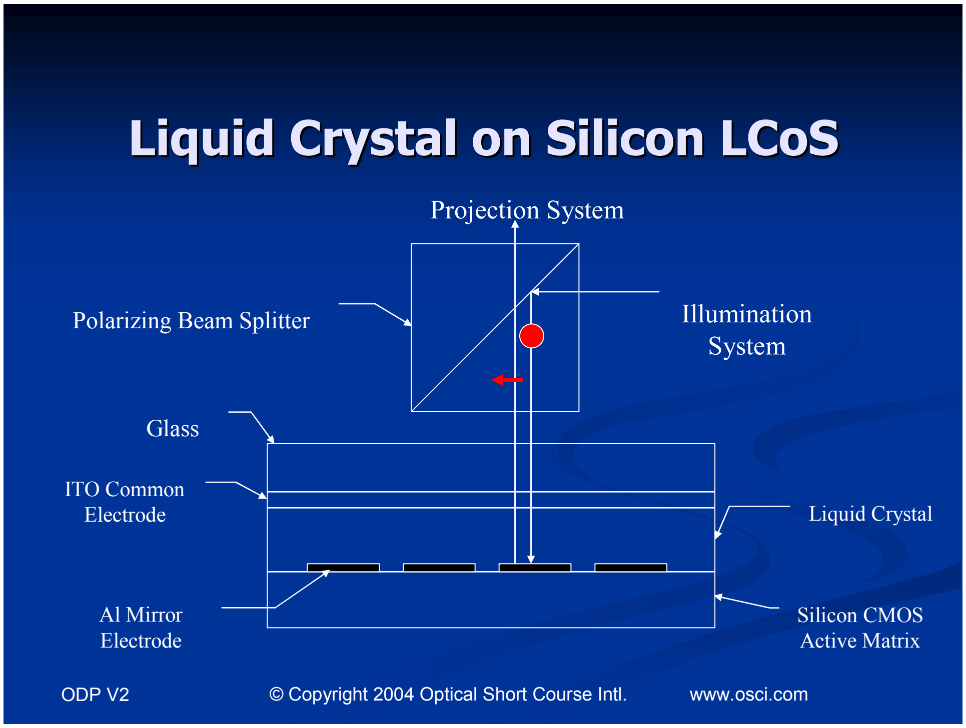

Figure 1. LCoS™ and D-ILA™ Panel Cross Section View
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

In Figure 1 we can see the cross section of an LCoS™ panels. We see the transparent glass substrate on the top of the panel sandwich. On the bottom side of the glass substrate is a coating of ITO or indium tin oxide which is optically transparent but electrically conductive material. This conductive coating becomes the common electrode in the panel. On the bottom of this electrode is the liquid crystal alignment layer. Then comes the liquid crystal material which is about one to three microns thick in most LCoS™ panels. Next is the liquid crystal alignment layer and then the individual pixel electrodes made from aluminum which are reflective. Below the aluminum mirrors are the switches and matrix communication busses to activate the individual pixel mirror electrodes. The switches and communication channels are built based upon CMOS technology on the silicon wafer which serves as the substrate for the whole panel.

If it is not clear yet a pixel is activated when there is a voltage placed between the common electrode and an individual pixel electrode which is also the aluminum mirror. From a polarization point of view we have linear polarization coming from the polarizing beam splitter PBS and it passes through the liquid crystal material on the way into the mirror and it receives a 90 degree phase shift. After reflection from the mirror the electromagnetic wave will receive another 90 degree phase shift and thus will exit the panel with a total of pi or 180 degrees phase shift. This phase shift corresponds to a 90 rotated about the optical axis and thus will reflect off the PBS and propagate towards the projection lens.

There are several different types of liquid crystal modes that can be used in displays. In the LCD panels we learned about several weeks ago in In The Box we learned that they use twisted nemantic or TN mode liquid crystal material. In the LCoS™ panels the two dominant liquid crystal material modes that are being used are the vertically aligned nemantic or VAN and the ferro electric liquid crystal mode or FLC.

Liquid Crystal Modes by Vendor
D-ILA uses VAN
Brillian uses New Mode – Patent Pending
CRL Opto uses FLC
eLCOS uses VAN
Aurora Systems uses VAN
Hana Microdisplay Technology uses TN and VAN

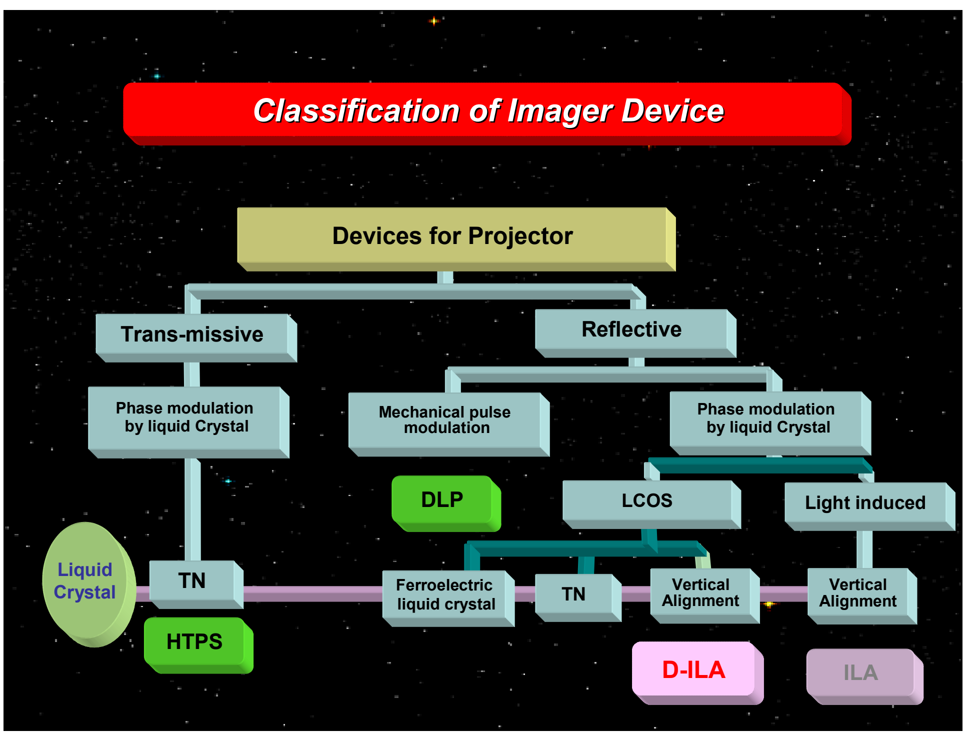

Figure 2. Spatial Light Modulator Technology Diagram
Graphics Courtesy of JVC http://www.jvc.com

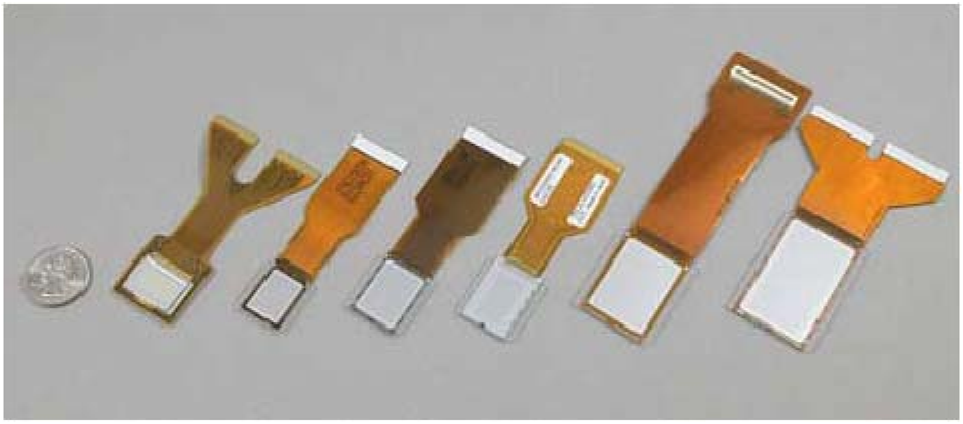

Figure 3. D-ILA Modulators of various resolutions
Photo Courtesy of JVC http://www.jvc.com/pro

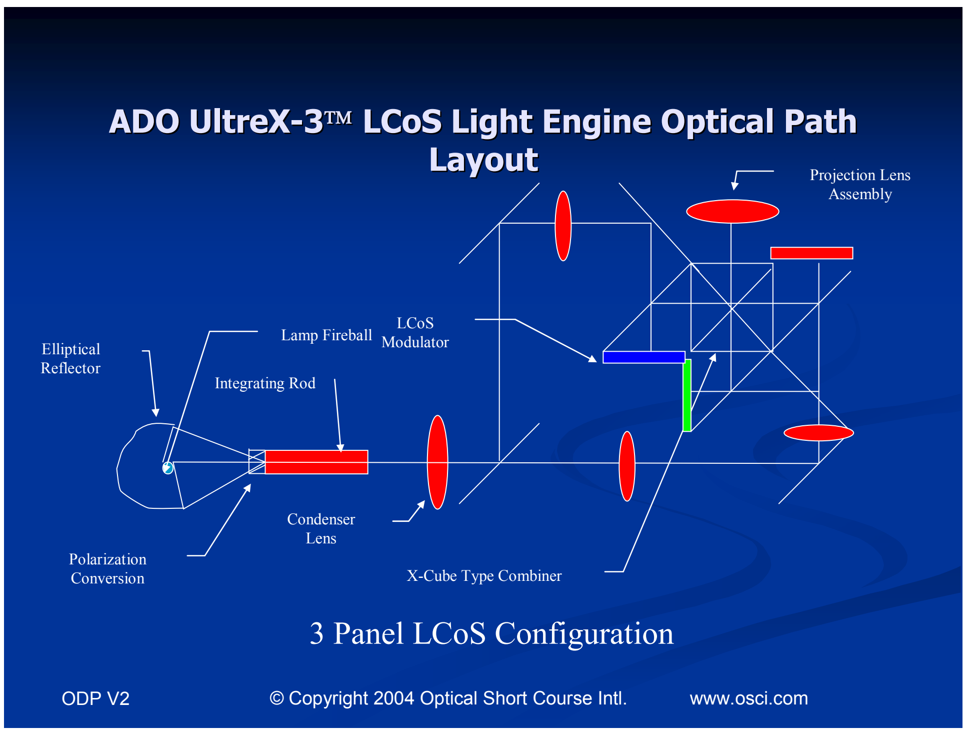

Figure 4. Single Panel DMD Light Engine Layout
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

Other D-ILA™ and LCoS™ System Design Features

As we can see in Figure 5 below the fill factor is about 92% for D-ILA™ and LCoS™ panels so this means that we are wasting 7% of the light due to the mirror spacing. D-ILA™ and LCoS™ lead the way in having the highest fill factor of any of the digital projection technologies. Having a high fill factor means that more of the illumination is used that falls on the panel and less goes to diffraction, scattered light, and absorbed energy to heat the modulator. A high fill factor also means less of a screen door effect can be seen in a projected image. The screen door effect is seen when the image of the panel is magnified or the viewer is very close to the screen and the inter pixel lines can be clearly seen in the image. It is give this name as it appears one is looking at the projected image while standing near a window screen or screen door.

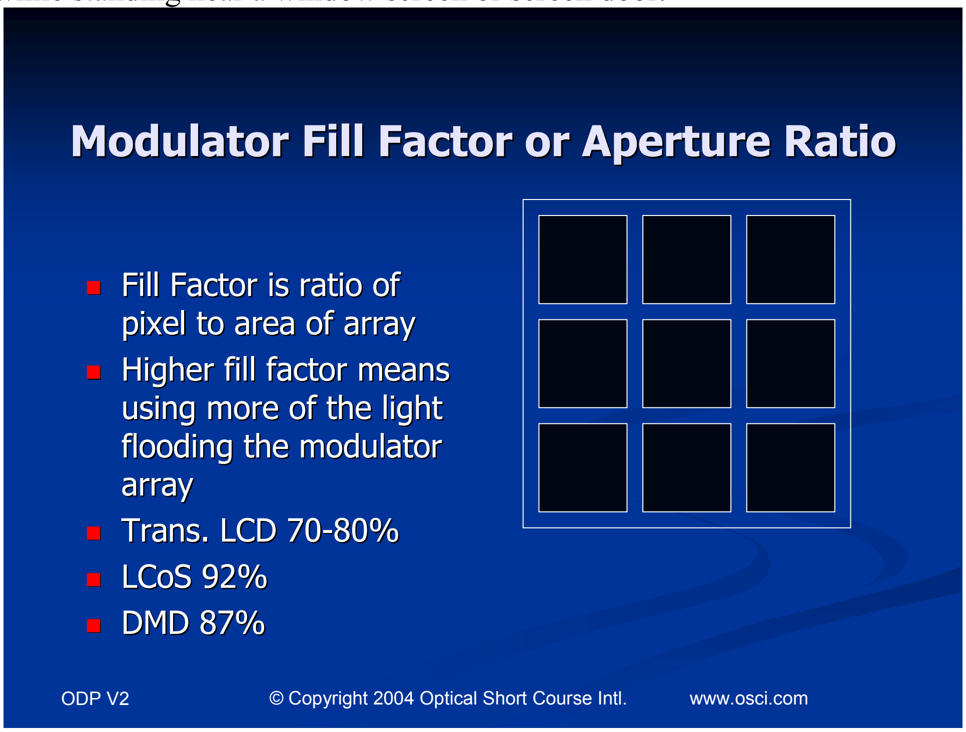

Figure 5. Modulator Fill Factor
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

The panel optical efficiency is defined as putting 100 units of unpolarized light into a modulator and if all the pixels are turned full on how much light is reflected or transmitted by the panel. This will include reflection and transmission of the modulator pixels, window anti-reflection coatings, glass absorption, scatter, diffraction, etc; basically all of the optical affects are taken into account. The DMD™ has an optical efficiency of about 60% where LCoS at 35% is much lower.

The DMD™ panels are able to put the most screen lumens per panel of the three technologies. In the market we can find DMD™ projectors putting out 4000 screen lumens per panel in the large venue three chip digital projectors. The closest competitor in the LCoS™ or D-ILA™ arena is the D-ILA™ technology. The D-ILA™ technology has the capability in their large venue projectors to put 2333 and 1667 screen lumens per panel through their system. One of the reasons according to JVC is because of their advanced optically stable inorganic alignment layer technology.
LCD and LCoS™ seem to have a problem in their organic alignment layers especially with the absorption of the UV and blue photons. These higher energy photons seem to attack the polyamide alignment layer and cause optical damage and color stability

problems with the panels. Many of the LCoS™ companies are working on solving this problem with future alignment layer development efforts, but because life testing takes so long it will be a while before we see them willing to sign up for higher lumens per panel lifetime warranties. This is a similar story to what we have seen in the bulb lifetime arena.

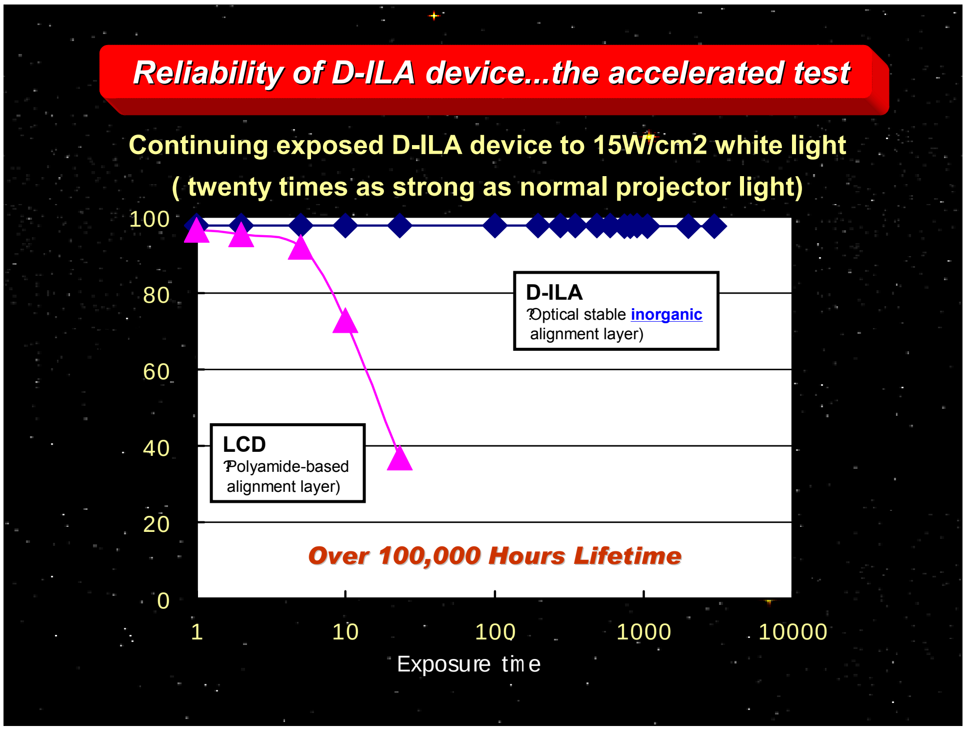

Figure 6. D-ILA high optical power density testing of panels
Graphics Courtesy of JVC http://www.jvc.com

Figure 7 Brillian LCoS™ RPTV

Figure 8 JVC D-ILA™ RPTV

Summary and Concerns of D-ILA and LCoS™ Technology

Cost, Confidence, and Competition. I am very bullish on this technology for several reasons. I think that there is quite a bit of competition among the various panel developers and manufacturers. I also like the fact that these manufacturers can leverage LCD technology, capital equipment, training, and experience into LCoS™ manufacturing. I think the exit by Philips and Intel is a two edged opportunity or problem depending upon your personality. The dual exit hurt the confidence of technology managers worldwide and made them question LCoS™ technologies viability. The exit also hurt some of the smaller players that were supporting these large giants. On the positive side companies like Brillian, JVC, and Sony must be doing back flips of joy with the early exit of these two competitors and drooling over the reduced competition and implied larger market shares.

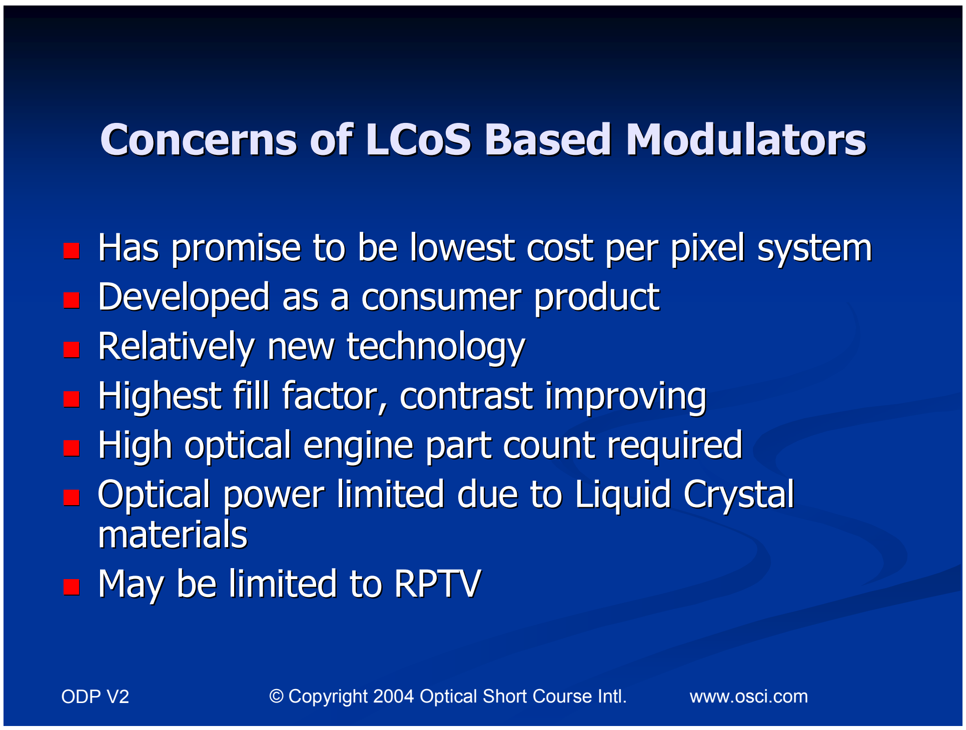

Figure 8. LCoS Modulator Technology Review
From OSCI's Optics of Digital Projectors DVD Course
http://www.oscintl.com/prod01.htm

The cost per panel of LCoS™ is not yet to the point of reaching the mass consumer market but the increasing volumes will drive this price down into the range along with the competition among vendors. D-ILA™ and LCoS™ technologies have a strong lead in the number of pixels per panel, at 1900 x 1200 and it will only get higher as the semiconductor industry continues on its Moore's Law feature size decreases. If you haven't seen an LCoS™ or D-ILA™ display, get off the couch and go check one out for yourself. Oh Yea, leave your check book and credit cards at home, because you will want one soon. Let me know which is your favorite.

D-ILA™ is a Registered Trademark of JVC Corp.
LCoS™ is a Registered Trademark of Brillian Corp.

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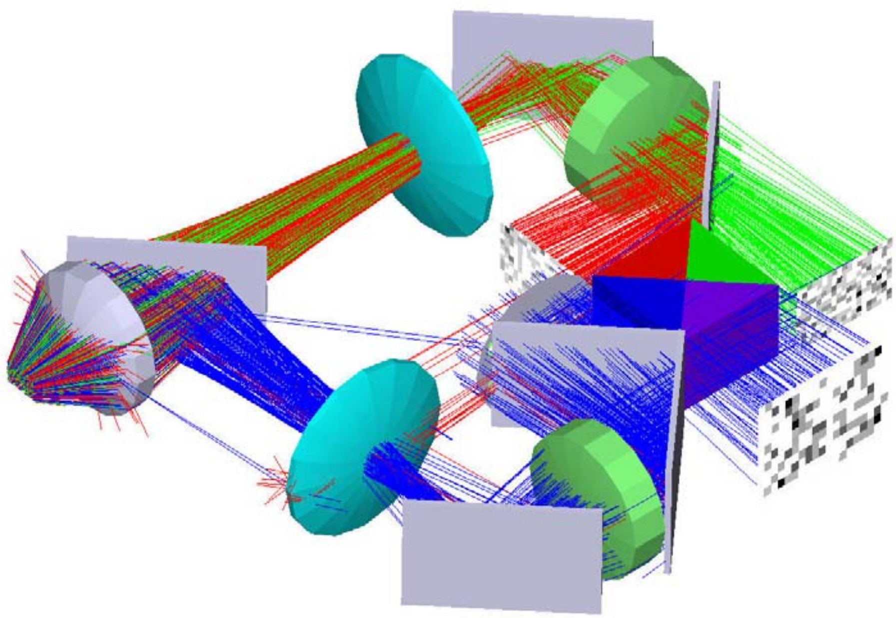

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