Optical Short Course International

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In The Box

Optics of Digital Projectors Weekly eNewsletter

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Who Needs True Color in Their Digitally Projected Images?

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Every business and organization who markets products, services, and their brand through the use of common visual media methods needs to project true colors. Like your business.

Can you imagine projecting the Coca-Cola brand image at a large event like the Super Bowl or World Cup and having the Coke red looking like a citrus orange color? You just confused 100 million customers by souring the red brand with a false color orange image, a high leverage, high visibility mistake. Sure you gain you legendary fame in the marketing field as the false color fool of Coke, or worse are dubbed "citrus boy" by your cynical admirers. Of course you might get serendipitously promoted for your chromatic genius if you happened to let this mistake happen at the Orange Bowl college football halftime show.

Picture an architect or interior designer at the crucial presentation of their creative work to their #1 customer after months of creative labor and painstaking color selection and balance. This happens thousands of times every day worldwide. They plug their laptop into the roof mounted projector in the customer's conference room and shazaaam! On the opening slide of their master piece they are suddenly hit with chromatic fever. Their eyeballs twist and contort into a variety of solid geometric shapes in order to shake their retinas awake from their color atrophy. Their stomach knots up because their months of hard work have just been color contorted to the Munsell color chart from hell. Next their complexion runs the whole color range of the spectrum locus of the C.I.E. 1931 chromaticity diagram and stops at bright red. Finally, sweat fills their forehead like they just finished the Boston marathon, as their passionate creative work has been chromatically distorted.

How about an animator at Pixar who is developing a scene for their next animated movie like The Incredibles. After working for weeks to design the characters movements and body language and then place them into the correct background scene you want to show your work to the technical directors. You move your animated creations from your workstation to the projector in the preview room and wham your colors are all screwed up.

These color scenarios happen every day to designers who make their living by the creative color schemes that they design for their customers and clients. This issue of In The Box enewsletter was created to let you know that we feel your pain and would like to help you understand some of the limitations and capabilities of current digital projector color technology. This issue and the next several will deal specifically with color in digital projectors. We hope you find them informative.

Who needs true color? You do!

A short list of the true color critical industries and functions are listed below:

- Digital Artists
- Computer Animators
- Digital Cinema
- Photographers – Film, Digital
- Printers – Offset Inkjet, Digital
- Scanned Photograph Agency
- Stock Photography
- Brand Marketing of Corporations
- Architects – Residential, Industrial
- Interior Designers
- Illustrators
- Industrial Designers
- Advertising Agencies – Print/Web
- Textile Design & Mfg.
- Clothing Designers
- Digital Product Catalogs – Print/Web

These types of professionals cannot and will not tolerate false colors in the image projections of their creative works. Colors have been used as distinguishing marks in trademarks issued by the US Patent and Trademark Office. Color can be creatively used to direct the attention, convey a mood, symbolize emotions, and create mental states. Color is simply a powerful marketing tool that can visually stimulate psychological affects. True colors and mixtures of colors can accurately create the desired affect. False colors create visual and psychological confusion and unwanted reactions and perceptions in the viewer.

How can we describe the True Colors we <u>Must</u> have and <u>Need</u>?

An international organization called C.I.E. (Commission Internationale de l'Eclairage) developed a quantitative method to describe color precisely on a two dimensional orthogonal XY position chart.

The chromaticity diagram gives us a precise method to quantify the exact color we must have and need for our visual displays, by giving an x and y coordinate. For example x = 0.33 and y = 0.1 gives us a purple. This is more precise than saying "Give me a purple towards violet and with a medium saturation".

C.I.E. 1931 Chromaticity Diagram in x y Color Space

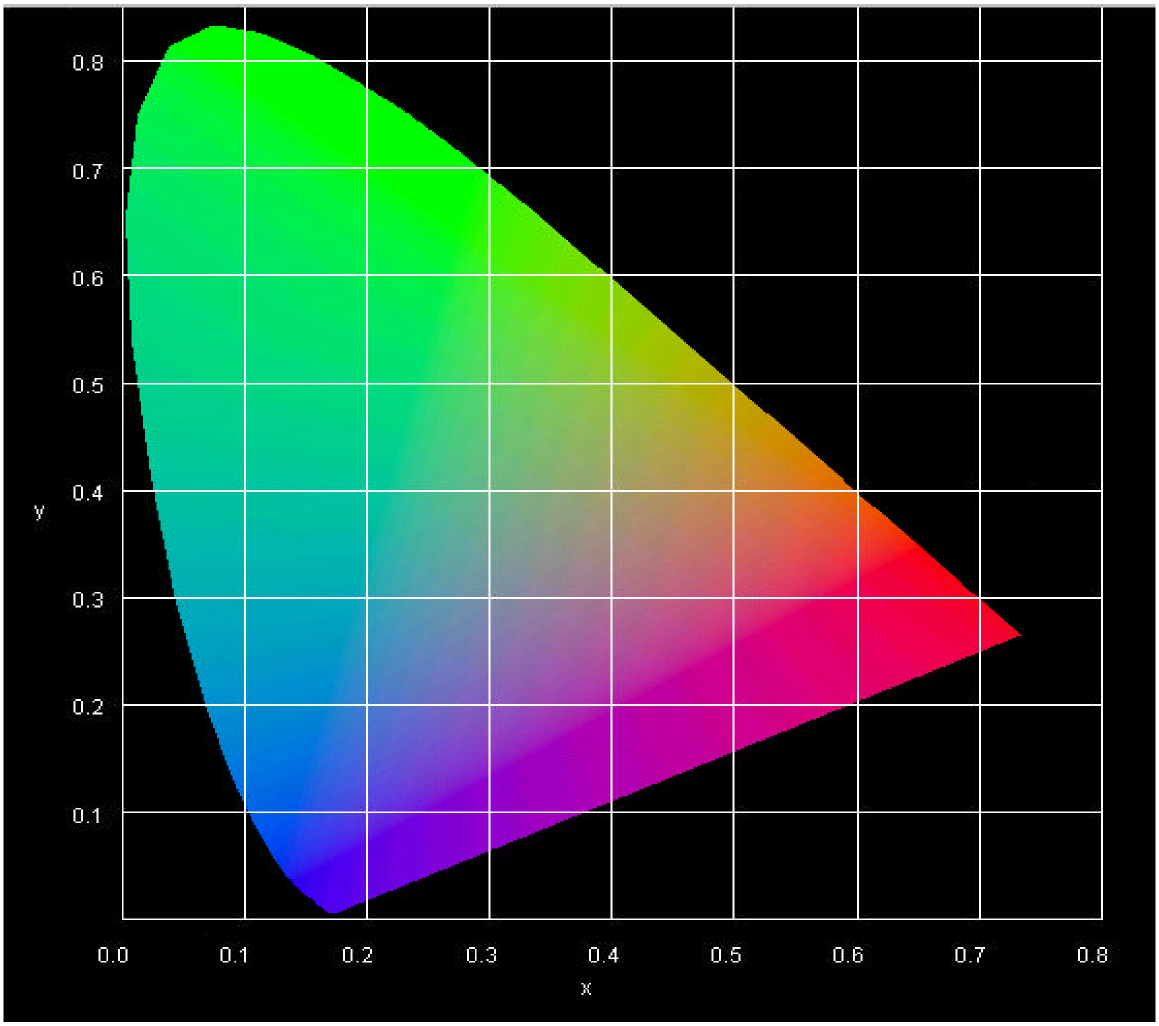

Figure 1. C.I.E. 1931 Chromaticity Diagram

What Colors in the C.I.E. Chromaticity Diagram Can Digital Projectors Display?

The current vintage of digital projectors can only display a small limited percentage of the total available color space in the chromaticity diagram. A simple method to quantitatively compare the color gamut of humans to displays is to compare the area of their color gamuts. The color gamut of the typical human observer is the area of the

Current Vintage Digital Projectors Have Ability (sic) To Display ~25% of Human Observer Color Gamut

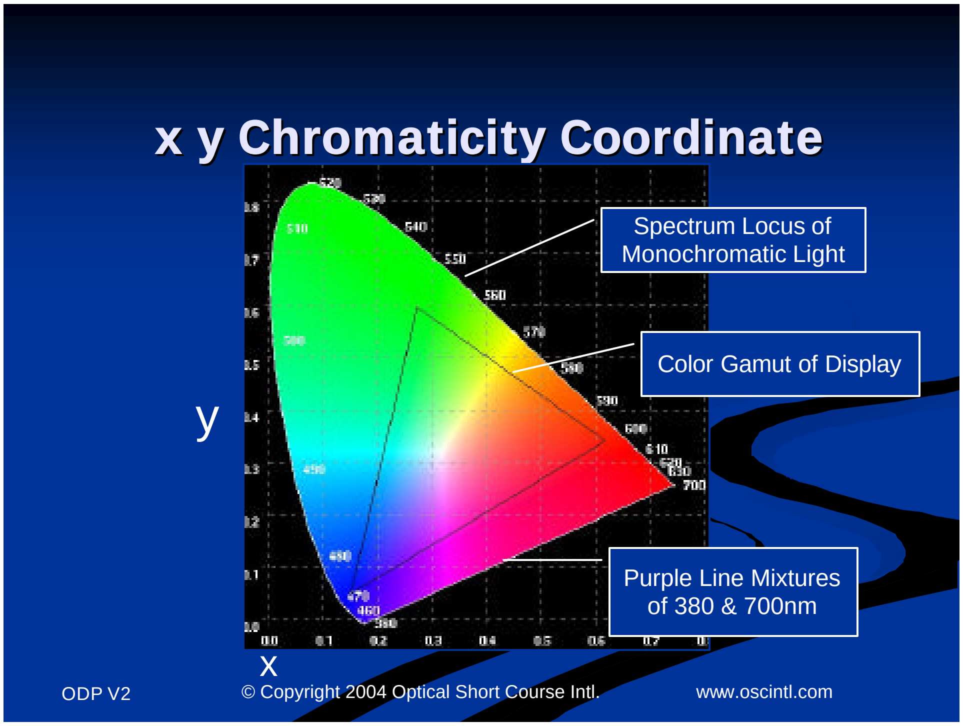

Figure 2. Color Gamut Comparison of Human Eye and Digital Projector
Graphics from our newest DVD course: Color In Digital Projectors
http://www.oscintl.com/prod03.htm

in the chromaticity diagram of Figure 2. This area is called the color gamut of the observer and represents all of the colors that the standard human observer can see if these colors are present in an image. The smaller triangle shown in Figure 2, is the color gamut of a current vintage digital projector. The vertices of the triangle are where the red, green, and blue primary colors are located. In general a display device can display any color within its color gamut or the triangle above by mixing various magnitudes of each of the three primary colors.

We can compare current vintage digital projectors by calculating the area of their color gamut, which is the area of the triangle in Figure 2. The area of the display device can be related to the area or color gamut of the standard human observer. A comparison of the color gamut areas from Figure 2 shows that the current vintage digital projector technology can only display about 25% of the visible colors that one can see with the human eye.

If we try to display a red it will look orange, "citrus boy"! If we want to display a nice purple it will look unsaturated. A nice south pacific white sand beach scene cannot display the true bluish green tropical ocean color. The nice deep dark green of your favorite golf course will look yellowish.

This is certainly not the position we want to be in to display the important creative images of our critical project or hard earned colorful company brand.

What parts of the digital projectors limit the color gamut to only 25% of the standard viewer?

The color gamut of a digital projector depends upon the interplay of a large number of the components in the image color chain. We will go into the details of each component in the image color chain in this paper we will list them to give a view of the complexity of the true color objective in digital projectors.

- Digital Image Color Content
- Light Source
- Color Filters in Color Wheel
- Optical System Spectral Transmission
- Projection Image
- Projection Screen Spectral Transmission/Reflection
- Viewing Environment
- Human Visual System

The digital image color content typically starts our as a set of RGB values that range from 0 to 255 counts of color for each of the red, green, and blue colors that make up one pixel in the digital still image or video. The front end color processing chips in a digital projector may have to perform some color processing to change the original digital content colors and remap them to the display color. If the display cannot display a certain color or range of colors then that color will be remapped to a color that the display can present to the viewer. This is one area where untrue colors can come from.

There are several types of light sources used in digital projector light engines and they are mercury, xenon, and LED sources. Each of these light sources has a different amount of power in each of the wavelengths or colors and therefore has a different ability to display true colors. If we look at the power spectral distribution of these lamps we will see the distribution of power in each of the colors.

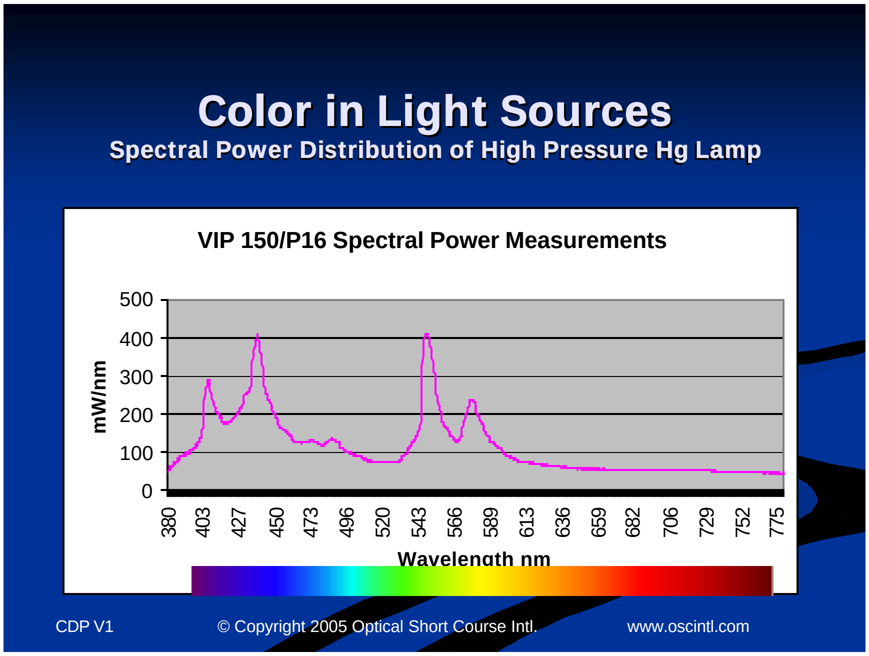

Figure 3. Spectral Power Distribution of Mercury Lamp
Graphics from our DVD course: Optics of Digital Projectors
http://www.oscintl.com/prod01.htm

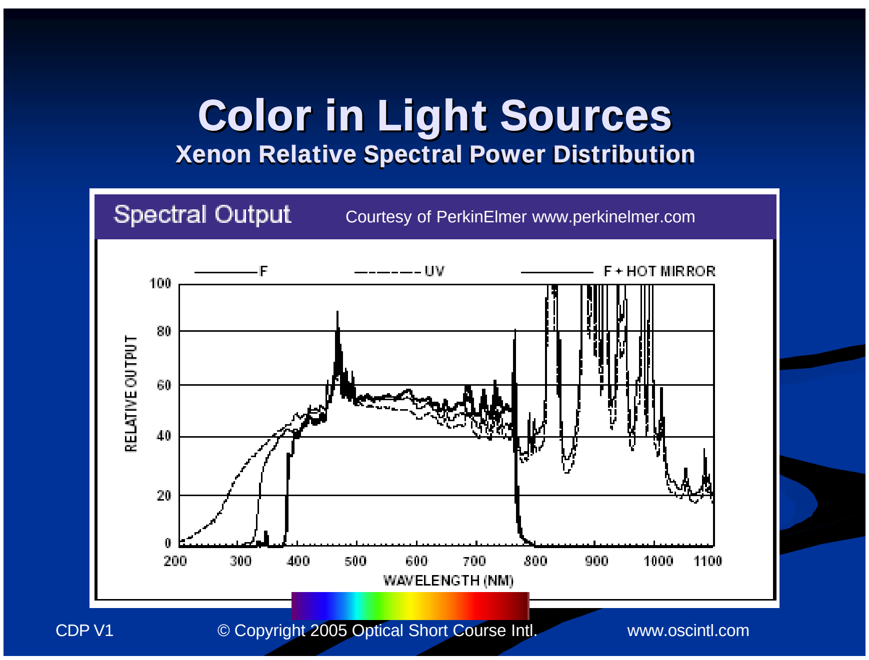

Figure 4. Spectral Power Distribution of Xenon Lamp
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What we can see by comparing these two different types of lamps from a color point of view is that the mercury lamp has power spikes of color in the blue, and green. There are no power spikes of color in the red with mercury lamps. In the xenon lamps we can see that the spectral power distribution is even throughout the visible spectrum with a spike in the blue. Relative to the mercury lamp we can pick the best color transmission bands for our color filter wheel because there is a relatively equal amount of power in each of the red, green, and blue regions of the xenon lamps. With the mercury lamps our choices of where to place our color filter transmission bands is limited to using these color spikes if we want to get the light energy that exists in them. LED sources used in digital projectors have a red, green, and blue central color but their spectral bandwidth ranges from about 20 to 35nm depending upon the color. The relative amounts of power available from current high power LED's also varies by color so we have to be careful about mixing RGB LED's to ensure that we can achieve the correct correlated color temperature when we wish to display white.

The color filter segments of red, green, blue, dark green, and white which make up a color filter wheel have their own spectral band pass transmission values. The width of the spectral band determines where the chromaticity value lies for that particular primary color. Recall that a monochromatic color or laser line width will lie on the spectrum locus of the CIE chromaticity diagram, it is the "D" shape of the diagram where pure colors lie. If we chose a narrow band width to get our green color for example, we would find out that we could not pass much power in the narrow bandwidth of that color filter. So there is a system design tradeoff between narrow band width and spectral power transmission. Typical RGB color filters have a half power bandwidth of between 75 and 150nm, they are chosen during a systems tradeoff analysis.

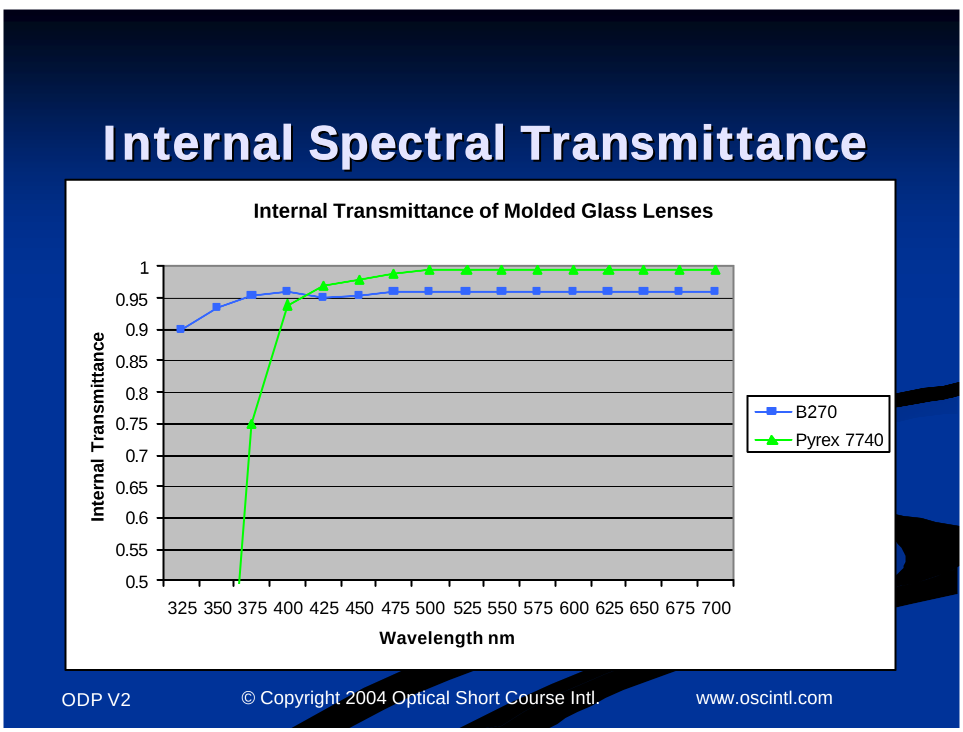

Figure 5. Internal Spectral Transmission of Glass Lens Elements
Graphics from our newest DVD course: Color In Digital Projectors
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We can see in the internal glass transmission graph above that different glass materials will transmit the color in the spectrum differently so we must pay attention to the optical glasses that are chosen for our lenses and prisms in the digital projector light engine.

We must also pay attention to the optical coating that are put onto the mirrors and lenses and how they behave in optical transmission of the color spectrum from the lamp. For example we can see that the spectral transmission of the Unaxis Silv-FLEX mirror has a high reflection versus angle of incidence. Similar transmission graphs are available for antireflection coatings on lenses which are used in the illumination system and projection lenses.

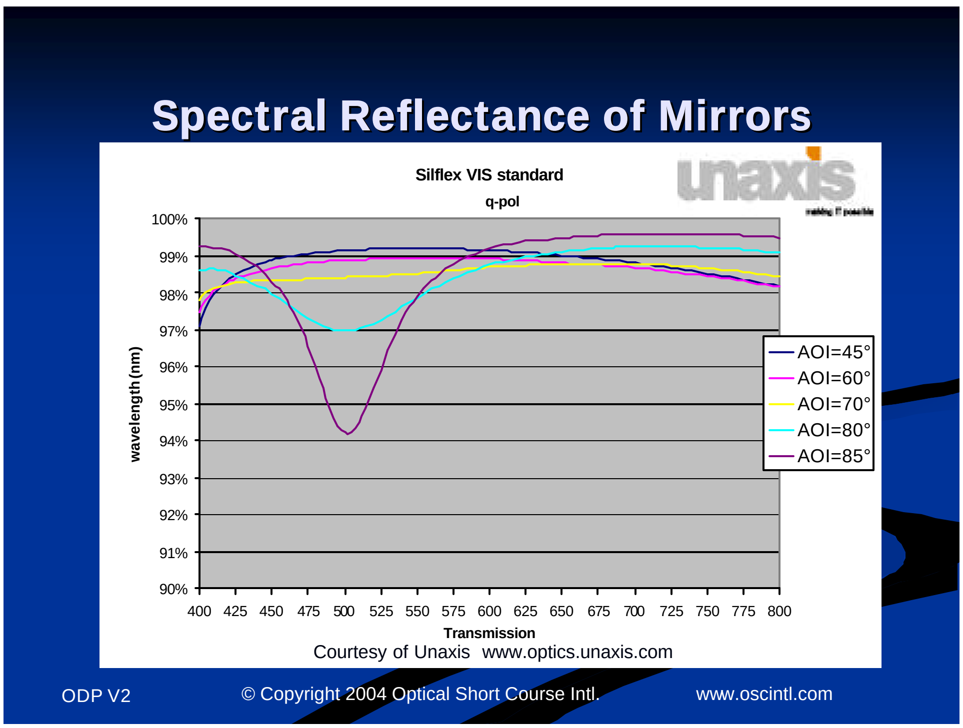

Figure 6. Unaxis Silflex VIS High Reflection Coating Graph
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Some of the other system design parameters that affect our ability to display true color with digital projectors include the front or rear projection screen. Just like the lenses and mirrors with their spectral transmission and reflection the projection screens will have a variation in performance with wavelength. These color system components must be characterized as part of the overall color train so that we can display true colors for the viewers.

The projector instrument with the digital source media is often looked at as the whole color system. Along with the projection screen the viewing environment and the viewing instrument must also be accounted for in the total color system. These last two system components the viewing environment is very important. What I call illumination noise is often present in different viewing environments that digital projectors are used within. Often a conference room or home theater will have window with some type of window treatment. There is also the room furniture including the walls, ceiling, and floor covering that will diffusely reflect the ambient light from the sun or room lights onto the screen. If for example you have a red carpet and a white or light grey conference table in the viewing room these will reflect light of their own color onto the screen as illumination noise. This illumination noise with its red and grey colors will mix with the digital projector color being shown from the instrument and alter the colors which are intended to be viewed from the screen.

Finally the human eye is the viewing instrument and it has its own performance characteristics that we must understand to optimize the true color viewing from a digital source media through a digital projector to our brain. Happy viewing.

OSCI performs technical consulting to help clients with digital projection systems reach their full color potential. We leverage our alliances with the leading companies in the display industry to achieve these objectives for our clients. We also educate our clients about color in digital projectors with our DVD courses Optics of Digital Projectors and our newest course Color in Digital Projectors. See our website for more details: http://www.oscintl.com

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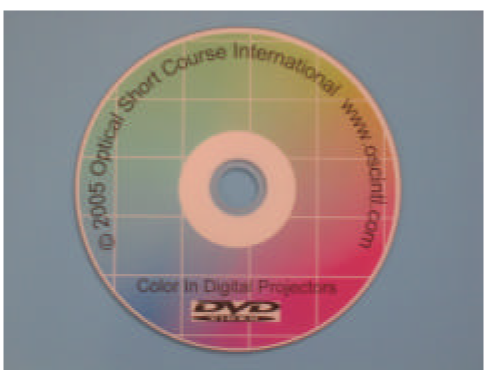

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