Optical Short Course International

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What's "Inside The Box"?

Optics of Digital Projectors Weekly Newsletter

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Projection Condenser Type Illumination Systems

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In last weeks issue of In The Box we learned about the history of illumination systems and some of the different types of illumination systems. This week we will take a deeper look at the projection condenser or sometimes called special illumination system. This type of illumination system as its name implies are often used in projection systems and also in lithography systems. Like all types of illumination systems the projection condenser type illumination system has a source, condenser optics, an object at the illumination plane, and a projection lens with an entrance pupil diameter and location.

The function of this illumination system is to capture light from the source and provide uniform illumination at the illumination plane and fill the entrance pupil of the projection lens with an image of the source.

Overview of Projection Condenser Illumination System

The projection condenser illumination system layout is shown in Figure 1 below. We can see the light source on the left represented by a coiled filament. The light from the source is collected by a condenser lens assembly and is imaged into the projection lens entrance pupil. The object is shown close to the condenser lens assembly. In practice the object is located between the condenser lens assembly and the projection lens entrance pupil. It is often located closer to the condenser lens because the illumination is more uniform at this location than closer to the projection lens entrance pupil. There are often opto-mechanical constraints like fold mirrors, mechanical or optical beam interferences that keep one from locating the object plane in the most desirable location.

The size of the field at the illumination plane is controlled by the projection lens entrance pupil diameter. The degree of coherence is again controlled by the condenser lens iris diaphragm. The benefits of the projection condenser are that the object plane or illumination plane is uniformly illuminated and it is a shorter optical path between light source and projection lens assembly. The projection condenser illumination system is often used in digital projector light engines.

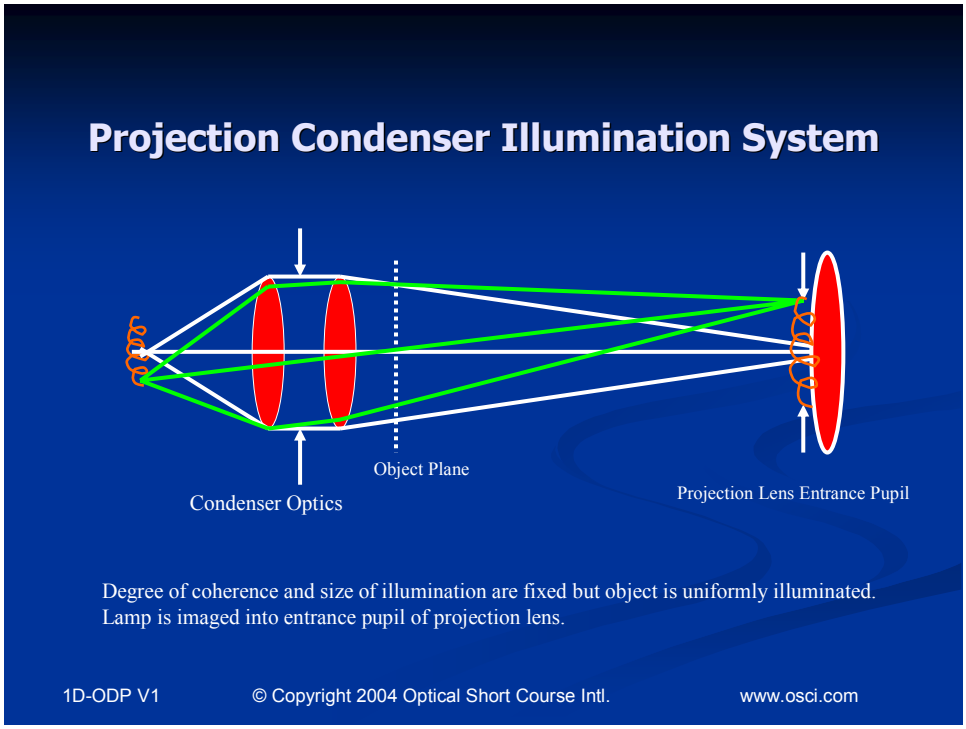

Figure 1. Projection Condenser Illumination System Layout

This general overview gives us an idea of what a projection condenser illumination system looks like why don't we take a closer and more specific look at a digital projector light engine layout using a projection condenser illumination system.

Light Source

Digital projectors use mercury and xenon arc lamps as the dominant light source currently for front projection systems. In the arc lamps there is a plasma arc or fire ball which emits the light we want to capture and eventually get it to the screen for viewing. These arc lamp sources are designed into elliptical or parabolic mirrors with the fireball at one foci of the mirror and we get focused light or collimated light respectively. Almost all single panel DMD light engines use an elliptical reflector with the fire ball at one foci and the entrance of the integrating rod at the second focus as shown in Figure 2.

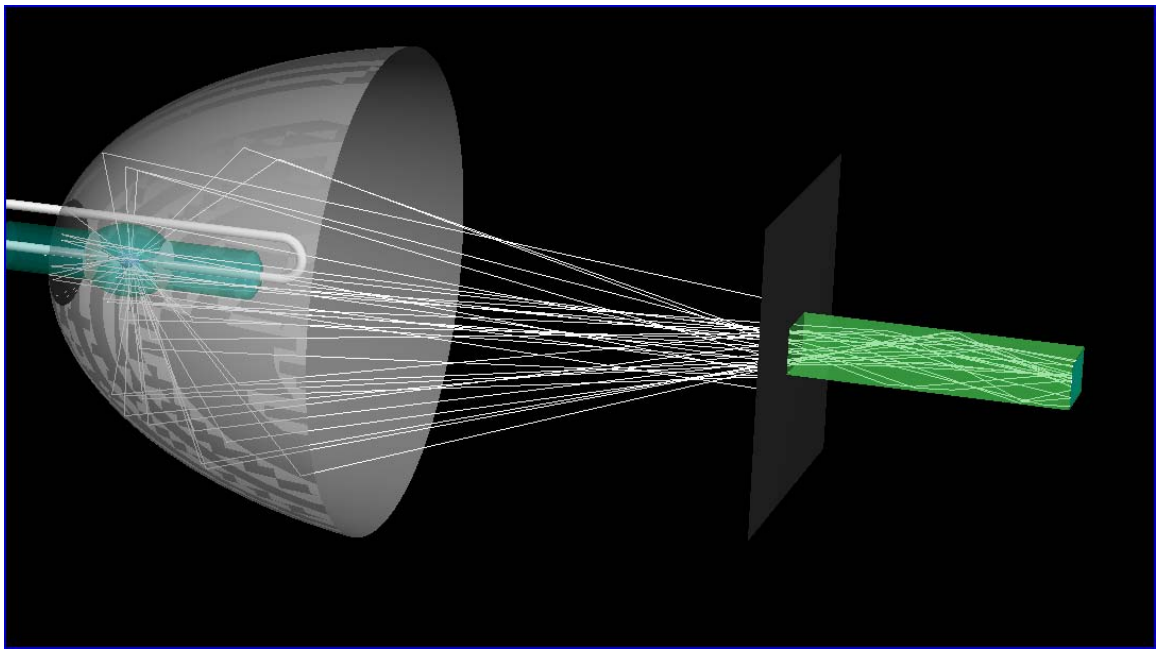

Figure 2. Elliptical Reflector: Plasma and Integrating Rod at two foci of ellipse

Projection Condenser Illumination System

The lamp assembly and the integrating rod are certainly part of the illumination system and digital projector light engine. If we study the projection condenser illumination system in Figure 1 again we will consider the light source or filament to be the exit surface of the integrating rod. In this digital projector light engine illumination system design the exit of the integrating rod will be imaged into the entrance pupil of the projection lens. We will have the condenser lens assembly capture the light out of the integrating rod exit surface and "optically plumb" it down the optical axis towards the illumination plane where the spatial light modulator or DMD lies and also finally into the entrance pupil of the projection lens.

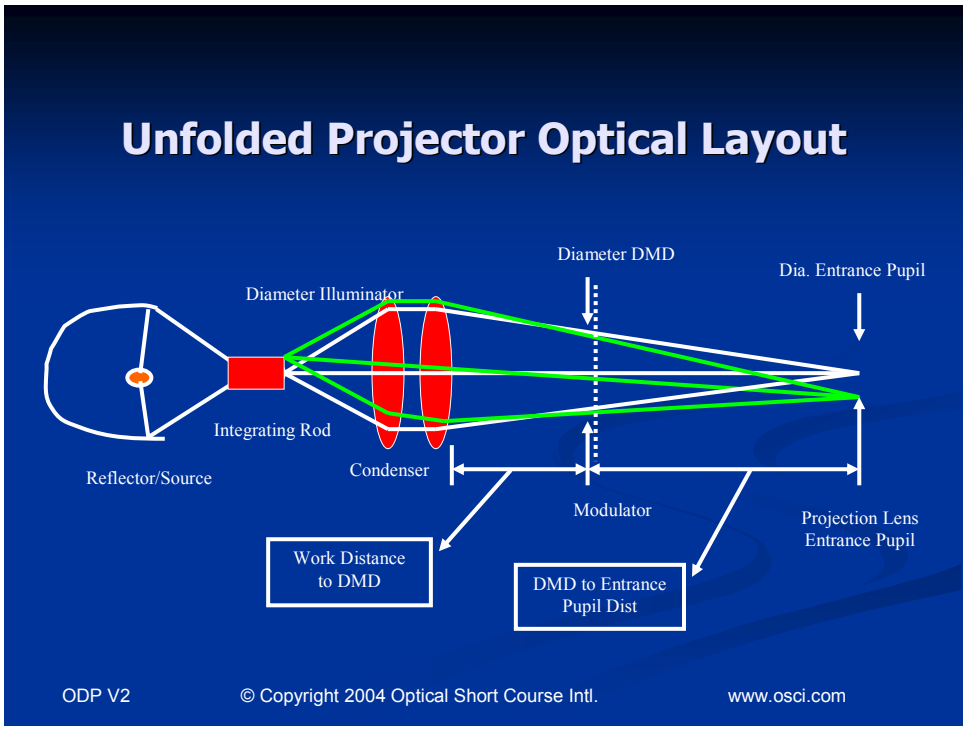

Figure 3. Digital Projector Light Engine Illumination System Layout

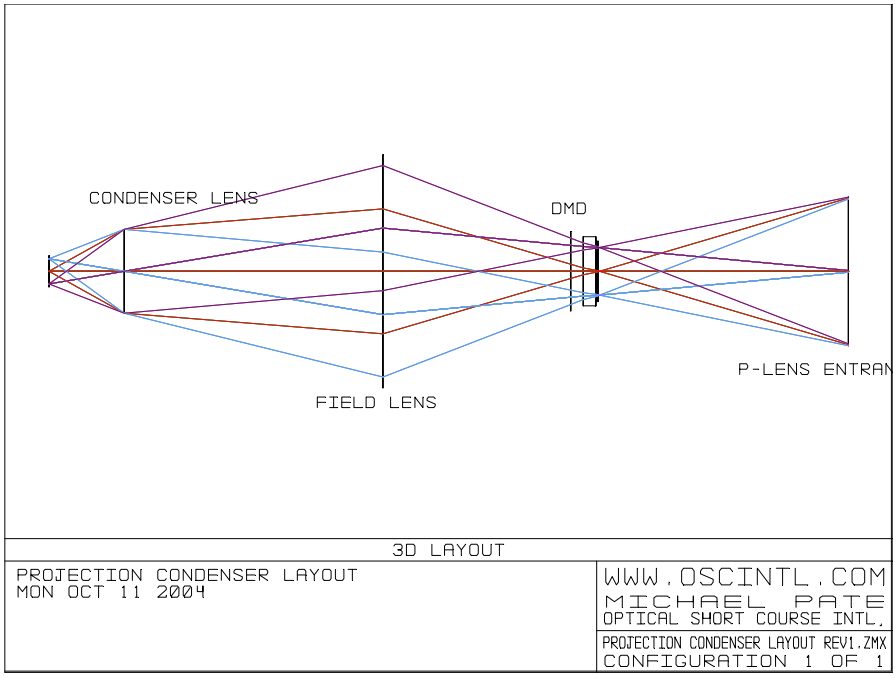

Figure 4. Projection Condenser Layout with Zemax

We can see an illumination system layout in Figure 4 using what are called perfect lenses shown in the figure as vertical lines that refract the rays passing through the lenses. On the far left we have the exit surface of the integrating rod and we can see that the perfect condenser lens captures this light and condenses it down towards the field lens. The field

lens which is also shown as a perfect lens images this light from the condenser lens down onto the DMD and then on towards the entrance pupil of the projection lens. You will notice that the image of the exit of the integrating rod is located at the DMD or illumination plane and is magnified in size. The illumination system magnification is an important design parameter for this projection condenser illumination system design. We don't want to over fill the illumination plane and waste light or under fill and have a missing part of the object or DMD not illuminated for display on the screen. The magnification in the illumination system is a function of the condenser lens and field lens focal lengths and their spacing, the integrating rod size, and the DMD size.

Because the light at the exit of the integrating rod is spatially uniform, as we learned in a previous edition, the illumination at the DMD is also spatially uniform as required. In this unfolded optical system layout we can see that the light that transmits or actually reflects in the folded system, forms a pupil that just fills the entrance pupil of the projection lens assembly. This projection condenser illumination system layout meets the design criteria of the digital projector optical engine design.

The next steps in this light engine design would be to perform a detailed optical design of the condenser lens assembly and the field lens assembly and finally of the projection lens assembly. We know from this illumination design layout with perfect lenses what the required focal length and apertures are as well as the airspaces between the lenses so we can proceed with our detailed lens design. We would also check the illumination system magnification and illumination uniformity at the illumination plane or DMD. Finally we would design our projection lens assembly with our entrance pupil axial position and our diameter. If we did not like some of our condenser lens, field lens, or projection lens first order optical properties we would redesign the layout before we started a detailed optical design of the system.

Summary

We have seen this week how one can start with an illumination design layout and then perform a system layout of the illumination system. This system layout design of an illumination system lets us understand the first order properties of the optical design layout so that we can understand what our system will look like before we start the detailed design of the system. Finally we discuss the next steps in the detailed optical design and illumination design of this single panel DMD light engine design using a projection condenser illumination system.

Next week we will take a look at another prominent illumination system type called a Köhler illumination system. So stay tuned and keep looking for your weekly dose of In The Box to understand the optics of digital projectors.