

Rear Projection Screens for Different Applications

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Abstract

Fresnel Optics has been awarded a development contract with the United States Display Consortium (USDC) to produce rear projection screens and Fresnel lenses to be used in Rear Projection Monitors. The USDC program is broken into two sections: production of 2 different prototype screens using customer input; and large volume production. Screens up to 32 inch diagonal will be developed as part of the USDC program.

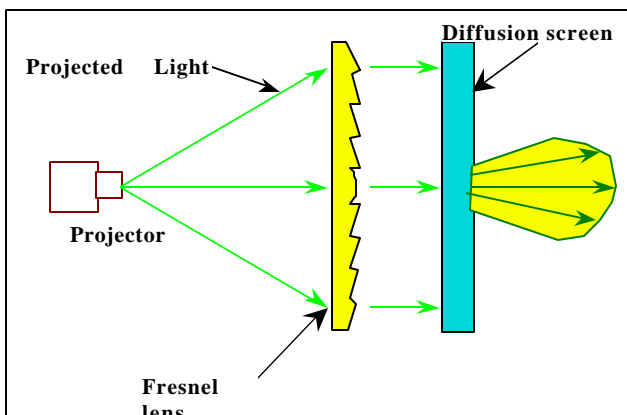
The distinctive requirements of projection monitors demand unique screens that have different technical specifications from screens used in rear-projection televisions. Specifications of the screens being designed include: Viewing Angles, Contrast, Speckle Contrast, Gain, Color Shift, Resolution, Luminance Uniformity and Display Artifacts. How these specifications interact with the projection engine will be discussed. Fresnel lenses are used in most rear projection systems. The attributes of using a Fresnel lens in this application will also be discussed. Preliminary screen specifications will be presented.

1.0 Introduction

Rear projection screens have been dominated by the lenticular screen with bulk diffusion and a black stripe for contrast enhancement. This type of screen has been able to produce the projected image with sufficient resolution and contrast for today's rear-projection television. With advances in projector resolution, this type of screen becomes increasingly more difficult to produce. Other screen technologies are becoming more prevalent as the viewing requirements for the screen become progressively more challenging.

In this paper we will look at the changes in screen viewing requirements and how the different technologies address those changes. Specifically, we will look at how different applications will change the viewing requirements of the display and the screen.

2.0 Background



Rear projection screens are typically made up of two components: a Fresnel lens and a diffusion screen (figure 1). The Fresnel lens takes the light being projected from the projector and turns the light toward the viewing screen. This collimation of the projected light allows for significantly improved brightness uniformity across the viewing area (figure 2 and picture 1).

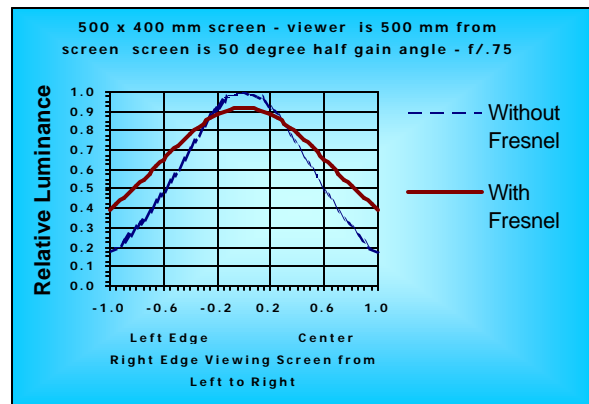


Figure 2



Picture 1

The Fresnel lens cannot make the corners as bright as the center for a number of reasons. The primary reasons are that the screen is farther from the projector in the corners and that the light from the projector needs to be stretched over a larger area than originally projected (figures 1& 3).

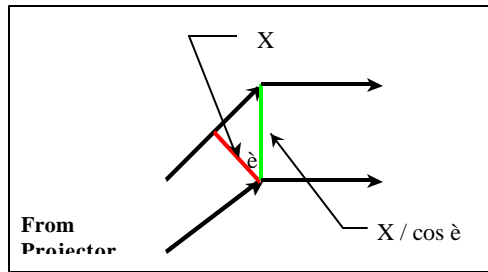


Figure 3

However, the advantage of more uniform brightness and greatly increased brightness at the corners of the display add to the contrast capabilities of the display by increasing the top end of the dynamic range.

The diffusion screen takes the incoming light and disperses it in many directions so that the viewer can be anywhere in a viewing area and see each part of the display. Without the diffusion screen, the viewer would not be able to see any part of the display except what is being directly projected into their eyes, similar to a laser beam. You cannot see the laser beam as it passes through a piece of glass unless you are directly in the path of the beam; however, you can see the laser beam if it passes through a ground piece of glass as the grind acts as a diffusion screen.

2.1 Viewing Angles

Diffusion of the light through the screen is not uniform in all directions (Lambertian) but typically is brightest normal to the screen and then gradually falls off in brightness as the viewer moves away from normal to the screen. This decrease typically follows a Gaussian or normal distribution. In projection screens, amount of diffusion leads to the definition of viewing angles.

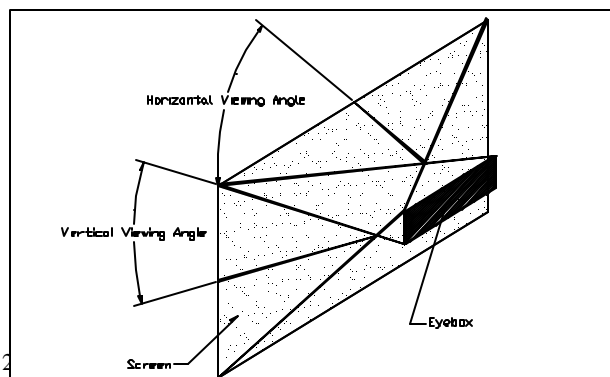


Figure 4^[1]

Viewing angles are usually defined as the angle where the brightness is half the maximum brightness. This is the half gain angle. Since the viewer's eye can only be normal to the screen in one place, different areas of the screen will have different levels of brightness that are presented to the viewer. Half gain is used as the viewer cannot easily distinguish that the brightness has diminished by this amount. Consequently, when the viewer is anywhere inside an area (or volume) created by the half gain angles of the screen and the corners of the screen, the viewer perceives the image to have relatively even brightness. (figure 4.)

The area (or eyebox) where the viewer "sees" the relatively uniform brightness increases as the viewer moves away from the display. Consequently, for displays that will be viewed from closer distances, the viewing angles must be wider for the viewer to perceive that the image brightness is even across the display.

3.0 Rear Projection Monitors

Rear projection monitors will have many different display requirements from rear projection television. Just as a computer monitor is different from a television, the same holds true for the larger rear projection monitor.



Figure 5

To look at the differences, between monitors and televisions, we can build a table of the differences (Table 1) and then decide how this will affect the display requirements of the monitor.

| Display Parameter | Monitor | Television |
|------------------------------|----------------|-------------------|
| Distance to viewer | 15-20 inches | 40-100 inches |
| Information Displayed | Static | Moving |
| Resolution required | High | Medium |
| Noise Allowable | Very Low | Low |
| Ambient Lighting | Medium | Low |

Table 1

As noted previously, with the close viewing position with monitors, viewing angles must be wider than for television. CRT's are well positioned in this case because of their wide viewing angles. LCD displays, on the other hand, have been less than optimal because of their narrow viewing angles.

3.1 Rear Projection Viewing Angles

For best viewing, RP monitors should have viewing angles of $\pm 30^\circ$ vertical and 40° horizontal (HWHM). This is significantly different from rear projection screens for television. Television does not need to have wide vertical viewing angles; therefore, RP screens for TV are typically 35° horizontal and $8-10^\circ$ vertical. These decreased viewing angles have the added advantage for television of allowing a higher gain screen. This in turn allows the television manufacturer to deliver less lumens to the screen than would be required of a low gain screen.

3.2 Display Noise

With television moving pictures, display noise, is masked by the motion. However with the static nature of the information projected on computer monitors such as text, spreadsheets, graphs, and still pictures, display noise becomes a much greater concern. Viewers in a monitor application have nothing to distract their attention from display artifacts. Display noise can be electronic noise that affects the way the individual pixels are presented, however we are interested here in noise that is caused by the screen system and its interaction with the projector.

Screen noise can be from defects in the screen, moiré patterns caused by interaction between the pixels, the Fresnel lens, and any repeating pattern on the screen such as a lenticular pattern, or speckle noise.

Screen defects requirements in monitors are much more stringent because of the close position of the viewer. They can resolve a significantly smaller defect than before. Also those defects can

have less contrast and still be annoying to the viewer. Consequently a mottled screen that is goes unnoticed in a television becomes unacceptable when looking at the white background of most office software applications.

With the tightened specifications, moiré contrast noise that was once acceptable now must be addressed again.

Lastly, speckle noise, caused by the narrow apertures of LCD and DLP projector becomes a concern for monitor viewing and must be addressed. Speckle is a problem that must be jointly addressed in the design of the screen and image projection subsystems.

3.3 Ambient Lighting

Ambient lighting when using a monitor is significantly higher than that of a normal TV or Living room. As such, greater ability of the screen to control the reflection of the ambient light is needed in this application. This will increase the bottom portion of the dynamic range of the projector; just as adding a Fresnel lens increases the top portion of the dynamic range.

Further, the projector manufacturer is tasked with producing a projector with more brightness, as the eye will be saturated by the surrounding room light and not be able to perceive the darkest areas. An extreme example of this would be to have a perfectly non-reflecting display and have a floodlight be positioned just above the display with the floodlight facing the viewer. The viewer would not be able to perceive the added bottom end dynamic range, as that has been eliminated from the viewer's capabilities by the overpowering floodlight. In the real world, the projector manufacturer can overcome some of this by having a good, low reflective screen and by increasing the lumens that get to the screen.

3.4 Resolution

The resolution of the display must be related to the distance that the viewer is away from the display and the expected size of the display. Simple geometry shows that a 20 inch diagonal display viewed from 20 inches away will require more pixels than a display that is a 40 inch diagonal and viewed from 60 inches away. As the monitor displays have become larger, the resolution of the displays has progressed from SVGA to XGA because we do not move farther away from the display but rather display more information. The monitor screen must be able to produce these high-resolution images without degrading the image themselves. We can expect that RP monitors will need to resolve SXGA and higher resolutions.

4.0 Screen Technologies

Different screen technologies tackle the requirements for television and for monitors with varying degrees of success. The screen industry leader in today's television – the double lenticular with black stripe – has insufficient resolution for high-resolution monitors, nor will it be best for new, higher definition televisions.

High-resolution screen technologies today include, Tinted Bulk diffusers; Tinted Bulk diffusers with a lenticular; glass-beaded screens, and tinted surface relief diffusers.

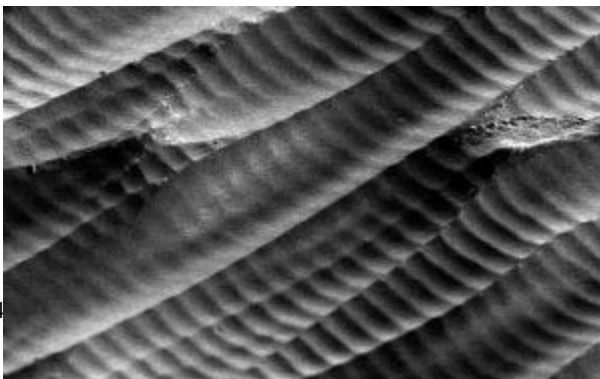
4.1 Bulk diffusers

Bulk diffusers use plastic that have been impregnated with small particles of material that have a different index of refraction from the plastic. These particles are dispersed randomly throughout the plastic, hence the name bulk diffusers. Bulk diffusers have very high-resolution capabilities, but limited contrast control relying on tinting to reduce ambient light reflections. This tinting reduces the projected light through the screen. Bulk diffuser can have asymmetric viewing angles with the use of a lenticular, but the addition of a lenticular allows the possibility of moiré patterns occurring.

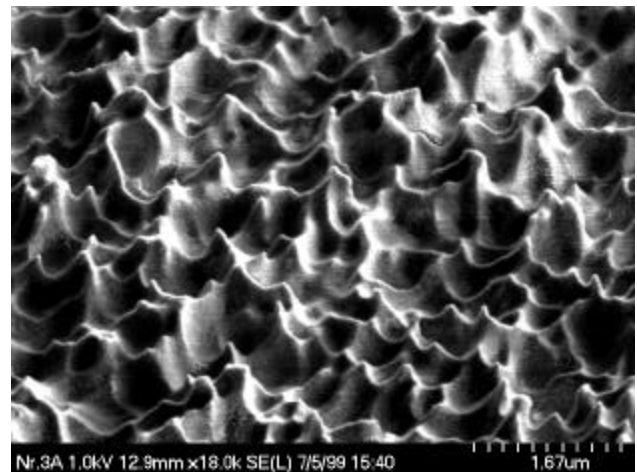
4.2 Beaded Diffusers

Beaded screens use a sheet of transparent beads imbedded into a black plastic substrate. These beads are pushed through the black plastic so that just the tip of the bead is clear through on the viewer side of the screen. By doing this, the ambient light hits the mostly black surface and is absorbed. This allows the beaded screen to display the blackest blacks and hence the best contrast. The back of the bead focuses the projected light through the clear tip of the bead, keeping projected light losses at a minimum. The beads are small enough for this screen to have high resolution. This screen suffers from the inability to have separate viewing angles in the vertical and horizontal directions, limiting the screen gain or brightness of the display. Because this is not a lenticular screen, moiré noise is not a big factor, but uneven distribution of the beads can give a mottled look that can be disturbing to the viewer. Speckle is still an issue to be resolved.

4.3 Surface Relief Diffusers (SRD's)



Surface relief diffusers are engineered perturbations in the surface of the plastic that refract the projected light into a diffusive pattern. This type of screen has very fine features allowing for high resolution. The screens can be engineered to have different viewing angles in the vertical and horizontal directions. (pictures 2 & 3). Since the patterns are random, there is no periodicity to create moiré patterns. Two advantages of SRD's are high efficiency and a high degree of flexibility in defining viewing angles. Because of their efficiency, SRD's can have very high gain, however, for good contrast control tinting is sometimes necessary, which negates some of brightness advantage.



Symmetric Surface Relief Diffuser

Picture 3

We are working on creating SRD screens that have the necessary size, resolution, speckle control, contrast enhancement, and screen gain to produce the best possible display for rear projection monitors.

5.0 Conclusions

Monitor applications of rear projection systems will demand significantly better viewing criteria from both the projector and

the screen. Because the viewer is very close to the screen and that the information on the screen is normally static in nature, the viewer will be able to see much smaller and dimmer disturbances in the display. Secondly, the high resolution required for this application will require different technology from screens used in today's rear projection televisions.

6.0 Acknowledgements

A portion of the work presented here was done under the sponsorship of the USDC (contract No. RFP 99-49)

7.0 References

^[1] Bush, Matthies, Stewart, Rear projection screens for high ambient light applications, Proc. SPIE Vol. 3690, p266-276.