Short Throw Projection System With Zoom

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Abstract:

Front projectors with shorter projection distance start to gain a lot of interest mainly for Educational Market or Interactive Display Board segments. The shorter projection distance is necessary to avoid the user to hit projected image rays and to reduce the necessary volume for the fixed installation of the projector.
We have developed very wide angle projection optics with ±80 degrees field angle to allow a projection distance of 425 mm for 85 inches projected image size. The optical system is based on the association of Projection Lens and Concave Mirror offers a 1.1x Zoom feature integrated in the Projection Lens part.

In this paper we describe and discuss the opto-mechanical system and its measured performances.

Introduction

In a traditional front projection system, the projection optics uses a combination of a wide angle Projection Lens and a decentered microdisplay. A throw ratio larger than 1 limits the projection distance to over 3m for a 100 inches image.
Recently, wider angle lenses using refraction were developed, allowing for a throw ratio of 0.5. However, these lenses require a large aspherical final element to produce a good looking image. The throw ratio of 0.5 also seems to be the minimum that can be achieved with refraction only systems

Another approach uses an optical system where refracting optics is combined with an aspherical curved mirror. Production of injection moulded mirrors with minimal surface error in high volume has been achieved, maintaining high image quality. This concept reduces the projection distance drastically, thus throw ratios of around 0.2 are now commercially available.
This concept was first pioneered in RPTV systems. Mitsubishi [1] [2] demonstrated the use of convex mirrors. The use of concave mirrors was later demonstrated, for example by Thomson [3].
To be used in a front projection system, a focusing function is necessary. It has been developed in the last few years for example by Ricoh [4]. The commercially available solutions are however restricted to fixed focal lengths, the implementation of a zooming function would allow for more flexibility in use.
This paper will present an ultra wide angle design based on a concave mirror, including a focusing and zooming function, developed by Optinvent.

Ultra Wide Angle Optical System Description

This approach uses projection optics based on an aspherical mirror associated with a projection lens. The aspherical mirror is concave.
Figure 1 shows the optical layout of this system. The microdisplay is decentred versus the optical axis. The refractive projection lens forms an intermediate aberrated image between the projection lens and the concave mirror. The later enlarges this intermediate image on the screen with small geometrical aberration.

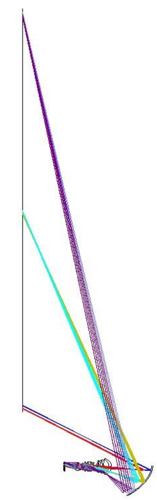

Figure 1: Ultra wide angle projection system

Angles as high as 80 degrees can be obtained by this technique that allow a very short distance between the concave mirror and the screen.
The main challenge here is to balance aberrations between the projection lens and concave mirror to get a good looking image on screen.
An additional challenge is that the whole projection system must be short, so that the system will fit entirely before the screen. The length of the system must also remain the same when operating the zoom and/or the focusing function. If the length were allowed to change, the mechanics would be extremely difficult to design, as great precision would be required when moving the mirror. As the minimal focusing distance is 425mm, it is necessary that the system stays shorter than 300mm in order to accommodate the mechanics and the other parts necessary in a projector, such as the electronics. A length of 290mm was achieved. This forces the refractive lens itself to be a wide angle lens, field angles of ±45° were necessary.
It is also a challenge to control the concave mirror shape error in production (figure 2).
Optinvent worked out the shape error and found a very simple and elegant way to manage this parameter in production and to relax error tolerances thus allowing low cost moulded mirrors in large volumes.

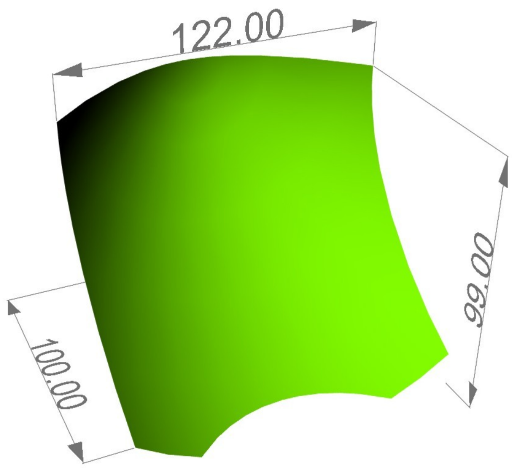

Figure 2: Concave mirror at the heart of the ultra wide angle projection system

A concave mirror system has several advantages over a convex mirror system. First, since the light is focused by the concave mirror before reaching the screen, it becomes possible to put a well defined mask shape with a glass plate to isolate the mirror from dust and to reduce ghost images in the system. Second, angles of incidence on the mirror are lower (<25°), lowering the sensitivity of the system to small defects on the surface of the mirror that might otherwise generate diffraction effects.

As the lens is highly non telecentric, the preferred microdisplay type is DLP. The lens is also quite fast (f/2) to allow for a bright image despite the large screen size. Because of the zooming function, the very large projection angle and this large aperture, 13 lenses of which 3 aspheres are necessary.

Figure 3: General lens outline

The focusing function allows the system to be used in a front projection system. The shortest focusing distance is 425mm, the longest focusing distance is 540mm. The function is performed by moving the final group of lenses as shown on figure 4. Moving

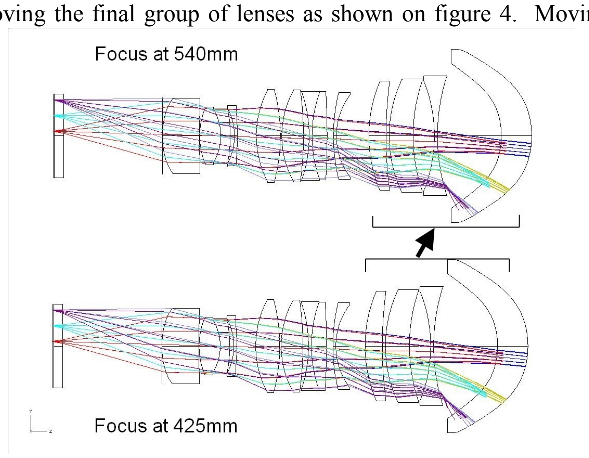

Figure 4: Description of the focusing function

this group allows to correct the distortion and astigmatic aberration that appears when distance changes.

The zooming function allows some flexibility in the use of the projector. This function is performed with 3 groups of lenses, as shown on figure 5. As can be seen, the zooming and focusing functions are independent, the system is parfocal. This is a nice feature as zooming do not require any focus adjustment.

It is also worthy of note that the f-number is constant versus the zoom position. That is because all moving parts are located after the stop, which is close to the entrance of the lens due to the high non telecentricity.

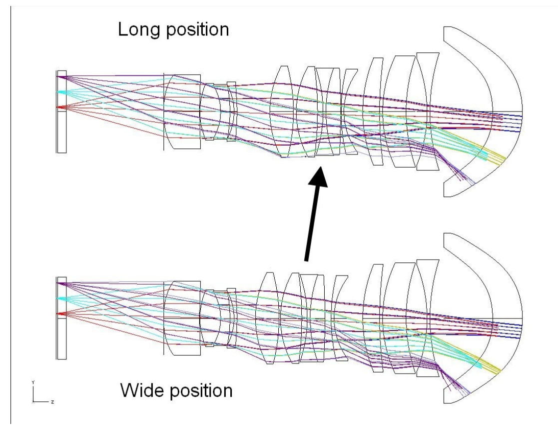

Figure 5: Description of the zoom function

Table 1 summarizes the image sizes that can be obtained with the system.

Table 1: Possible image sizes

	Focus @ 425mm	Focus @ 540mm
Zoom @ wide position	86 inches	112 inches
Zoom @ long position	77 inches	100 inches

As can readily be seen, the zoom ratio is slightly larger than 1.1x, while the focus allows the image to grow by about 30%. The minimal throw ratio is 0.19.

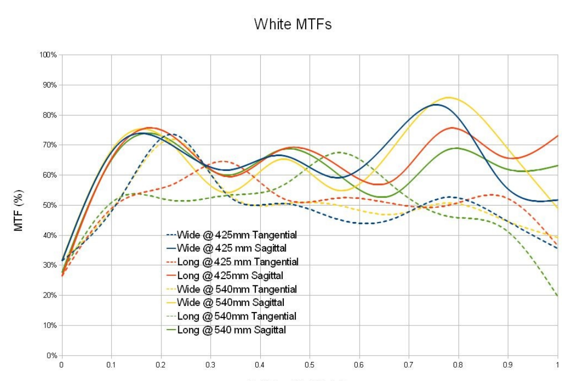

Figure 6: MTFs for the 4 extreme configurations

Figure 6 shows the MTF performances for a Nyquist frequency of 37cycles/mm that corresponds to a pixel size of 13.7µm, suited for an XGA panel.
The TV distortion is maintained below 1% (Figure 7).

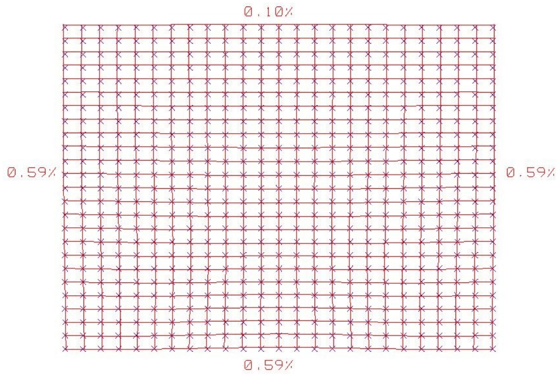

Figure 7: TV distortion, wide @ 540mm

The lateral color is below 1 pixel with a maximum of around 0.75 pixel. It is still acceptable for a lamp based system.

Figure 8: Projection system in operation on a test bench

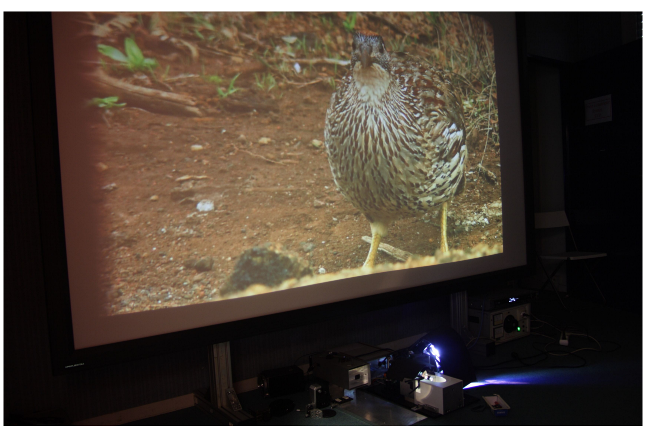

Figure 9: Projection system and the resulting image

Conclusions

Optinvent has developed an ultra wide angle projection system with a zooming and focusing function. Thus, it has been demonstrated that the ultra wide angle systems can have all the functions more classical projection systems already have.

About Optinvent:
Optinvent is a company created in February 2007. The start-up was created by two former Thomson employees who spun-off the projection optics activity. For more information please see Optinvent's web site: www.optinvent.com

References

[1]: Shikama, S., Suzuki, H., Teramoto, K., "Optical System of Ultra-Thin Rear Projector Equipped with Refractive-Reflective Projection Optics" SID Symposium Digest, 46.2, pp. 1250-1253 (2002).
[2]: M.Kuwata, T.Sasagawa, K.Kojima, J.Aizawa, A. Miyata, and S. Shikama, Wide-Angle Projection Optics for Thin Rear Projectors, IDW/AD 2005, pp 1887-1890.
[3]: Benoît & al, patent WO 2006/058884, Folded projection system for a front or rear projector.
[4]: Nagase & al, patent WO 2008/111591, Projection optical system, projector device and image reading device.