Ultra Wide Angle Optical System for Laser TV and Short Through Distance Front Projector

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Abstract:
Micro Display based (Rear & Front) projectors in general offer HD and are lower cost than LCD and PDP for large screen size. Current non slim RPTV sold in the market do not fit customer needs in terms of form factor and the limited life time of the lamp. Slim and low chin cabinets using Laser sources (Laser TV) enable this technology to compete against LCD or PDP panels for larger screens above 60 inch.

On the other hand, Short Throw Distance front projection is an emerging market. It allows to project a large image with a projection system located only around two feet from the screen. This technique offers new products for projector market for several applications like Home Video Education and Simulators.

Both Slim RPTV and Short Throw Distance projectors need a wide angle projection system with low cost and high performance optical components.

We've developed several generations of wide angle optical engines using either UHP or Laser sources. In this paper, we present the latest generation of this optical engine that should drastically change the look of RP TV's with a form factor close to that of a flat panel. The system could also be used for Short Throw Distance to display bright images on large screen with a projector located near the screen.

A technical description of the optical system used on both applications and design results will be discussed.

Introduction:

In a traditional projection system, the projection optics uses a wide angle Projection Lens centred on the system optical axis. A field angle of <±45 degrees is used that intrinsically limits the projection distance to nearly 1m for a 40 inch image. It is impossible to use larger field angles with on-axis optics for RPTV's where the traditional folding system uses one or two flat mirrors. This results in a large footprint and a large chin for the projection cabinet.

On the other hand, wider field angles for front projector introduces large distortion with traditional refraction optics. The front projector needs to be placed far away from the screen for images larger then 70 inches.

In order to slim down the RPTV cabinet and to shorten the distance for front projectors, a wider angle projection system and a non centred imagery system are necessary.

The best approach uses an optical system, were refracting optics is combined with an aspherical curved mirror. Production of injection moulded mirrors with minimal surface error in high volume has been achieved while maintaining image quality. This concept reduces the projection distance drastically.

First, convex type aspherical mirrors were introduced by Mitsubishi [2],[3], and the concave type was introduced by Optinvent.

This paper will present the latest generation of an Ultra wide angle optical design based on a concave mirror developed by Optinvent. Optical characteristics (MTF, distortion, lateral colour) will also be shown.

The implementation of this design in a Laser TV (with Laser light source) as well as in a Short Projection Distance Front projector (with UHP lamp type) will be described.

Ultra wide angle optical system description:
This approach uses projection optics based on an aspherical mirror associated with a low cost projection lens. The aspherical mirror is a ***concave*** type.
Figure 1 shows the optical layout of this system. The Micro display is decentred versus the optical axis. The long focal length projection lens forms an intermediate aberrated image between the projection lens and the concave mirror. This latter enlarge this intermediate image on the screen with small geometrical aberration.

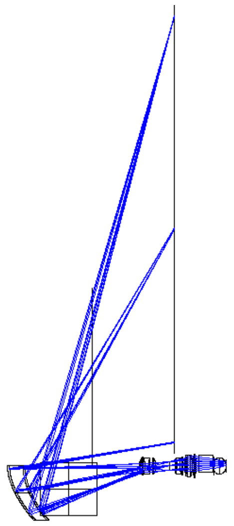

Figure 1: Ultra wide angle projection system

Angles as high as 80 degrees could be obtained by this technique that allow 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 perfect image on screen.
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.

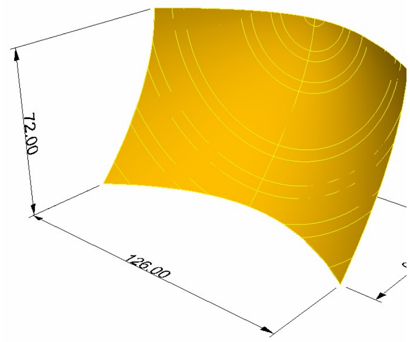

Figure 2, *Concave mirror at the heart of the Ultra wide angle projection system.*

The concave system has several advantages. First, since the light is focused by the concave mirror before reaching the screen, it is recommended 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, the projection lens in our design is made only by using spherical glass lenses and with very few elements (<10) to reduce tooling and piece-part cost and temperature sensitivity. Furthermore it is possible to add a zoom function to the projection lens to offer a zoom feature for Short Throw Distance Front projectors.
The system could use any type of Micro Display (DLP, LCOS or HTPS) and the system aperture is quite low (F/2.8) in order to use UHP or Laser light source. For Laser, the PJ lenses number is reduced to 7, while the mirror dimensions is reduced.

Slim Laser TV:
The optical system is based on the concept outlined in figure 1 and uses an F/7 aperture Laser source. This system reduces the RPTV depth to 7 inches and has a very low chin (below 5 inches). The system does not need costly reflective or exotic hybrid Fresnel lens screen. A refractive type Fresnel screen is used, reducing tooling and unit cost.
Several companies expressed strong interest in Laser sources for RPTV. Recently Mitsubishi announces the future market launch of a Laser TV. Several Laser companies are working hard to produce low cost Laser sources for RPTV

applications [4]. While requested optical power is met, low cost is still the main challenge for future success. In order to increase market and customer interest in Laser based RPTV, we think that an improvement on form factor should be part of the package to offer a new “re looking” for this product.

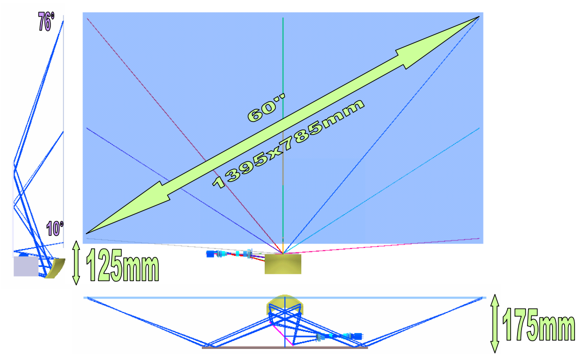

Figure 3, Layout of Slim Laser TV developed by Optinvent

The imagery system described in figure 3 shows the actual dimensions for slim Laser TV. The Footprint is about 175mm (6,9inch), the Chin is about 125mm (4,9inch). The concave mirror dimensions is about 130mmx72mm. The projection lens has only 7 elements.

The image performance for a DLP type Slim Laser TV (0.55inch panel) are summarized in the Table 1 below.

MTF @ 50 lp/mm	Distortion EIA	Lateral colour	Brightness uniformity
50% G 40% R 30% B	<0,5%	R-G: 6µm B-G: 6µm	70%

Table 1, Slim Laser TV optical performances

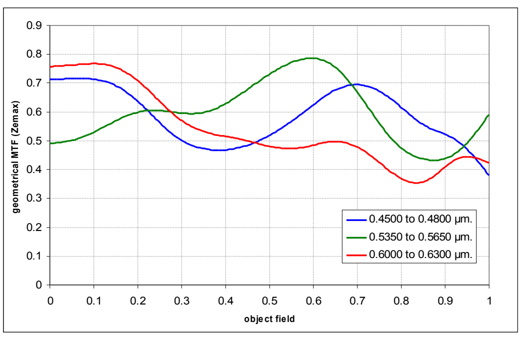

Figure 4, R,G&B MTF versus Field @ 65lp/mm

Figure 4 shows the MTF performances for a Nyquist frequency of 65cycle/mm that corresponds to a pixel size of 8µm, suited for Full HD panel.

The Distortion is about 0.5% (Figure 5) and the Lateral colour is about ¼ of pixel.

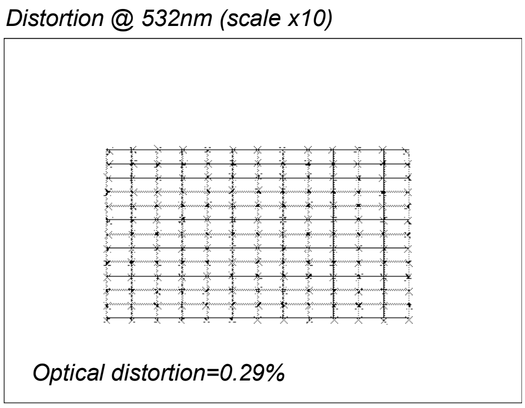

Figure 5, Optical distortion

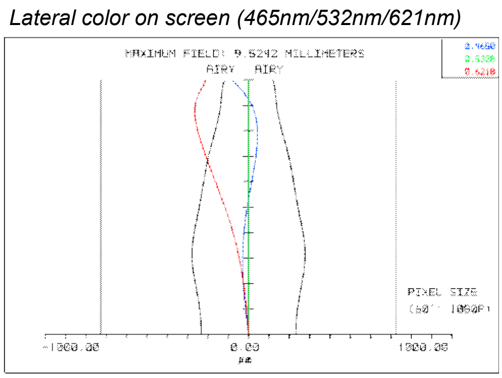

Figure 6, Lateral colour

As a result of this design, the look of this Slim Laser TV is very close to a Flat panel (figure 7).

Figure 7, Laser TV as a result of ultra wide angle projection system

Short Throw Projection Distance Front Projector:

The ultra wide optical system is also based on the system in figure 1. The light engine uses a UHP lamp. The system aperture is about F/3. The projection distance, defined as the distance between the concave mirror centre and the screen, is about 50cm for a screen diagonal of 66 inches. This yields a projection throw ratio of 0,29 is the lowest value compared to what we can find today in the market (about 0,66). The design is based on 3LCOS system with 0,7inch diagonal that has Full HD resolution (1920x1080). The optical performances of this system show an MTF about 40% and a distortion of 0,5% for 66 inch screen diagonal .

Figure 8 shows a representation of short throw distance projector with an optical engine configuration placed vertically in front of the screen. The configuration could also be set up with an optical engine in the horizontal direction.

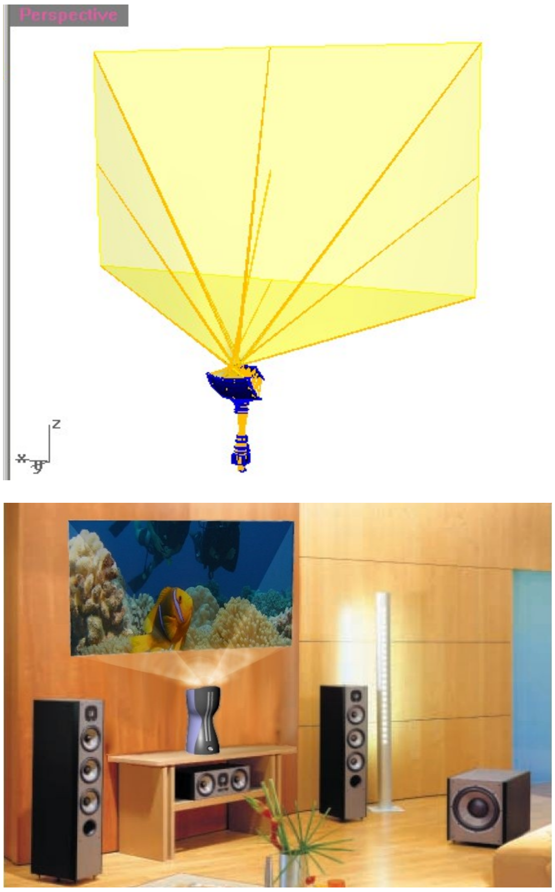

Figure 8, Short Throw Distance Front Projector with a vertical configuration for the optical engine.

Another main advantage of the ultra wide angle optical system is its capability to embed zoom optics in order to enlarge and control the projected image size. A zoom function can be incorporated in the projection lens that is able to perform x1,27 zoom ratio while maintaining optical distortion of less than 0,56%.

Screen "	52 "	59"	66"
Distortion	-0,53%	+0,33%	+0,56%

Table 2, Short Through Distance Front Projector with x1.27 Zoom; Distortion performances

As outlined in figure 9, the zoom function enlarges the image while the bottom of the image is still located nearly at the same point. This feature is user friendly and the projector location does not need to be changed when the zoom function is activated.

An inherent property of this system is that the distortion value changes with image size. The design is optimized for 59 inches, with a distortion value of +0,33%. When zoom function is activated, the distortion value change from -0,53% to +0,56%, while crossing by 0% distortion value @ 56 inch image size.

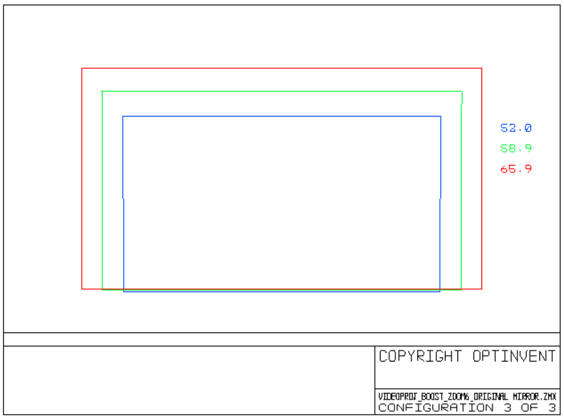

Figure 9, Simulated Zoom feature on Short Through Distance Front Projector.

Conclusions:

Optinvent has developed an ultra wide angle projection system that allows to have slim Laser TV for RPTV market as well as for a Short Throw Distance Front Projector to address home video, Eduction and simulator application.

About Optinvent:

Optinvent is a new 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

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[1]: J. Gohman, M. Peterson, Scott Engle, "Slim Rear Projection" SID Symposium Digest, 70.4, pp. 1922-1925(2005).

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