Slim Rear Projection system for Laser TV

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Abstract:
Micro Display based Rear projection TV (RPTV) offers Full HD and potentially lower cost than LCD and PDP for large screen size. Today millions of RPTV's sold in the market do not fit customer need in terms of form factor and the limited life time of the lamp. Slimmer and low chin cabinets coupled with Laser or semi-conductor long life light sources enable this technology to compete against LCD or PDP panels for larger screens above 56 inch.
We've developed several generations of slim RPTV optical engines for either UHP or Led based projection systems. In this paper, we present the latest generation of the slim optical engines that should drastically change the look of RPTV's with a form factor close to that of flat panel displays. We also combine this slim feature with a Laser based projection system. A technical description of the optical system used as design results will be discussed.

Introduction:
In a traditional non slim RPTV cabinet, 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 cabinet footprint. The traditional folding system uses one or two flat mirrors. This results in a large footprint and a large chin for the projection cabinet. In order to slim down the cabinet, a wider angle projection system and a decentred imagery system are necessary. So the solution to the problem is in the optical projection system.
Several solutions have been proposed in the past. Some of these are based on polarised light bouncing back and forth on a large reflective surface polarizer. However, since image quality is sensitive to component flatness and higher contrast is required for the projected image, all of these approaches were abandoned. A pure optical approach has therefore gained interest and two categories have emerged. One uses refractive components with relay optics that shows good results, but it is not necessarily appropriate for large volume in terms of tolerances and cost. The other approach uses a catadioptric optical system, were refracting optics is combined with an aspherical curved mirror. This approach has higher potential and is linked to the capacity to produce an injection moulded mirror with minimal surface error in high volume while maintaining image quality. This concept not only allows an overally reduction in depth but is also able to reduce the chin dimension. This is important because RPTV has to compete in overall form factor with LCD and PDP.
First, convex type aspherical mirrors were used. Then later on, concave type mirrors were introduced. A comparison of the two systems will be described.
This paper will present an optical design for slim RPTV that is based on a concave mirror. Optical characteristics (MTF, distortion, lateral colour) as well as mirror shape tolerances will be shown.
A specific focus on Laser based slim system will be made showing the potential for low cost slim function.

State of art on Large screen TV:
Figure 1 shows a summary of depth performances for several Large screen TV including RPTV as LCD and PDP panels.
The depth is quite linear for non slim RPTV. For LCD the depth is nearly 3to 5 inches, while for PDP, the depth is nearly 4 to 6 inches and exhibits large stand for

large screen size (mechanical support to sustain very big weight). When hanging on the wall, PDP panel should be located nearly 4 inches from the wall to avoid heating problem, limiting then its slim factor.

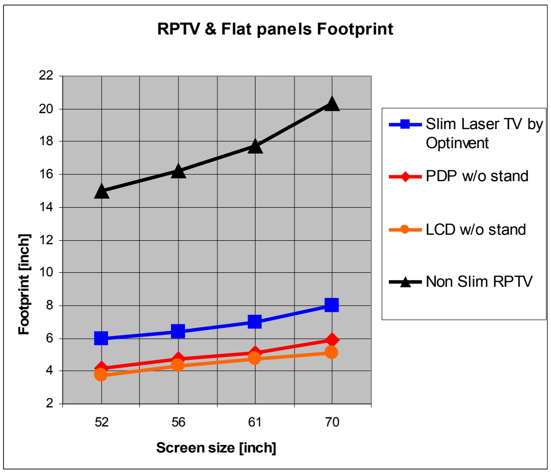


Figure 1

For slim RPTV, the current depth for current slim product is about 10 inches. The new generation of thin RPTV, that is subject of this communication in about 7 inches. We can also notice that chin performances is very important for slim type RPTV's. To have similar look as the LCD or PDP flat panels, the slim (or thin) RPTV should be less than 5 inches.

The challenge for a new slim RPTV design is then double: small depth and low chin.

Slim (or thin) RPTV design:

There are two types of smaller depth RPTV's: Refractive type optics and catadioptric (refractive & reflective) type optics.

Refractive type slim systems:

For refractive type, only a decentred projection lens is used to project and fold the beam inside the cabinet. Infocus [1] was the first to introduce 7 inches RPTV with a refractive optics. In this design the projection lens is decentred by more than 100% versus the optical axis. The projection lens is made by nearly 25 elements, adding cost and tolerances issues for large volume production. The system is based on relay optics. A first group images the Micro Displays inside the PJ lens. A second group enlarges the MD image, while pre-correcting the residual aberration.

Another lower cost approach is used with a small shift (less than 100%) to still use the PJ lens in a normal way. This method is not enabling to reduce the cabinet depth drastically. The reduction factor for the depth is below 25%.

The conclusion about these approaches is the need for another optical system to perform thinner cabinet while maintaining lower cost for the optics.

Catadioptric type slim systems:

This approach uses projection optics based on aspheric mirror associated with a low cost projection lens. Mitsubishi [2],[3] was the first to introduce this concept with a non telecentric system based on DLP MD. The aspheric mirror is a ***convex*** type. Cabinet depth is reduced to nearly 10inches, but chin still quite large. The aspheric mirror dimension is still big, to have cost reduction for large volume.

Optinvent team (within Thomson group at that time) was the first to introduce another catadioptric system based on aspheric ***concave*** mirror associated to a low cost projection lens. This system has several advantages versus convex type. First, the projection lens do not use aspheric element, which need longer development time and higher cost than conventional spherical optics. Second the system reduce the depth to lower values (<10 inches) and exhibits very low chin (below 7inches). And finally the system does not need costly reflective Fresnel lens. A refractive type Fresnel lens is used, reducing development cost and unit cost for the Fresnel lens. An additional benefit of concave mirror is the reduction of Flare and parasite (or ghost) images, since the beam is focused by the concave mirror. A dedicated stop avoids dust deposition and absorbs any beam that may contribute to ghost images.

Table 1 shows a comparison of optical performances for convex and concave slim

RPTV type. This comparison is made within Optinvent between in house 2nd Slim generations using convex type with our 3rd Slim generation using concave type.

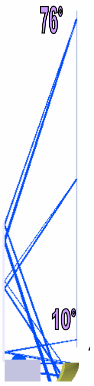
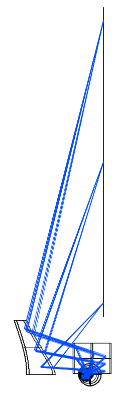
Slim type	Concave  	Convex 
Aspheric mirror Dim.	130 x 72mm²	160 x 92mm²
Aspheric Mirror Cost	Low	Fair
Light source & Aperture	Laser source, F/7	UHP Lamp, F/2.8
Telecentricity	Telecentric	Telecentric
PJ Lens	w/o aspheric lens,7 elements	with aspheric lens, 9 elements
Field curvature		
Optical distortion	0,3%	1%
MTF @50lp/mm	xx%	xx%
Fresnel screen	Refractive	Reflective
Fresnel Incid. angle	10 to 76deg	52 to 78deg
Dust issue	Closed system	Open system
60/62 inch RPTV footprint	~7 inch	~10 inch
60/62 inch RPTV chin	~5 inch	~7 inch

Table 1

New Generation slim for Laser TV:

Several companies expressed strong interest in Laser source for RPTV. Recently Mitsubishi announces the future market launch of Laser TV. Several Laser companies are working hard to put low cost Laser source for RPTV application [4]. While requested optical power was met, low cost challenges still the main factor for future success. In order to increase market and customer interest in Laser based RPTV, we think that improvement on form factor should be part of the package to offer new “re looking” for these product.

From a technical point of view, Laser light source should benefit in decreasing optics cost, especially for slim type RPTV’s. This is why, Optinvent worked out hardly to improve its first generation concave concept to meet this target.

The concave system described above still suffers some drawbacks. First, in order to reduce system cost, the aspheric mirror dimensions should be reduced as the number of elements inside the projection lens.

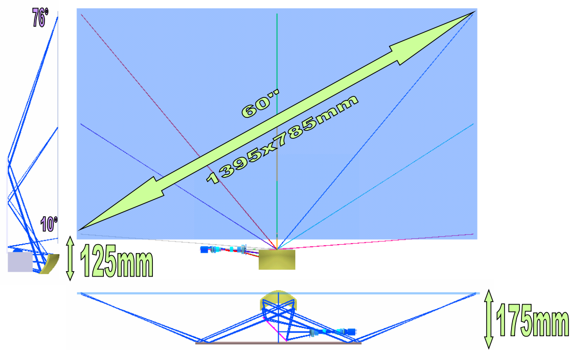


Figure 2

Optinvent has been working to reduce element cost and complexity and came out with an improved concept that shows lower cabinet depth and small chin with a lower cost for the optics.

First the beam “étendue” is quite small. System aperture is fixed to F/7. This value is a trade off between speckle reduction and cost reduction for optics.

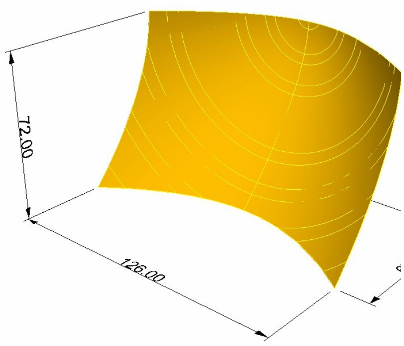


Figure 3, *Concave mirror at the heart of the slim Laser TV system.*

The imagery system described in figure 2 shows the actual dimensions for slim Laser TV. The Footprint is about 175mm

(6,9inch), the Chin is about 125mm (4,9inch). We have decreased aspheric concave mirror dimensions (see figure 3) for Laser TV design to 130mmx72mm, instead of 190mmx90mm for UHP lamp design. The projection lens has only 7 elements, instead of 9 for UHP lamp design.

The image performances for a DLP type Slim Laser TV (0.55inch panel) are summarized in the Table 2 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 2

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.

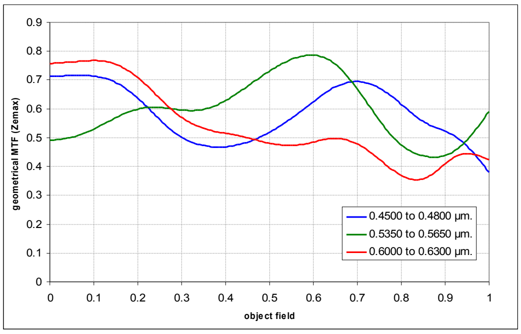


Figure 4

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

Distortion @ 532nm (scale x10)

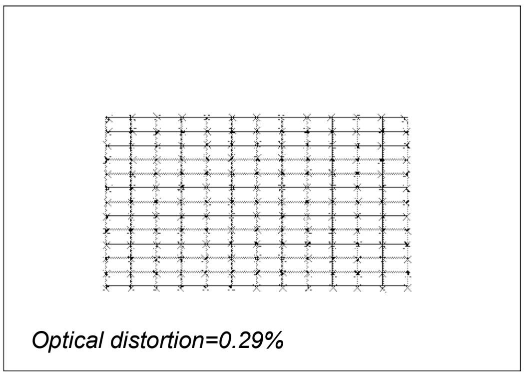


Figure 5

Lateral color on screen (465nm/532nm/621nm)

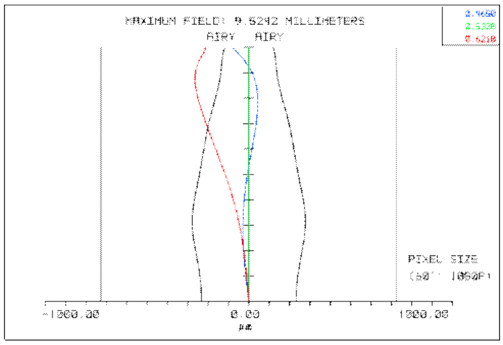


Figure 6

Conclusions:

We have developed a new optical design for Slim Laser TV. The concept is based on the use of small aspheric concave mirror associated to a low cost 7 elements Projection lens. The system offer high image quality. The Footprint and the chin are respectively 7 and 5 inch. The look of this Slim Laser TV is very close to a Flat panel (figure 7).

Figure 7

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

References:

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

[2]: 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).

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[4]: Greg Niven and Aram Mooradian, Trends in Laser Light Sources for Projection Display. IDW