Wide Viewing Angle Screen Design of High Definition LCD Projection System

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Abstract

We propose multi-layer aspheric lenticular lens for rear projection screen to provide wide viewing angle. Each pitch of lenticular lens sheet is divided by three region and image light from projection optical system is propagated widely on each region due to different focal point. Besides, to improve vertical viewing angle of screen, we propose glass bead embedded screen on observer side of lenticular lens.

Introduction

HDTV (High-definition TV) broadcast is becoming a very strong significant tendency. Some features such as high resolution and brightness, high contrast ratio, large screen and compactness are required for HDTV display. The solution of HDTV is PDP, direct view CRT or projection TV. In US market, most of HDTV is projection type display.

To achieve high picture quality of projection type HDTV, many problems should be solved such as brightness, contrast and so on. Compared with another flat panel display or CRT, viewing angle of rear projection screen is smaller than that of another display.

Why screen is important? That answer is very simple.

A TV viewer enjoys picture realized on screen.

A projected picture of LCD or CRT through projection lens illuminates the screen. Screen is consisted of lenticular lens and Fresnel lens.

Rear projection screen generally includes a combination of Fresnel lens sheet and lenticular lens sheet. This lenticular sheet is generally constructed as follows; specifically, as is shown in Fig. 1. Convex cylindrical lens surface is formed on both sides of sheet, and projected image light is formed in the boundary areas between respective cylindrical lenses on one side of sheet. (i.e., the side from which projected light is emitted), with light – blocking layers (light-absorbing black stripe). The reason that convex cylindrical lens surface is formed on both the front and back sides is that in cases where the projector is a three-tube CRT type projector, it is necessary to correct the aberration for the three colors (R,G and B) with the lens on the incident sides.

To achieve excellent picture of high definition TV broadcasting, the characteristics of screen is required qualities as follows

- Enhanced brightness by high Gain
- Wide viewing angle compare to CRT
- High Resolution
- High contrast under room illumination condition
- Escape Moiré Pattern, Hot Band and Scintillation

Until now, three types of screen is used as follows; specifically, as is shown in tables 1, both side lenticular lens of DNP and Kuraray in Japan company, one side lenticular lens of Toppan and, beaded film type of 3M.

Compared to a screen of three-tube CRT type, LCD type is not required to correct the aberration for the three colors. On such reason, convex cylindrical lens surface of lenticular lens in LCD type is formed on observer side.

But the viewing angle of LCD type screen is smaller than that of CRT's; specifically alpha horizontal viewing angle is under 70 degree and alpha vertical viewing angle is under 20 degree in LCD type, approximately 10% lower than that of CRT's due to the manufacturing limit of half angle (θ) about 25 degree in fine pitch i.e., 0.18mm.

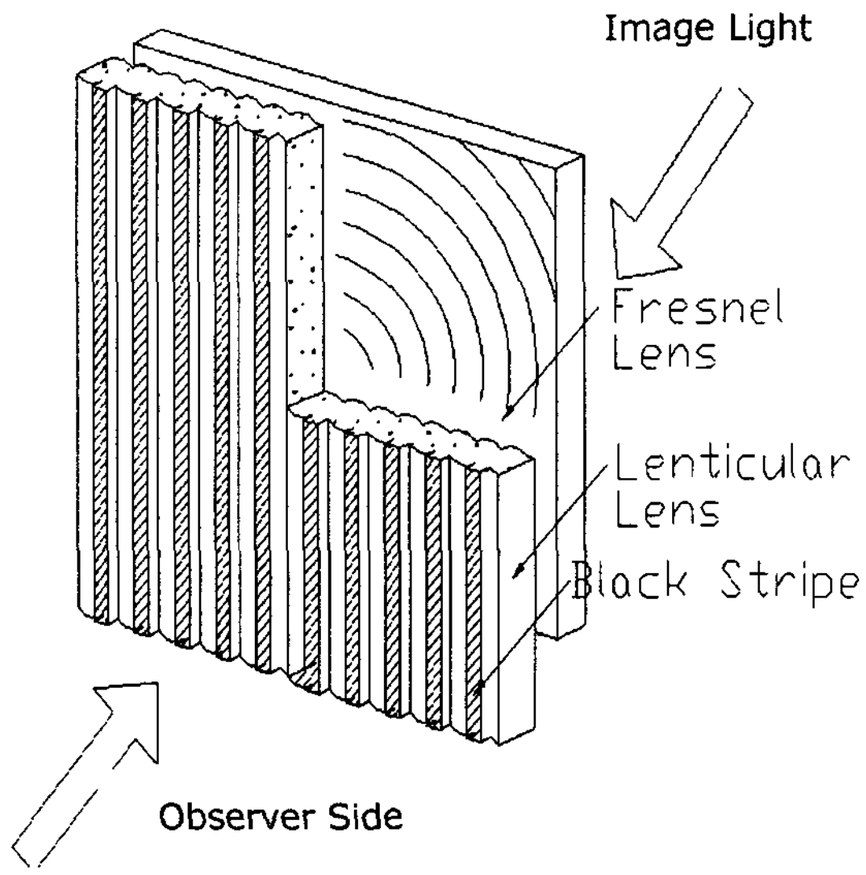

Fig. 1. Configuration of projection screen

Screen Design

Lenticular Lens I

We propose lenticular lens of multi-layer aspheric structure to provide wide viewing angle without manufacturing limit of half angle. To get sufficient wide viewing angle, divide the pitch of lenticular lens to several segments to provide wide angle beam propagation on each segment in Fig. 2 with table 1.

items	Layer 1	Layer 2	Layer 3
Curvature	0.35	0.25	0.13
Conic Constant	-0.555	-0.5	-0.12
Refraction Coefficient	1.49		
Pitch	0.155		
Thickness	0.198		

Table 1. Design factor of Lenticular lens I

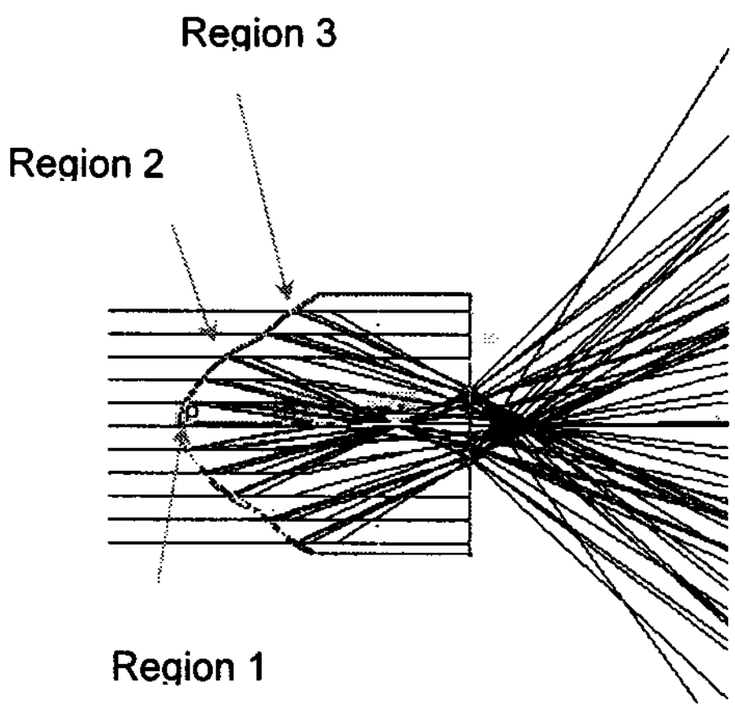

Fig. 2. Beam Propagation of Lenticular lens Ⅰ

The focal point of region 1 is located inside the lenticular sheet, which provides image light to cover wide range on exit side of lenticular lens uniformly. The focal point of region 2 is passed over the exit side surface of lenticular lens, which provide image light to pass densely at the edge of exit side of lenticular lens and continuously rare until center of exit side. The focal point of region 3 is more beyond than that of region 2, which provide image light to pass at the edge of exit side dominantly and is very rare except that.

To enhance brightness of projection system, the gain of screen must be high maintaining viewing angle. To get over 100 viewing angle degree in horizontal direction maintaining sufficient half angle, we proposed three-domain lenticular lens structure with different curvatures one another to minimize internal reflection and manufacturing risk in region3.

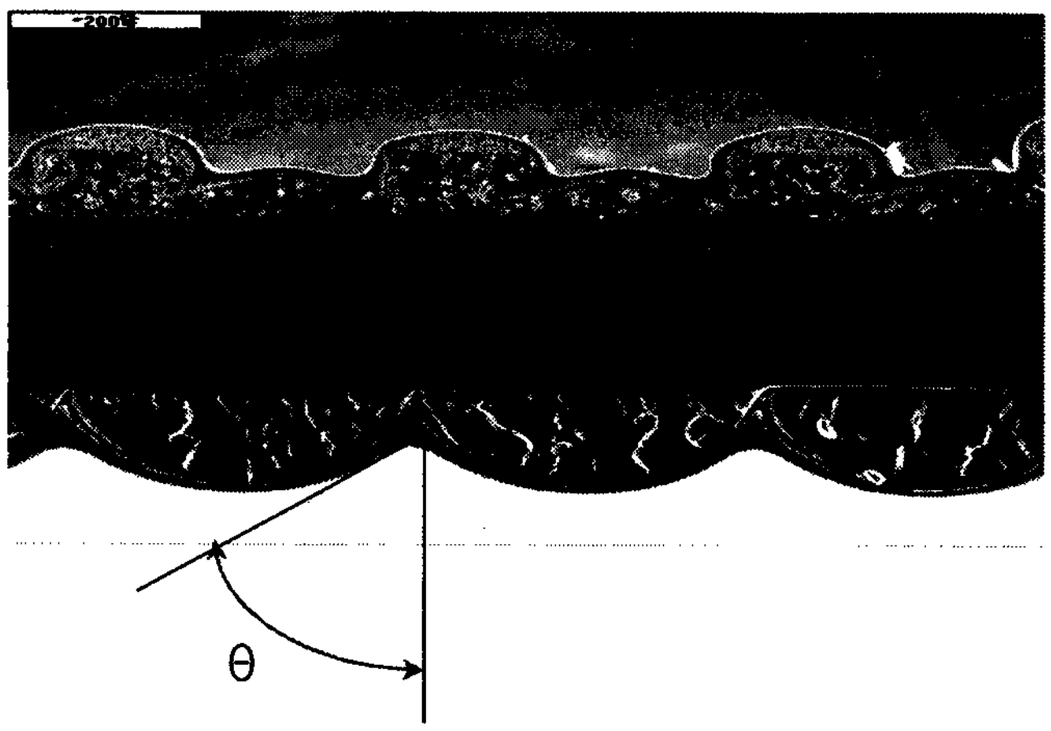

Fig. 3. Cross view of lenticular lens and half angle (θ)

Lenticular Lens Ⅱ

Until now in lenticular lens type of screen in Fig. 1, viewing angle of vertical direction depends on diffuser dispersed in lenticular lens sheet. To get wide vertical viewing angle in these type screens, we need denser diffuser. However, the more diffuser is added in, the more scattering loss is happened.

To improve both vertical and horizontal viewing angle, we proposed as; specifically, as is shown in Fig. 4. Convex cylindrical lens surface is formed on entrance sides of sheet, and glass bead is located at focusing point on optical axis of cylindrical lens.

With simulation results, we obtained over 110 degree in horizontal viewing angle and over 70 degree in vertical viewing angle.

Items	Specification
Curvature	0.14
Conic Constant	-0.26
Refraction Coefficient	1.49
Pitch	0.155
Thickness	0.198

Table 2. Design factor of Lenticular lens Ⅱ

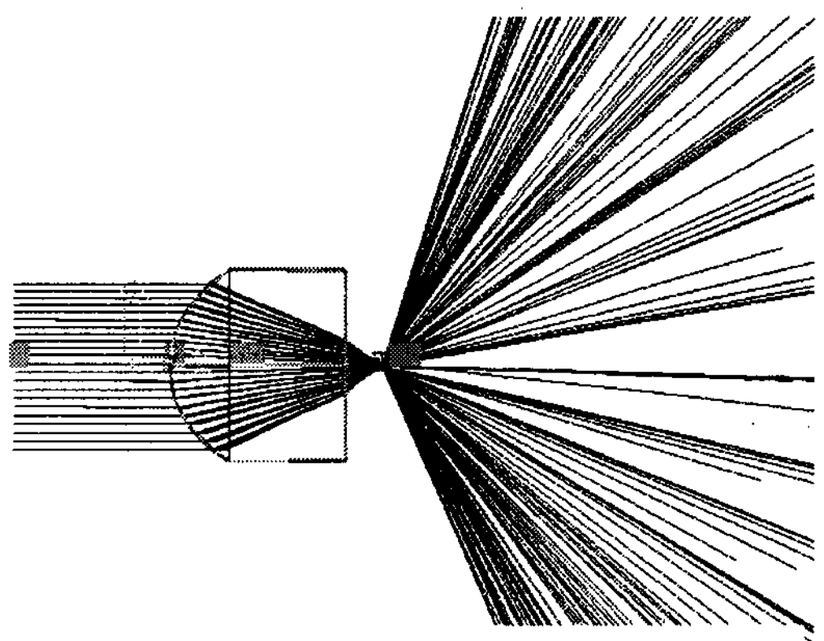

Fig. 4. Beam Propagation of Lenticular lens Ⅱ

Conclusion

We proposed a multi domain lenticular lens structure to improve viewing angle with reducing manufacturing risk. In addition, to improve vertical viewing angle, we proposed entrance side cylindrical lens and glass bead on that respective another side.

References

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