Analysis of Eye Response to Low Brightness 3D Displays and Increase Brightness in 3D RPTV using Long Life, High Power DPR System

Kenneth Li
Wavien, Inc., 29023 The Old Road, Valencia, CA 91384, USA
TEL: +1-661-294-2900, ext. 250, e-mail: kli@wavien.com
Keywords: 3D, projection, illumination, uhp, DPR

Abstract

3D displays requires multiplexing of left and right pictures on the same screen so that they can be viewed independently by the view using various schemes, including LCD shutters, polarizers, narrow band filters, and lenticular lenses on the screen. All these methods reduce the effective screen brightness by as much as 10X. The eye responses to the lower brightness are analyzed and found to compensate partially giving a lower perceived brightness. This paper presents such eye response analysis and a low cost approach to increasing brightness in a RPTV using the long life DPR system, increasing the screen brightness by over 2.5 times, while maintaining acceptable lamp lifetime.

1. Introduction

Artists have been trying to reproduce reality by drawings and paintings for many years in the past. With the invention of black and white photography over 100 years ago, the reproduction of reality was getting into a new era. 3D photography and viewing apparatus were also developed bringing a full immersive experience to the viewer. With the invention of motion pictures, it did not take long for 3D movies to be made. Due to various difficulties and constraints, 3D movies never become the mainstream entertainment experience. With the recent advancements in digital displays and cinema technologies, the many of the hurdles of 3D can be overcome. One major impediment in viewing 3D movies is the loss of light in the system, which reduces the effective brightness of the screen. To obtained comparable brightness of standard screen brightness, the illumination system has to be increased several times, which make standard system not feasible or impractical. This papers analyses the brightness of projection systems and eye responses to brightness. A DPR illumination system is also presented, which provides a practical system for 3D projection display where the brightness can be produced that matches to standard brightness, thus enhances the 3D viewing experience.

2. Standard 2D and 3D Display Brightness

The most common displays in the consumer market are LCD, Plasma, and Rear Projection televisions. Although both LCD and Plasma are more popular for smaller displays, the price will be too high for wide acceptance in the larger size displays. For 3D applications, the viewing experience is enhanced as the screen size increases. Towards this goal, this paper concentrates on the performance and enhance of rear projection televisions (RPTV). Figure 1 shows the typical components of the 3D viewing experience.

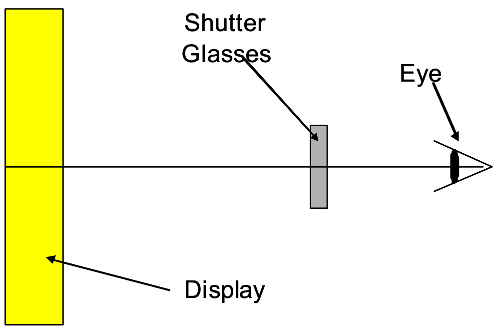


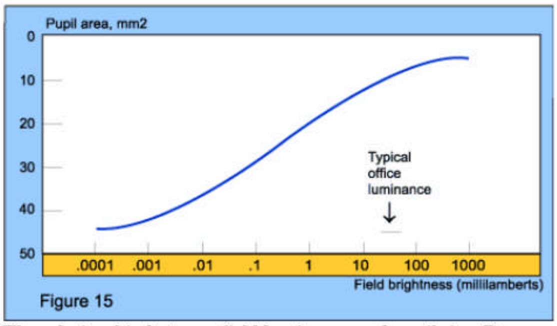
Figure 1 – 3D RPTV system components

The display is a RPTV operated at 120 frames per second. Alternating the right and left eye signals, each eye is operated at 60 frames per second with 50% duty cycle. An infra emitter is used to send these left and right eye signal to the shutter glasses worn by the viewer as shown. The shutter glasses are typically made with liquid crystals, turning the right and left eye glasses on and off in synchronization with the infra signal such that the right eye sees only the right signal and vise versa.

With losses shutter glasses, the theoretical perceived brightness of this system will be 50% of the original brightness, which will be 300 nits. With typical liquid crystal shutter glasses, which are based on polarized light, the efficiency will be less than 50%, with typical value of about 40%, giving an output of 20% or 120 nits. Due to the speed of the electronics and finite rise and fall time of the shutter glasses, in order to avoid crosstalk between the two eye signals, losses are introduced in the timing of the on/off cycle.

In our experiment, a Samsung 50” RPTV was used together with shutter glasses from Dynamic Digital Depth, Inc. The measured overall efficiency from the screen to the eye is 10% giving the eye brightness at the eye at 60 nits.

Although the brightness has dropped from 600 nits (~200 millilamberts) at the screen to 60 nits (~20 millilamberts) at the eye, the perceived brightness by the viewer will be higher as the pupil of the eye dilates as the brightness decreases, thus increases the perceived brightness. Figure 2 shows the eye response to the brightness of the incidence light.



The relationship between field luminance and pupil size (Reeeves, 1920). (The graph can be changed to cd/m^2 by multiplying millilamberts by 3.183.)

Figure 2 – Pupil size versus brightness

According to the graph, the pupil areas are 5 mm^2 at 600 nits and 10 mm^2 at 60 nits. The effective light collection efficiency is twice at the lower intensity of 60 nits increasing the perceived brightness to 120 nits. The overall change in perceived brightness from standard 2D to 3D viewing is 5 times less.

3. Brightness Increase using DPR

One way to overcome the brightness is to increase the power of the lamp, e.g. from 132 W to 300 W. This increase in power will effectively reduces the lifetime of the RPTV from about 4,000 hours to less than 1,000 hours, which make this approach not practical using standard reflector system. To achieve high brightness and long lifetime, the DPR system as shown in Figure 3 can be used, in which 6,000 hours can be achieved using the DPR system as shown in Figure 4.

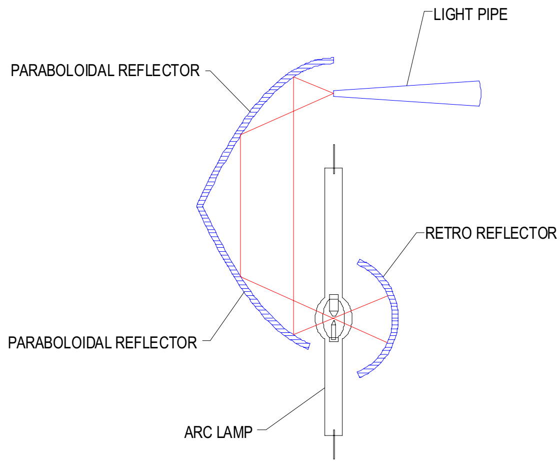


Figure 3 – Schematic diagram of a DPR system

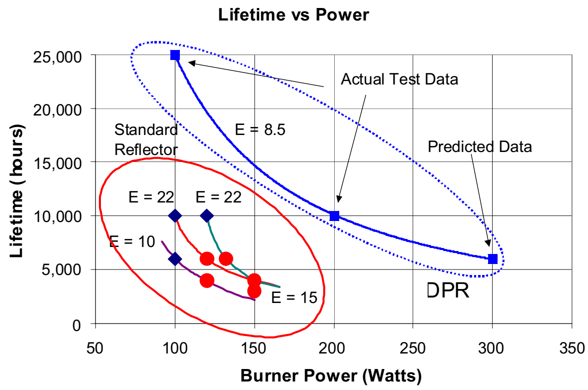


Figure 4 – Lifetime versus power versus etendue

A comparative system using the Samsung 50” RPTV and a 300 W DPR lamp was prototyped and an output brightness of 1,800 nits was achieved, which is 3 time brighter than the original system. With the same 3D system loss, the brightness at the eye is 180 nits. At this intensity, the perceived brightness of the system is about 2 times brighter than the original system. In practice, as observed, the pupil responds to the average of the screen and the environment, which is dimmer. This moves the operating region to the more linear region, making the perceived brightness even higher.

4. Summary

Using the DPR system, a high power lamp with long life become practical and can be applied to increase the brightness of RPTV for better viewing experience.