ATTEST to MUTED – Problems, Answers, and the Evolution of a Multiple Mobile Viewer Autostereoscopic Display

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Abstract

The evolution of a multi viewer autostereoscopic display is described. Development of the display was originally a part of the EC funded 'ATTEST' project and continues as another EC project 'MUTED.' The design of the original display is presented and the limitations of the prototype are described. The current iteration of the design is presented.

1. Introduction

The ATTEST (Advanced Three dimensional Television System Technologies) project (IST-2001-34396) ran from 2002 to 2004. Led by Philips, Eindhoven, there were seven other participants in the project which had the ambitious objective(1) of producing an entire 3D-TV broadcast chain, from capture/synthesis, through coding and transmission, and ultimately, display. There were two facets to the display development: a single user system which was the responsibility of FhG HHI and a multi user system produced by DMU.

A common philosophy was shared in both displays; it was deemed to be essential for a TV application that the system should be autostereoscopic and viewers should enjoy freedom of movement. In addition, the DMU display would cater for several viewers simultaneously. Both approaches use headtracking to provide viewer mobility

The ATTEST project culminated in the production of the HHI 'Free2C' display (Figure 1) and a 'proof of principle' prototype of a multi viewer display was demonstrated by DMU(2). The multi viewer display was adequate to demonstrate the principle of operation but had fundamental limitations. Addressing these limitations is the objective of the MUTED (Multi User 3D TElevision Display) project. MUTED is an EC funded 'STREP' project (IST-5-034099) of thirty months duration, it commenced in July 2006 and will bring together over thirty person years of effort involving seven participants from across Europe.

2. The ATTEST displays

It is beyond the scope of this article to offer a detailed treatise of the Free2C display, for which readers are referred to the literature (3). Essentially, the display is a lenticular system in which a TFT monitor (in portrait orientation) is mated to a lens sheet comprising cylindrical lenticules. Each lenticule spans two pixel columns so the display provides a single stereoscopic view. The system differs from a conventional lenticular display in its ability to accommodate movement of the viewer. This is achieved by monitoring the viewer's head position and moving the lens sheet, laterally, and fore and aft, relative to the TFT.

Figure 1 The Free2C display – courtesy Fraunhofer HHI

The core concept of the multi viewer display is to produce image regions, or exit pupils, in space in front of the screen at the viewer's eye positions. Figure 2 illustrates this concept where an exit pupil is formed with the use of a large lens and a vertical light source. Altering the position of the illumination source causes a corresponding change in the position of the exit pupil.

In order for 3D to be observed, two adjacent exit pupils must be formed; this is achieved by placing a second illumination source to one side of the existing source to produce an additional exit pupil.

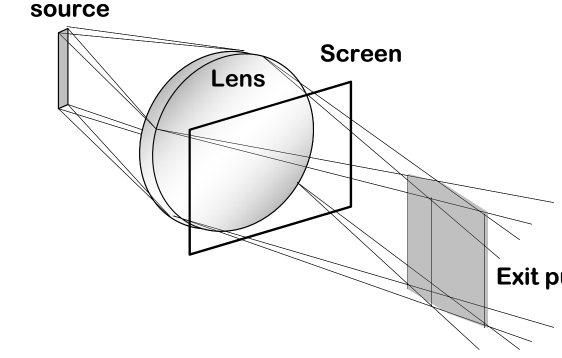

Figure 2 Exit Pupil Formation with Lens

The display operates in a vaguely similar manner to the Free2C system by using an LCD with left and right eye images interlaced on alternate pixel **rows**. A lenticular screen is fixed and placed behind the LCD screen where it is used to focus a steerable backlight through the left and right image rows of the LCD. Crucially, steering of the viewpoint is accomplished not by lenticular movement but by movement of the light source. Provision of an additional light source, adjacent to the first, produces another exit pupil and provides scope for displaying a stereo pair.

The practical realisation of the multi viewer display was somewhat different. To counter lens aberrations which would limit the off axis performance of the system, an array of lenses is used in conjunction with multiple light sources. A single element of the array is illustrated in Figure 3. The illumination sources comprise 256 white LEDs located around the periphery of the rear surface. Ten identical elements are combined to form the complete array and two arrays are used to form left and right exit pupils

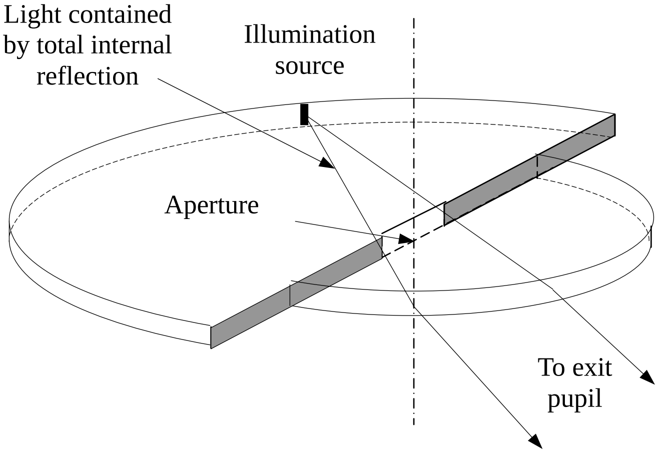

Figure 3: Co-axial Optical Element

The complete display is shown in Figure 4. The folding mirrors are used to optically extend the width of the steering arrays. The screen assembly is derived from a NEC 2110 TFT display.

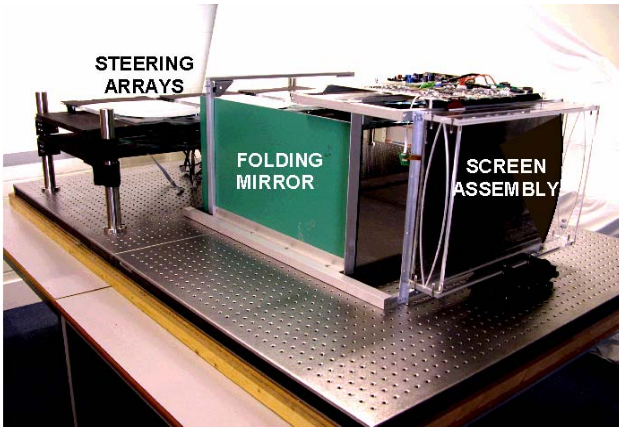

Figure 4: Complete Multi Viewer Prototype

3. Multi Viewer Prototype Performance

The significant problems encountered in the prototype are lack of brightness, crosstalk and image banding. Investigation found that crosstalk was caused by diffraction at the LCD due to the periodic nature of its pixel structure. It was found that diffraction is a particularly severe problem with the NEC LCD used in the prototype due to the vertical microstructure in the sub-pixels that has a small pitch of fifteen microns (See Figure 7). In Figure 5 it can be seen that the first order component of the diffraction pattern approaches a considerable 20% proportion of the zero order component.

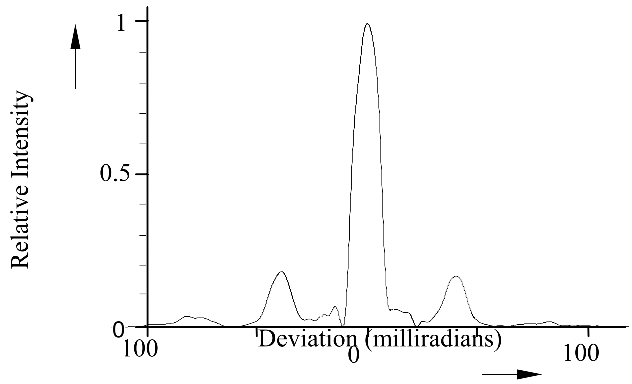

Figure 5: TFT Diffraction

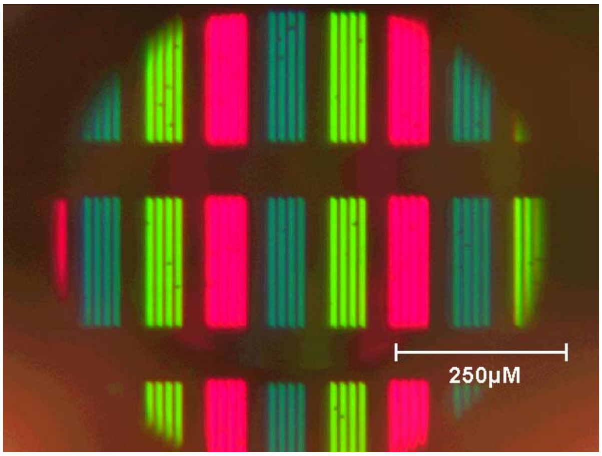

Figure 7: TFT Sub-pixel Microstructure

The effect of screen diffraction can be seen in Figure 6 where the relative intensity profiles across the viewing field are shown. The continuous line of the graph shows the profile for the output of a single optical array element at a distance of 2.8 metres and with no LCD in the light path. Here a beam approximately 100 millimetres wide is formed when 10 LEDs are illuminated. The lines L and R show typical eye spacing, and the exit pupil intensity without LCD is shown to fall from maximum to around 1% of this value well within this interocular distance, resulting in little crosstalk. However, with the LCD in place the profile is changed dramatically, this is shown by the dashed line. With eyes positioned again at the lines L and R, the crosstalk is now in the region of 15% which is unacceptable.

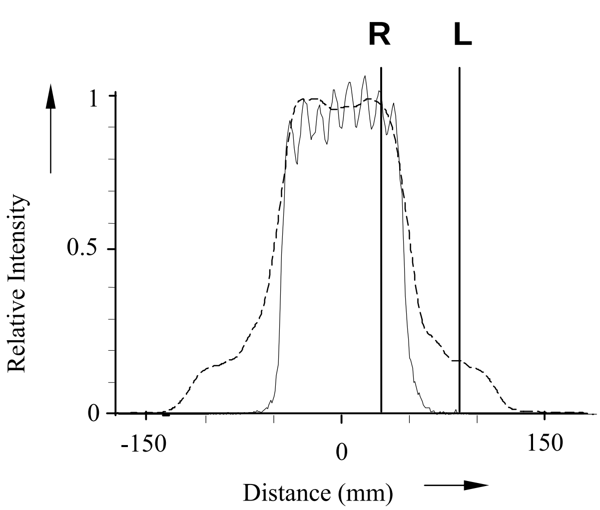

Figure 6: Exit pupil diffraction profiles

Although some level of diffraction is inevitable at the LCD, it is possible to reduce this to tolerable limits. For example the prototype LCD could be rotated through 90º, in which case the effect of diffraction would be reduced due to the lack of a horizontal high spatial frequency sub-pixel component when in this orientation, although this would adversely change the aspect ratio of the display. Another option would be to use a monitor type LCD that has a simple pixel structure but has a relatively restricted viewing angle. The most satisfactory solution would be a careful choice of LCD that is better suited to this application. As the original contiguous LCD backlight is effectively replaced by an array of discrete LED illumination sources, the appearance of banding is a potential problem. Variation in intensity and colour between the devices gives rise to the appearance of vertical banding. Here the variation in LED colour was more noticeable than the variation in LED brightness. Even though all of the LEDs used were chosen with very tight specification in the same CIE chromaticity region, the colour variation could be clearly seen with the screen showing a blank white image. However, when there is an image on the screen, especially if it is moving, the effect is less noticeable.

4. The MUTED approach

It might have been possible to reduce the crosstalk of the ATTEST display to an acceptable level by judicious selection, and possibly orientation, of the LCD, however the lack of brightness was a more fundamental problem. Despite the backlight containing over five thousand LEDs only a small proportion of these contribute to the image brightness. Ultimately there seemed to be no simple solution to this problem and an alternative illumination scheme was sought. By making the rear surface of the steering elements flat it is possible to project light onto this surface, the viability of this approach was verified by constructing an array of steering elements and a conventional data projector was used as an illumination source. Since the illumination pattern is sparse, this is an inefficient approach as very little of the light from the projector lamp reaches the steering optics. To combat this problem a holographic projector is used. This is an adaptation of a system developed by project participants Light Blue Optics (LBO). The term "holographic" refers not to the projected image, but to the method of projection. A diffraction pattern corresponding to the required illumination pattern is displayed on a phase-modulating Ferroelectric Liquid Crystal on Silicon (FLCOS) microdisplay. When illuminated by coherent laser light, the desired pattern is projected. (Figure 9)

Rather than blocking light, the phase-modulating FLCOS microdisplay steers the light to exactly where it is needed, making the system highly efficient. Unlike conventional projection systems, LBO's technology does not require a projection lens. Instead, a demagnification lens pair expands the diffracted image from the microdisplay, producing an ultra-wide throw angle of greater than 90°. The projected images are in focus at all distances from the projector, eliminating the need for a focus control. The diffractive method of projection naturally lends itself to miniaturisation, and is able to correct for arbitrary optical aberrations.

An added benefit of this approach is the increased colour gamut afforded by the laser illumination. Figure 8 illustrates this on the CIE chromaticity diagram.

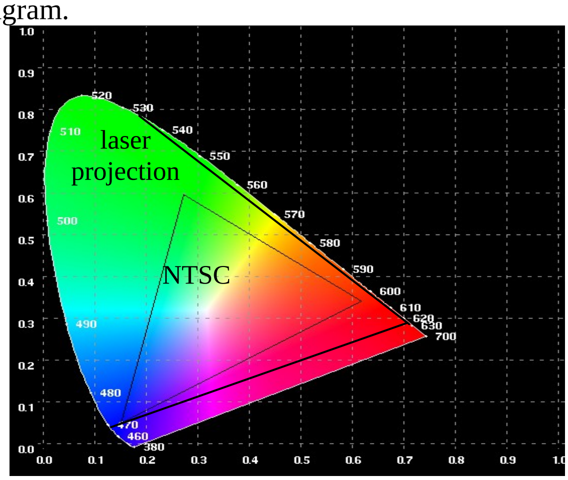

Figure 8: Increased colour gamut

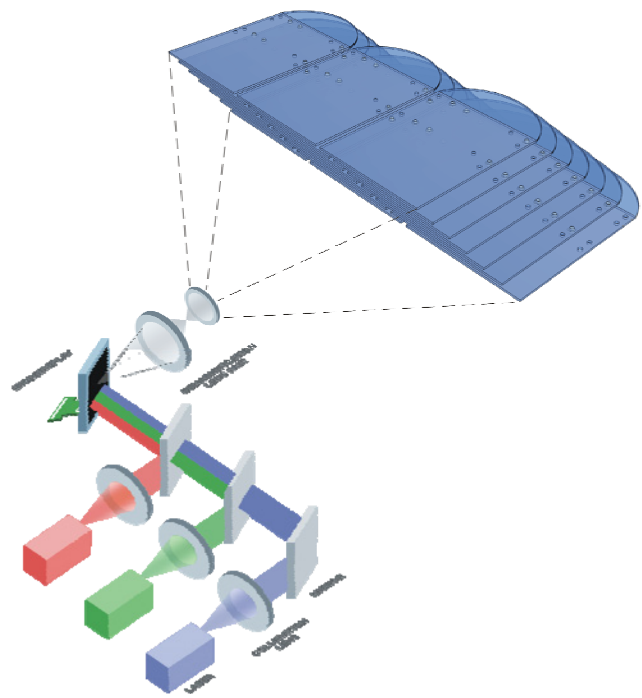

Figure 9 – Holographic projector schematic diagram

5. Summary

Work continues on the development of the MUTED display. Demonstration of a monochrome prototype is planned for later this year with a colour system following in 2008.

6. References

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