Paper No 17.2: Head-Tracked Dynamic Exit Pupil Multiuser Autostereoscopic Display

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Abstract
In this paper, a glasses-free (autostereoscopic) display is described where the controlled illumination for a liquid crystal display (LCD) backlight is derived from a laser source where the laser is used not for its coherence properties but for its ability to have close control on its direction. This allows light exiting the LCD to be directed to the left and right eyes of several viewers who can move freely in both the X and Z directions. Light directions are determined by a spatial light modulator (SLM) that is controlled by a multiuser head tracker. This paper is principally concerned with the SLM and the Gabor superlens screen that is used to provide the angular magnification required to give a sufficiently wide viewing field,

1. Introduction

The display described here is based on research carried out in the HELIUM3D display project that ran from 2008 until 2011and was supported by the European Union [1–3]. The project covered several aspects of 3D-related research including near and far-field gesture tracking [4,5] high-precision head tracking [6]and human factors [7,8].The autostereoscopic displays developed are of two types, one of these being essentially a projection display and the other the direct-view LCD display with a controllable backlight. Both the systems use head tracker controlled exit pupil formation; an exit pupil is a region in the viewing field where either a left or aright image is seen across the complete area of the screen. If a left/right exit pupil pair follows a viewer's head, special glasses do not have to be worn. The object of the research is to build a display where several exit pupil pairs can move around over a large region so that multiple users with a high degree of freedom of movement can be served .The unique feature of the HELIUM3D approach is that viewer scan move freely in the X direction (laterally) and in the Z direction (toward and away from the screen). In order to obtain the requisite control over the light, a laser is used as the light source as lasers have a low étendue (the product of source size and solid angle emitted).

2. Principle of Operation

The projection and the direct-view versions operate on The same principle where the image on the viewing screen is a column that is scanned horizontally. For a given eye, the beam from the column is always directed towards that eye as the scan progresses. When there are multiple viewers several beams are produced simultaneously from the column, one for each viewer. Left and right images are presented on alternate scans so full-resolution images are produced by temporal multiplexing. Illumination is provided by the scanned beam from a green laser as shown in Figure 1. The display described here does not incorporate the light engine used by the projection version; instead the image is produced on an LCD located at the exit of the complete optical system. The purpose of the display is to produce exit pupils where illumination is seen over the complete duration of the scan by an eye located at the pupil. This requires the direction of the emergent light from the scanned image column to change direction as the column traverses the screen so that an exit pupil is formed; this is referred to as dynamic exit pupil formation .In Figure 1, the laser beam travels from point X on the field lens, through point Y to point Z over the duration of the scan. The combined action of the field lens and the horizontal diffuser ensures that for any position of the beam landing on the field lens, the complete width of the SLM is always illuminated. The SLM is a linear array where transparent apertures are formed whose positions and widths are determined by the position of the viewer and the time elapsing since the start of the scan. If there is more than one viewer, there will be as many apertures formed as there are viewers. After exiting the SLM and projection lens, a vertical diffuser forms a vertical line on the screen so that point X at the start of the scan forms the line SS0. Similarly, points Y and Z form lines MM0and EE0, respectively, later in the scan period.

3. Implementation

The display is implemented by using the laser-scanned optic sas the backlight for a 120-Hz display as shown in Figure 2; the optics behind the LCD acts merely as a steerable backlight and has no image information passing through. A horizontal line is formed on L2from the scanning spot and this line is transferred to the front screen via the projection lens L3. In order to fill the complete height of the screen, a vertical diffuser is located in front of L3.The scanner and the SLM must be run in synchronism for the exit pupils to be formed, and alternate scans cover the left and right exit formation periods. When the left exit pupils are formed a left image is displayed on the LCD. When the right exit pupils are formed a right image is shown on the LCD. Therefore the LCD must also be synchronized; the most convenient means of achieving this is to use the video signal to the LCD as the master and the SLM and scanner synchronised to this. With the left and right images displayed sequentially there are periods when the LCD image is refreshed; during this time both left and right images are displayed simultaneously and light must be blocked to the viewers in order to prevent them from observing the incorrect images. This unwanted effect is overcome with the use of an optical chopper in the laser beam, as shown in Figure 2, which blocks light during the addressing periods. The image of an aperture produced on the SLM is created in the viewing field by the screen which is an assembly that incorporates a Gabor superlens; this is a lens array that comprises, in its simplest form, two layers of lenses. Figure 3(a) shows a section of a superlens; in this case there are three layers as the central lens array contains a field lens that prevents light passing to17.2 / P.