Interference-filter-based stereoscopic 3D LCD

A. Simon, M. G. Prager, S. Schwarz, M. Fritz, and H. Jorke

Abstract

A novel stereo 3D LCD for passive interference filter glasses is presented. A demonstrator based on a standard 120Hz LCD was set up. Stereoscopic image separation was realized in a time-sequential mode using a LED-based scanning backlight with two complementary spectra. A stereo brightness of 3 cd/m² and a channel separation of 30:1 were achieved.

Keywords: 3D stereo, 3D LCD, wavelength multiplexing, interference filter

1. Introduction

Stereo imaging techniques based on the interference filter technology have drawn much interest in the last few years in relation to projection system applications, particularly cinema [1] and simulation visualization. The common feature of these techniques is the high degree of realism that the viewer experiences when image contents are provided him or her in a most natural way—that is, with the viewer perceiving two independent images in the right and left eye.

A number of different approaches using active shutter glasses in combination with LCDs or PDPs have been published of late [2-5], but the use of the wavelength multiplexing scheme [6] in the direct-view display applications has not yet been reported. In this paper, the feasibility of this approach for the backlit, direct-view LCD is demonstrated.

The desired system is based on the wavelength multiplexing principle, which codes image information within different spectral ranges (Fig. 1). To separate the image information and to assign the correct image information to the respective eyes, each eye has to be supplied with a narrow-band pass filter. This filter must have a triple-band characteristic to selectively transmit the narrow bands associated with the image content coded in such bands. Using, for instance, two triples of narrow bands, stereoscopic images can be shown via wavelength multiplexing, where each image is a full-color one.

Images are time-sequentially coded and refreshed at a frame rate of 120 Hz. Therefore, the image resolution is maintained, and no compromises have to be made. The left and right images are illuminated with the two complementary spectra. As the LCD is a hold-type display, where parts of the left and right image contents are displayed at the same time, a scanning backlight (Fig. 2) is required. Image separation at the viewer's end is achieved using compatible interference filter glasses.

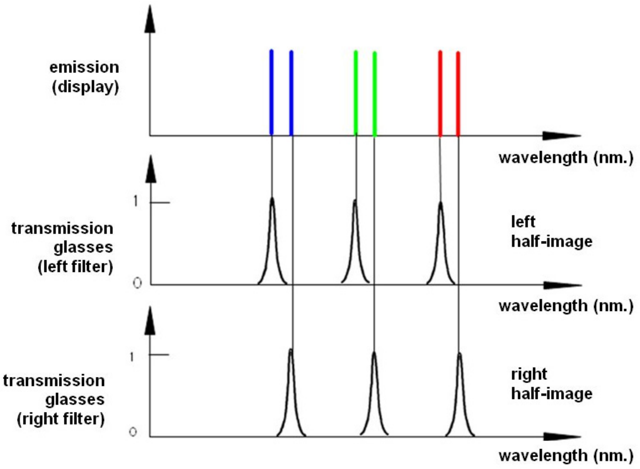

Fig. 1. Stereo display principle using two wavelength emission triples and two matching complementary spectral filter sets for the glasses.

2. Experiments

The demonstrator setup uses a 120Hz Samsung SyncMaster 2233RZ 22" monitor. Combined with the Nvidia 3D vision package and a Geforce graphic card, this system supports 120Hz page flipping in the open GL mode. A sys-

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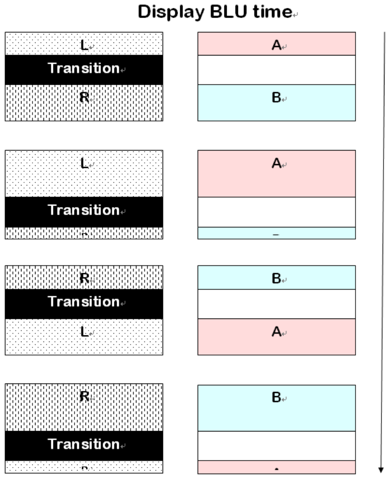


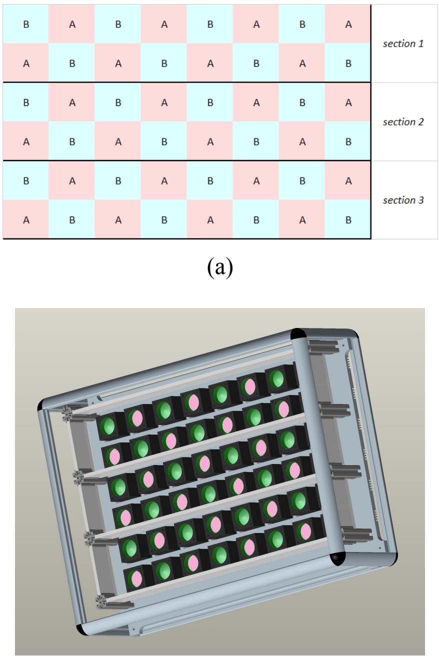
Fig. 2. Time synchronization between BLU and display driving.

tem based on the interference filter technology (INFITEC) was designed and used in place of the commercially available shutter glasses.

The core of the system is a LED-based scanning direct backlight unit. The backlight (Fig. 3) is sectioned into three scanning subregions, which can be illuminated with the spectral filter characteristic A or B. The driving unit allows the individual timing adjustment of each region relative to the synchronization signal from the graphic card.

For spectral characteristic A, the LEDs were chosen to fit the interference filter characteristics, and for spectral characteristic B, the type B filter characteristics (Fig. 4). The use of the color-bin-selected LEDs resulted in the around 70% spectral transmission efficiency of the interference filters. In this paper, 40-lm/W LEDs from Philips Lumileds were used, which were driven at a current of 700 mA (red) or 1000 mA (blue and green).

Interference filters require the control of the light incidence angle because the oblique incidence angle shifts the transmission bands towards the blue-wavelength region. This shift is smaller than 2.5 nm if the incidence angle is limited to ±10°. Therefore, a collimation optics consisting

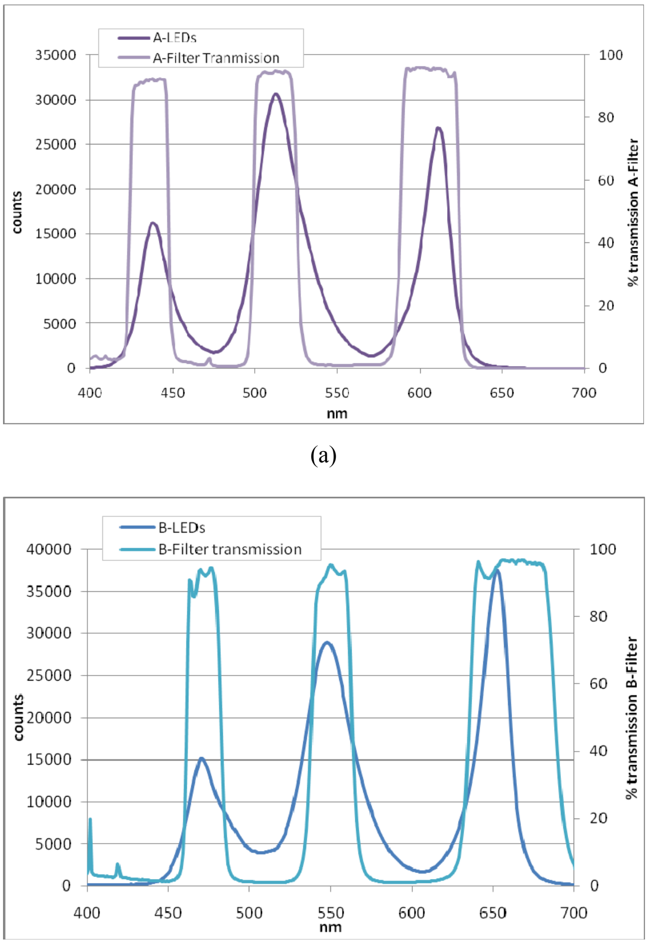


B	A	B	A	B	A	B	A	section 1
A	B	A	B	A	B	A	B	
B	A	B	A	B	A	B	A	section 2
A	B	A	B	A	B	A	B	
B	A	B	A	B	A	B	A	section 3
A	B	A	B	A	B	A	B	

(a)

(b)

Fig. 3. Backlight unit composed of two spectral complementary illumination sources (A and B): (a) schematic diagram; and (b) mechanical setup.



(a)

(b)

Fig. 4. Ideal LED emission spectra and interference filter transmission: (a) A-filter spectrum; and (b) B-filter spectrum.

of a condenser lens was placed onto a narrowing tube on top of the LEDs (Fig. 5). The average light transmission of this optical unit without an interference filter was merely 28%. Furthermore, the maximum light transmission was limited by the width of the LED spectra.

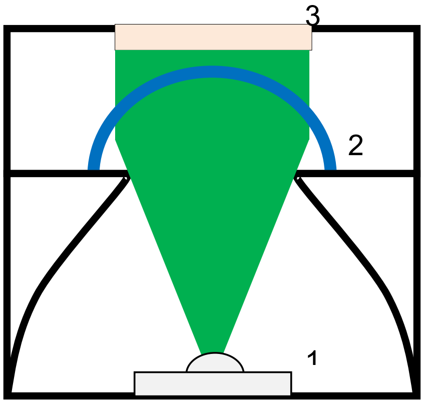


Fig. 5. Cross-section of the light cube: 1 = 4x LED (RGGB); 2 = condenser lens; and 3 = interference filter.

3. Results and Discussion

The illumination time of the system was determined by the switching time of the LCD and the number of BLU segments. To avoid crosstalk, the BLU segment was turned on only upon the completion of image switching. The OFF and ON switching for this LCD panel were 2-3 ms. Each BLU segment illuminated 1/3 of the image at a time corresponding to 1/3 of a frame (2.8 ms). The addition of all contributions allowed a short (0.5 ms) illumination time.

In the experiment, the threshold for obtaining a good image was obtained at a duty cycle of $\leq 40\%$, which was equivalent to an illumination time of ≤ 3.2 ms. The power consumption of the system was 107 W. The brightness of the display in the mono mode averaged 10 cd/m², and in the stereo mode, 3 cd/m². The crosstalk for the alternating black and white images accounted for 0.1 cd/m² (3%). This result fits the spectral measurements of the alternating black and white frames for the left eye (A-filter) and the right eye (B-filter) (Fig. 6). The viewing and measurement angles averaged 22°. Due to the low signal sensitivity, the noise did not allow the exact spectral crosstalk to be determined. The white balance of the system has not yet been implemented.

The aforementioned values were compared with those of the complementary perpendicular filter blocking of back-light sources A and B. In both cases, the channel separation was above 100:1. Therefore, the major contribution to crosstalk originated from the incomplete switching of the LCD when the illumination frame started.

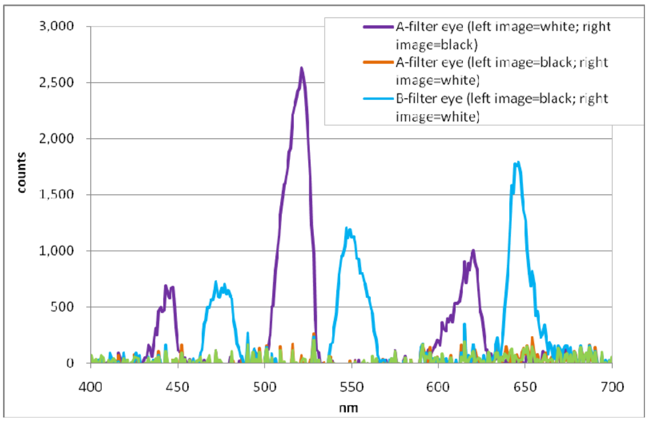


Fig. 6. Measured spectral emission of the demonstrator displaying alternating white and black frames for the left eye (A-filter) and the right eye (B-filter).

The brightness of the demonstrator is still low due to the low-end realization of the optical design for collimation and homogenization (Fig. 7). The limited availability of the proper LED color bins and the inefficient beam shaping reduced the overall light emission to 12% of the original LED light output. In addition, the use of two stacked semi-transparent diffuser sheets for homogenization further reduced the overall emission of the BLU.

Fig. 7. INFITEC 3D-LCD Demonstrator.

4. Conclusions

The feasibility of the INFITEC system with a fast-switching LCD was demonstrated. The passive-glasses INFITEC wavelength multiplex principle has been translated for use in stereo 3D-LCD applications. A demonstrator-based BLU using two complementary color spaces with a 120Hz off-the-shelf LCD was shown.

The actual inefficient light output also resulted from the nonavailability of efficient, low-cost, narrow-band-emitting light sources.

This technology is of potential interest for areas where active shutter glasses or polarizer glasses cannot be used.

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