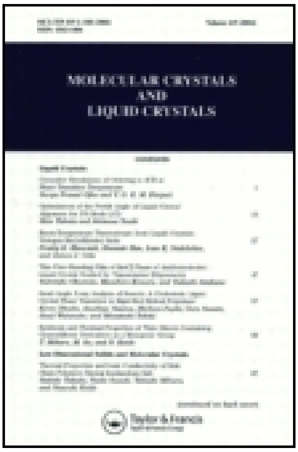

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Backlight Output Enhancement Using Cholesteric Liquid Crystal Films

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BACKLIGHT OUTPUT ENHANCEMENT USING CHOLESTERIC LIQUID CRYSTAL FILMS

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Abstract Dichroic polarizers are used to produce linearly polarized light in direct view displays; however, these elements introduce an inordinate amount of loss. Alternatively, a cholesteric liquid crystal (CLC) film and a quarter-wave plate (QWP) combination can be utilized in a display backlight to both polarize and enhance backlight output. A 45% increase in forward propagating light intensity from a notebook computer backlight outfitted with a broadband CLC film and a QWP is demonstrated here. Polarized backlight output is studied for two types of CLC films: one, a single layer broadband CLC, and the other, a stack of red-, green- and blue-reflecting CLC films. In addition, light output was measured at different positions on the backlight and for different types of rear reflectors.

INTRODUCTION

Because of recent breakthroughs in CLC materials research, it is now possible to fabricate a single CLC film that is capable of exhibiting selective reflection across the entire visible spectrum[1, 2]. This exciting technology is quickly being developed for incorporation into LCD backlights, to enhance their luminous efficiency[3].

In this paper, several aspects of CLC-enhanced LCD backlights are explored experimentally. In particular, polarization-resolved, forward-propagating backlight output is measured as a function of CLC type, rear reflector type, and as a function of position on the lightpipe. The details of the experimental apparatus and each of the experiments performed are described in the following sections.

EXPERIMENTAL APPROACH

A schematic diagram of the experimental apparatus used to measure LCD backlight output is shown in Fig. 1. A backlight from a notebook computer was detached from its case, and its diffusers were removed. What remained is the lightpipe, cold-cathode-fluorescent lamps (CCFLs) and drive electronics, and the rear reflector. The CLC films under study were placed directly in contact with the lightpipe. A circular polarizer (QWP+LP) for either right-, or left-circularly polarized (RCP or LCP) light was placed on top of the CLC to convert transmitted circularly polarized light into linearly polarized light. The circular polarizers are sheet polarizers (Polaroid, HNCP37x0.030") which consist of a quarter-wave plate laminated to a dichroic linear polarizer. When two such polarizers are crossed, their extinction ratio is between 10~100 over the visible spectrum. Following the circular polarizer, an imaging system, matched to the f/# of the monochromator, was used to form an image of a 2x15 mm^2 area of the lightpipe on the monochromator slit. Finally, the dispersed light was detected by a photomultiplier tube (PMT) and transferred to a personal computer via a digital oscilloscope.

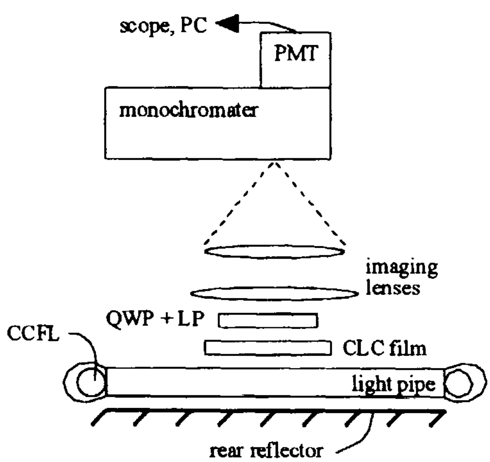

FIGURE 1 A schematic diagram of the experimental apparatus.

A COMPARISON BETWEEN TWO TYPES OF BROADBAND CLC FILMS

Two types of broadband CLCs were studied. One consists of a stack of right-handed (RH) red-, green- and blue- (RGB) reflecting CLCs, each consisting of a mixture of CLC silicones (Wacker Chemie, GmbH) and low-molecular-weight chiral nematics, while the other consists of a RH broadband (BB) CLC that achieves its wide selective reflection band because of its engineered pitch distribution. Transmission spectra of both of these materials is superimposed on the backlight lamp spectrum in Fig. 2.

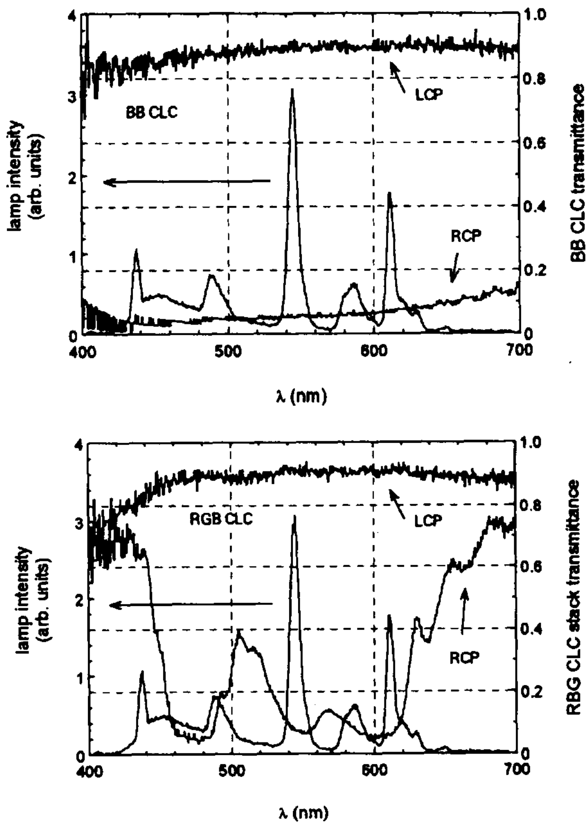

FIGURE 2 Two CLC spectra superimposed on a backlight lamp spectrum.

Both types of CLCs were placed in the backlight apparatus, using a metallic mirror for a rear reflector. It was found that integrated spectra increased by 66% and 52% for the BB CLC and RGB CLCs, respectively, compared to integrated spectra using a circular polarizer alone. (Note that without a CLC polarizer, a circular polarizer functions merely as a linear polarizer in the experiment.) The extinction ratios for the films were 7.2 for the BB CLC, and 4.3 for the RGB CLC stack. The enhancement and extinction characteristics of these materials is easily explained in terms of the overlap of their selective reflection properties with the lamp spectrum.

A COMPARISON OF DIFFUSE AND SPECULAR REAR REFLECTORS

The intent of the second experiment is to discern whether a diffuse or specular reflector is better suited for use in a CLC-based LCD backlight. In this experiment, the BB CLC film was utilized, and two rear reflectors were tested: (1) the original diffuse reflector that came with the backlight and (2) a front-surface Al mirror, cut to fill the entire plane of the lightpipe.

Backlight intensity spectra taken with the two mirrors are shown in Fig. 3. For the sake of clarity, the spectrum was truncated to include only the green spectral component of the lamp. The two lowest spectra in the graph were taken using the left circular polarizer, but no CLC; these data represent baseline data from which comparisons can be made of luminous backlight output with, and without a CLC film. Note that these spectra show that the diffuse mirror yields ~25% more light output from the lightpipe than the Al-coated mirror. However, when the BB CLC is incorporated into the backlight, its integrated output using the diffusive reflector is only 10% higher than when the Al mirror is used. Put another way, the backlight output increases by 45% when using the stock mirror, but increases by 66% when using the Al mirror. Hence, based on this measurement of forward-going light, it would seem that a specular reflector enhances the performance of a CLC-based backlight better than a diffuse reflector. This may not have any practical implications for CLC-based backlights, though, since Al mirrors have a reflectivity of ~90% across the visible, thus, a better specular reflector may not be able to enhance the performance of a CLC-based backlight any better than one incorporating current diffuse reflector technology.

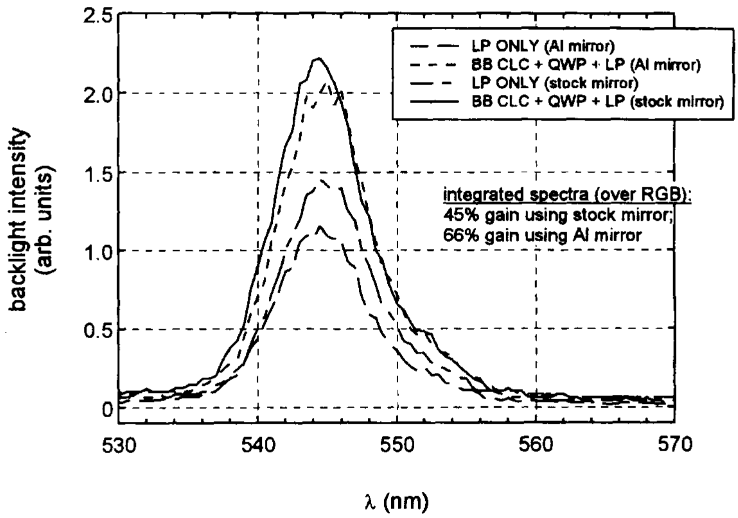

FIGURE 3 A comparison of two reflectors used in a CLC-based backlight.

BACKLIGHT OUTPUT AT DIFFERENT POINTS ON THE LIGHTPIPE

The final experiment that was performed involves looking at backlight enhancement at two different positions on the lightpipe. In this case, one site is at the center of the lightpipe and the other is 1 cm away from an edge holding one of the two CCFLs. The center of the lightpipe was measured to contain a 79% areal density of scattering material while the edge site was measured to have a 24% density of scattering material. Hence, this experiment was designed to investigate the effects of scattering from the lightpipe on light recycled between the CLC and the rear reflector.

For the present test, the BB CLC is utilized and the metallic mirror is used as the rear reflector. Since the absolute light output from the two sites being investigated is drastically different (due to the positional dependence of the scattering pattern density), polarized backlight output is normalized according to the level of light at the peak of the green lamp component when a LCP polarizer is inserted into the backlight, but the CLC is left out. Backlight spectra taken at the two sites is presented in Fig. 4. There is a 66% gain at the center of the lightpipe, and a 58% gain at its edge. Thus light recycling at the lightpipe is seen to be somewhat advantageous in CLC-based backlights.

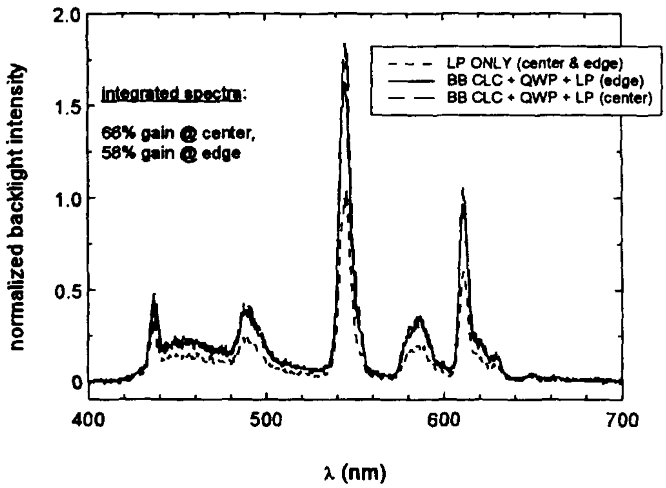

FIGURE 4 Positional dependence of backlight enhancement.

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