Title: Liquid crystal display efficiency enhancement using low-absorption color filters and color recycling

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ABSTRACT

A new technology, developed at Jet Propulsion Laboratory (JPL), using low-absorption color filters and color recycling system, is able to enhance the efficiency of current liquid crystal device (LCD) up to 500%. This technology can also be used to LCD projection displays, which will enable a single panel projector to reach an efficiency as same as a three panel projector.

Keywords: LCD, color filter, color recycling, display, projector.

A. Preference for oral or poster: both
B. Application sessions: Display system
C. Symposium topic: Novel display devices and systems

## Technical summary

One problem facing the direct view liquid crystal display (LCD) is low efficiency. At first, a half of the light is thrown away due to polarization requirement, then, over 2/3 of the remain light is wasted due to in-pixel dye color filter, and finally, the limited aperture ratio induce another factor of energy lost.

The new technologies of reflective color filter and color recycling system[1,2], invented by Dr. Yu Wang at JPL, can be used for flat panel display to replace current dye color filters to reduce power consumption, prolong battery operation time before recharge up to 500%, and lower manufacturing cost. This technology can also be used for LCD projectors, to enable a single panel LCD projector to reach brightness brighter than a three panel LCD projector.

The technology for color filtering in a liquid-crystal or other flat-panel display device will make it possible to brighten the display without increasing the amount of light supplied from behind the panel. The need for technology arises as follows: At present, each pixel in a typical color liquid-crystal display device contains three dye filters: red, green, and blue. Each filter transmits its single primary color and absorbs the other colors, so that less than one-third of the available light is used for viewing. In addition, the liquid-crystal display uses polarized light, so that half of the incident unpolarized illumination is necessarily wasted. The net result is that less than one-sixth of the incident unpolarized light is utilized. One does not have the option of increasing the illumination substantially to brighten the display because the increase in heat generated by absorption of light in the filters could harm the display device.

In the proposed technique, one would replace the dye filters with reflective color filters, for example: thin metal film filter[3,4], surface-plasmon filter[5,6] or interference filters, which are more reflective than absorptive. In addition, the filters and illumination optics will be arranged so that much of the light reflected from the filters would be reused as illumination. The overall effect should be an increase in brightness and efficiency.

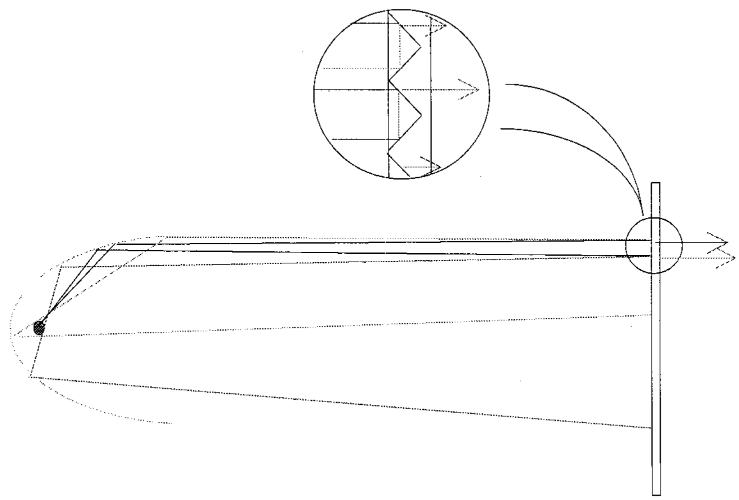

Fig. 1 Color recycling using surface plasmon filters.

Figure 1 illustrates this concept as applied to a liquid-crystal panel back-lit by a lamp with a collimating reflector. Light reflected from a color filter on the panel will return to the collimating reflector, where it will be reflected twice and sent to a different location on the panel. Of course, neither the original light from the lamp nor the light reflected from the panel will be collimated perfectly as shown in simplified form in the figure; all incident and reflected beams of light will have some angular spread. This spread would be beneficial in that it would make the illumination more nearly uniform across the panel. Therefore this panel can generate an image three times brighter than a same panel using the conventional dye color in-pixel color filters. In addition, the in-pixel surface plasmon color filters can be replaced by either thin metal filters or interference filter. Though Fig. 1 is an example of using this technology for projector, it can be easily converted to be used for a direct view panel.

I have reported using surface plasmon tunable color filters for flat panel displays[7,8]. Surface plasmon color filters can generate a very good color spectrum, and con be fabricated as in-pixel color filters to replace the dye color filters.

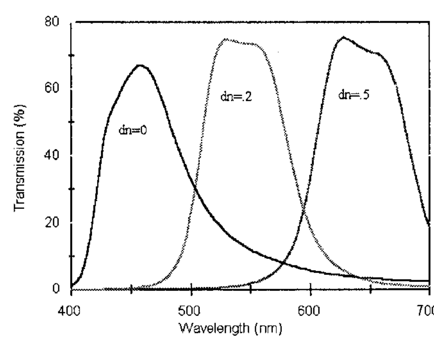


Fig. 2 Transmission spectrum of surface plasmon color filters.

In this case, one polarized color passes through the surface plasmon filter, and the rest of the light reflects back toward the light source.

The advantage of using surface plasmon color filters is that the surface plasmon filters can only allow light in one polarization direction—the p-ploarized light to pass through, and the s-polarized light will be reflected back. Therefore, the system of Fig.1 can also be used for polarization recycling, with some modification of the surface plasmon filters on the panel. Figure 2 shows a proposed configuration of an in-pixel surface-plasmon color filter, which will contain long, narrow microprisms in odd-numbered rows and shorter prisms oriented perpendicularly to them in even-numbered rows. Light that is p- or s-polarized to the longer prisms will be s- or p-polarized, respectively, to the shorter prisms. Each prism will pass light of only one polarization and reflect light of the other polarization. Thus, the polarized light not utilized in each pixel will be sent back to the collimating reflector and redistributed elsewhere on the panel, where some of it will be utilized in other pixels.

Therefore, the panel showed in Figure 2 not only recycles the color (which leads to a tripled efficiency), but also recycles the polorization (which leads to another doubled efficiency). Depends on design of optical system, a 300—500% efficiency enhancement can be expected. Note the surface plasmon color filters can be replaced by thin metal film filters or interference color filters, then another polarization recycle system has to be used, which is another technology invented at JPL[9].

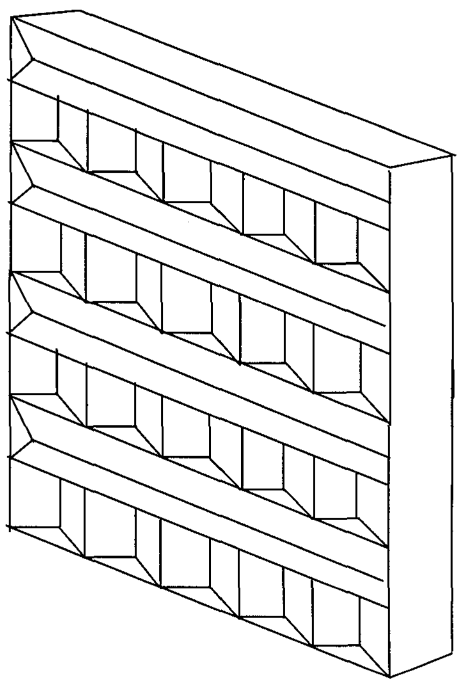

Fig. 2 LCD panel using surface plasmon filters for both color and polarization recycle.

Acknowledgments:

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