An RGB Laser-backlit Liquid Crystal Display

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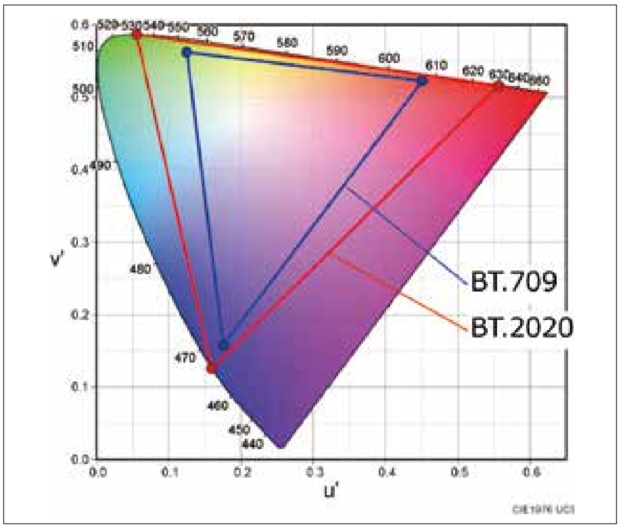
1. Introduction

Test broadcasts of 4K video began in Japan in 2014, and actual 4K broadcasts are scheduled to be started by CS during the 2015 fiscal year. In addition, according to the roadmap of the Ministry of Internal Affairs and Communications, the plan is to commence practical broadcasting of 4K/8K programs in 2018, and to broadcast most of the events at the 2020 Tokyo Olympic and Paralympic Games in 4K and 8K. This move towards high-definition video is due to the establishment of ITU-R Recommendation BT.2020 by the International Telecommunication Union (ITU) in 2012. This recommendation prescribes not only video formats for ultra-high definition television (HDTV), but also the color gamuts of display devices. Compared with the earlier ITU-R Recommendation BT.709, which relates to HDTV, BT.2020 calls for a gamut that is approximately 1.7 times larger on the u'v' chromaticity diagram (Figure 1).

To take advantage of the wide gamut characteristics of BT.2020 in a liquid crystal display, it is necessary to not only improve the performance of the color filters in the liquid crystal panel, but also to expand the color gamut of the backlight by increasing the color purity of the light source. Mitsubishi Electric has already researched the expansion of color gamuts by using laser diodes with high color purity as light sources for televisions, and in 2012 we released the *Real Laservue (LCD-55LSR3)* laser-backlit liquid crystal television. The *LCD-55LSR3* was the first consumer-oriented liquid crystal television to incorporate a backlight made using red semiconductor lasers.

■ **Figure 1: Color gamuts of HDTV (BT.709) and UHDTV (BT. 2020)**



We have now applied our laser backlight technology to a wide-gamut 4K liquid crystal display monitor that can display the BT.2020 gamut by using a backlight with semiconductor lasers in three primary colors (RGB), which we developed in partnership with NHK's Science & Technology Research Laboratories. This article presents an overview of this new display monitor.

2. Expanding the color reproduction range of a liquid crystal display

In a liquid crystal display, the liquid crystal display elements contain color filters that extract the red, green and blue spectral ranges of the light emitted from the backlight in order to display any color. If the backlight uses light-emitting elements that have a continuous spectrum over a wide bandwidth, like white LEDS for example, then to improve the color reproducibility it is necessary to use filters with a narrower passband. However, this means that less light passes through the color filters, making it difficult to achieve sufficient brightness. In other words, it is necessary to use more light-emitting elements and/or increase the input power, resulting in increased power consumption. Therefore, to improve the color reproducibility of a liquid crystal display, it is necessary to increase the color purity of the light source.

3. An RGB laser-backlit liquid crystal display

3.1 Backlight system

The backlight in a liquid crystal display is required to provide the liquid crystal panel with uniform planar illumination from its back surface. When using lasers as the backlight light sources, it is important to be aware that lasers and LEDs have very different emission characteristics. Compared with an LED, a laser has a much smaller light-emitting area and a smaller divergence angle, and it is thus not possible to ensure uniform illumination without performing adequate diffusion. Our newly developed RGB laser backlight has laser light sources places along the left and right edges of the screen, and diffuses this light by means of a diffuser component made of cylindrical light guide rods. These light guide rods are made from a transparent substrate containing a small quantity of a diffuser material, and have a laser light source situated at one end. Light emitted from the lasers enters the light guide rods in opposite directions and propagates along them by total internal reflection. Light that shines on the diffuser material contained in the light guide rods undergoes diffuse

Figure 2: Principle of light emission from light guide rods

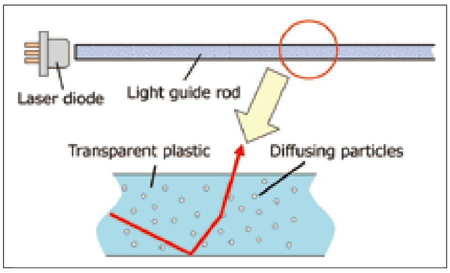
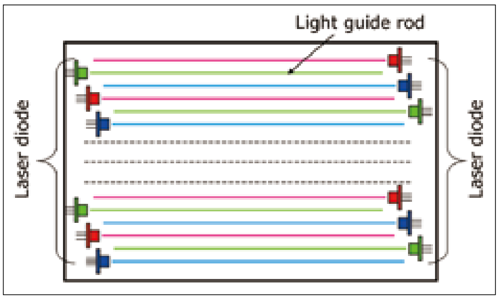


Figure 3: Layout of light sources



reflection (or transmission), which causes its propagation direction to change. When light whose direction has been changed in this way reaches the surface of the light guide rod at an angle that is too steep to satisfy the conditions for total internal reflection at the air-rod interface, it escapes from the rod in the circumferential direction and is emitted like light from a fluorescent tube (Figure 2). Although the light emitted from the light guide rods has a longitudinal intensity distribution, this is optimized by appropriately adjusting the concentration of diffusing material contained in the rods. As shown in Figure 3, the light guide rods are aligned with the light sources in the vertical direction of the screen.

3.2 Light sources

The gamut stipulated by BT.2020 is defined by RGB primary colors on a spectral locus shown on the chromaticity diagram corresponding to wavelengths of 630 nm (R), 532 nm (G) and 467 nm (B). In an RGB laser backlight, each of these light source wavelengths is selected as a target. For ease of handling, the light-emitting elements for each color are sealed inside a metal container (package) of the same shape, with a flange part (stem) diameter of 9.0 mm.

3.3 Liquid crystal panel color filters

As shown schematically in Figure 4, the color filter transmission characteristics have different passbands for the R, G and B colors. In particular, there is an overlap between the B and G passbands. Therefore, when displaying B on the screen, the color is diluted by being mixed with G light (reducing the color purity). To remedy this mixing, we adjusted the B filter. In Figure 4, the dotted line for B shows the initial transmission characteristic, and the solid line shows the improved transmission characteristic. By improving the color filter transmission characteristic in this way, we have actively suppressed the panel's loss of color purity.

3.4 Optical characteristics of the display

Figure 5 shows the results of using a spectral radiometer to measure the color reproduction range of this display, plotted on a CIE 1976 chromaticity diagram. The gamut is almost identical to that of BT.2020, thus confirming that this is an ultra-wide gamut liquid crystal display that can cover 98% of the BT.2020 gamut.

4. Summary

In a joint project, Mitsubishi Electric and NHK Science & Technology Research Laboratories have developed a laser-backlit liquid crystal display that has a wide color gamut corresponding closely with the provisions of BT.2020 by using RGB semiconductor lasers in the backlight. This display was presented at NHK's Science & Technology Research Laboratories Open House event in May 2015, and at CEATEC JAPAN 2015 in the following October.

Figure 4: Light source spectra and transmission characteristics of color filters (schematic)

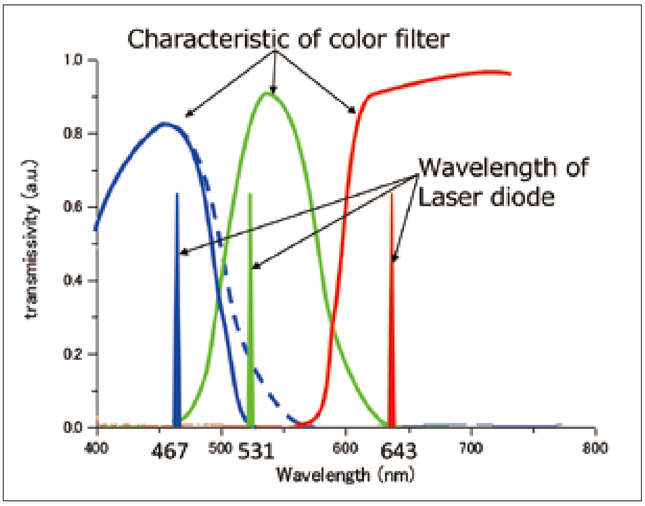


Figure 5: Measurement results: chromaticity diagram