56.3: 65-inch, Super Slim, Laser TV with Newly Developed Laser Light Sources

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Abstract
A new light source for laser TVs has been developed along with a 65-inch super slim laser TV that employs the light source. In this stylish laser TV set, a depth of 255 mm has been realized owing to the new laser light source, a compact optical engine and a small laser drive power supply which are optimized to the light source.

1. Introduction
The international standardization of color spaces has progressed in recent years, and is called an extended color space, allowing us to express a color gamut wider than sRGB and ITU-R BT.709 [1]. An extended color space, sYCC, applicable to still pictures is already widely used in digital still cameras and color printers [2]. In January 2006, another extended color space, xvYCC, aiming at moving pictures, was also standardized internationally. Display units having a wider color reproduction gamut have been released one after another while extended color spaces are in the process of international standardization. For liquid crystal panels, we see that the improvement of color filters and the enhancement of fluorescent substances that are used in cold cathode fluorescent lamps (CCFL) as well as the adoption of LED backlights have already started in order to increase the number of colors expressed.

As a means of obtaining a wider color gamut for display units, we have been developing laser TV sets that use three-primary-color lasers for the light source, and have previously released laser TV sets of 52 and 56 inches [3-4].

We have worked on this project to develop new laser light sources for laser TVs as well as a small power supply to drive them and a compact optical engine that are all optimized to the laser light source, aiming at the production of laser TVs, and eventually we prototyped a 65-inch laser TV product, all whose of components are housed in a thin enclosure.

2. Development of Laser TV
A super slim, laser TV with a screen size of 65 inches and a depth of 255 mm has been developed. Figure 1 shows the prototype of the super slim laser TV. Figure 2 shows appearance of the prototype units.

The full-fledged development of our laser TV started in 2005. Laser TV sets with the screen sizes of 52 and 56 inches have been prototyped so far and we have now successfully developed a 65-inch super slim laser TV product. Table 1 lists the specifications of laser TV. Figure 2 shows appearance of the prototype units.

During the development of the 52-inch laser prototype TV unit in 2006, we discussed the basic optical verification of a video picture display using laser beams, the color reproduction gamut of laser light source and the color expression method. For the 56-inch prototype unit developed in 2007, the verification of products with a slimmer depth was conducted. For each prototype unit, an optical engine was installed in the TV main unit for theoretical prototyping while the laser light source, the drive circuit for laser light source and the video picture signal processing circuit are housed in the pedestal that supports the laser TV main unit as shown in Figures 2a) and 2b. The laser light source and the optical engine are connected by an optical fiber cable.

For the latest prototype unit, all components are housed in the 255 mm deep enclosure as shown in Figure 2c. To achieve this prototype unit, the laser light source, power supply and optical engine were all made smaller, and a new laser module was developed, which provides 500 cd/m² (@12,000K) for the size of 65 inches. Further, a very advanced video picture signal processing LSI is used in the video picture signal processing circuit. The following section describes the basic technology.
Table 1 Specifications of laser TV

<table>
<thead>
<tr>
<th></th>
<th>New Prototype</th>
<th>2007 Prototype</th>
<th>2006 Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Size</td>
<td>65 [inches]</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>Luminance (@12,000K)</td>
<td>500 [cd/m²]</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Laser Power</td>
<td>23.3 [W]</td>
<td>19.6</td>
<td>18.0</td>
</tr>
<tr>
<td>Dimensions (HxWxD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV chassis</td>
<td>1012x1466x255</td>
<td>918x1280x263</td>
<td>864x1260x473</td>
</tr>
<tr>
<td>External Box</td>
<td>-</td>
<td>800x1700x700</td>
<td>800x1800x1000</td>
</tr>
<tr>
<td>Color Gamut on u’v’ (vs ITU-R BT.709)</td>
<td>208%</td>
<td>182%</td>
<td>179%</td>
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</tbody>
</table>

3. 65-inch Super Slim Laser TV

3.1 Laser TV Specification

The developed super slim laser TV has a screen size of 65 inches and a depth of 255 mm as shown in Table 1. The newly developed R, G and B lasers have a peak output of 23.3 W in total. In addition, the luminance of 500 cd/m² (@12,000 K) for the 65-inch screen size was achieved through the development of a small optical engine with improved light use efficiency. Figure 2 shows the color reproduction gamut of the latest laser TV plotted on a u’v’ chromaticity diagram. The laser TV ensures a color reproduction gamut of 208% in relation to BT.709 (u’v’-chart).

![Figure 2 Outline drawings of laser TV prototypes](image)

3.2 Compact Optical Engine

Figure 4 shows the optical engine for the newly developed laser TV. This optical engine incorporates a super wide-angle projection optical system, consisting of a projection lens and an aspherical mirror, and it can project images onto the 65-inch screen at a projection distance approximately 100 mm from the aspherical mirror. The adoption of a large convex aspherical mirror enabled color aberration and distortion, which was one of the problems of super wide-angle projection, to be reduced to an extremely low level. The utilization of laser beams with a higher directivity than lamp rays also contribute to making a product with a high f-number optical system, allowing us to make a more compact optical system and to provide higher contrast. Figure 5a shows the projection lens for the currently developed laser light source, and 5b shows the projection lens for the previously developed lamp light source [5]. The use of the high f-number in the optical system enabled the maximum effective diameter of the projection lens to be reduced to approximately 40% of the conventional value. Therefore, this super wide-angle projection optical system helped us realize an optical engine dedicated for our high image quality and thin, compact laser TV.
3.3 Laser Light Source Unit

Figure 6 shows the laser light source unit developed for this laser TV. To realize a thin laser TV, the 106 mm thick unit contains RGB laser modules as well as a cooling mechanism for the laser module, a power supply and a control circuit to drive them. The control circuit of the laser light source receives a laser turn-on timing signal from the video picture signal processing circuit, and drives the laser function according to the incoming signal. Inside the laser module, semiconductor lasers and coupling optical parts are installed, and the laser beams coming from the semiconductor laser are guided into the optical fibers by the coupling optical system. The laser light source unit and the optical engine are connected by optical fiber cable, and the laser beams emitted from the laser light source unit run through the optical fibers, and then the beams are guided to the optical engine.

3.4 Laser Light Sources

The prototype unit uses three RGB primary color lasers with wavelengths of 447 nm for blue, 532 nm for green, and 640 nm for red. The lasers have peak output of 7.6 W for red, 6.0 W for green and 9.7 W for blue, totaling 23.3 W. The proportion of these values is designed so that the color temperature of white will be optimized when displayed on the screen. The modules of the optical fibers connecting the laser light source units and the optical engines, including the coupling optical parts, have a volume of approx. 60 ml for red, 30 ml for green, and 220 ml for blue. Of these, green achieves high power with an extremely compact module.

Figure 7 shows the newly developed green laser. This single chip could succeed in producing a green light output of 6.0 W.
3.5 Image Processing
If conventional video picture signals are projected on a display unit with a wide color reproduction gamut, they produce unnatural video pictures with dark colors. This is caused by the large difference between the color space that is produced by the video picture signals and the color space that the monitor unit provides. Conventional video picture signals are generated according to the color space, which is defined on the basis of CRTs such as sRGB and ITU-R BT.709 [6]. With wide-color-gamut display units that have LED or laser light sources, the difference is conspicuous between the video picture signals and the displayed color space. If conventional video picture signals are projected without any adjustment, the small color space of the video picture signals is linearly enlarged on the large color space of the monitor, showing dark colors clearer while the pale colors are darker at the same time. If a skin color or other known color is expressed in red, in particular, we will have a strong sense of incompatibility. We have solved this problem using a natural color matrix (NCM), which is our unique color management technique. This NCM can disassemble video picture signals into a luminance component and 12 color components, and then reassemble them into video picture signals that fit the color space of the laser TV through a matrix operation. Typical colors were extracted from several scenes for assessment and displayed on a laser TV and a liquid crystal TV, and the chromaticity expressed on the screen was measured.

Figure 8 shows the results of measurement. As seen in the diagram, colors that are near to saturated are expressed in a deeper tone using the wide color reproduction gamut of the laser TV, but the skin color plotted at the center is expressed with almost the same chromaticity. Thus, it is possible to express colors near to saturated colors in the fresh colors that the laser TV produces by means of the nonlinear color mapping process that NCM provides, and to express pale colors such as skin color in the same way as a conventional TV. Due to this mechanism, it is possible to express even conventional video picture signals in vivid video pictures having deep and natural colors. As a matter of course, the NCM can express the color reproduction gamut of laser TVs also in the color reproduction gamut of ITU-R BT.709 in a controlled way.

4. Conclusion
A compact laser light source unit has been developed through the higher light output of a newly developed laser light source and a small power supply that drives this laser unit. In addition, prototyping a slim and stylish laser TV in a shape nearer to products has resulted in success, and all components are housed in a thin enclosure with a depth of 255 mm for a screen size of 65 inches by making a smaller optical engine by an optical design that best matches this laser light source.

5. References