

Extending the Gamut: Microlaser-based Display Technology

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Abstract

Advances in microlaser technology are enabling the development of display devices with the extensive color gamuts provided by laser wavelengths. In addition to providing wide gamuts, these devices also are capable of providing accurate and reproducible color in high resolution projection displays. The unique features of such displays are presented and the implications of the expanded color gamut are discussed.

Introduction

The search for improved illumination sources and for accurate color control in displays has provided the impetus for the development of compact microlaser systems. Laser-based projection displays offer advantages over traditional lamp and filter based technologies. Such systems have the potential to provide efficient high luminance displays with long lifetimes. Meanwhile, the color gamut provided by three laser-based primaries is much larger than those available from other sources. This larger gamut is expected to prove especially advantageous in industries where color fidelity plays a crucial role. In addition, the wide gamut facilitates the color matching of display devices to printing devices.

Prior to the development of microlasers, laser-based displays used inefficient gas lasers requiring cumbersome cooling equipment.[1] These systems were expensive and bulky, filling entire rooms with equipment. However, as laser efficiency has improved, interest in laser-based displays has resurfaced. Advances in microlaser technology now make it possible to provide laser sources for display applications requiring wide color gamuts. The recent development at Laser Power Corporation (LPC) of compact, stable microlasers at visible wavelengths provides sources which are ideally suited to self luminous display applications. In providing a wide gamut, such sources enable designers the opportunity to achieve true "picture window" imagery. To achieve such imagery, microlasers can be used either as backlights for 2-D spatial light modulators or as writing elements in direct-write raster scanning configurations.

Laser Projection Displays

Laser-based projection displays create images either by directly writing the image on a projection screen or by illuminating a spatial light modulator (SLM), an image of which is projected onto the screen. Direct write systems require the laser beam to be scanned across the viewing screen in a manner similar to that employed in a CRT. Hence, the laser beam intensity is modulated with video information and is scanned through vertical and horizontal beam deflectors to project a two-dimensional image. Deflection of the beam can be accomplished either with electro-optic devices, mechanical mirror devices, or acousto-optic devices. Consequently, direct write systems provide a measure of flexibility in resolution and in display format, depending upon the choice of deflection devices.

Fixed resolution devices using SLMs, such as active matrix liquid crystal devices or digital micro-mirror devices, can be backlit with microlaser light. The collimated nature of laser illumination lends itself to much greater efficiency than is possible with conventional lamps. Also, liquid crystal based devices, when illuminated with microlasers whose outputs are polarized, do not suffer the losses associated with the prepolarization required in lamp-based systems. More importantly, microlasers can provide display systems capable of extended color gamuts.

Microlaser-based Technology

Development efforts at LPC have focussed on the development of red, green, and blue diode-pumped solid-state microlasers for use in displays producing full-color images with extremely high resolution. Earlier work on laser-based displays encountered difficulties with the size and power requirements of gas lasers. Red, green, and blue microlasers provide a significant improvement over gas lasers, providing an estimated overall electrical to optical efficiency of 5% (which corresponds to an overall efficiency of 10 lumens/watt). Microlasers produced by LPC occupy less than 4 in^3 each and are capable of producing a watt or more of output power. These performance figures have allowed the development of highly efficient laser-based display systems. Toward this end, a joint venture between LPC and Proxima Corporation has produced a prototype laser projector with an all-inclusive size of 15" by 15" by 8" that provides 600 lumen full color images at 1280 by 1024 resolution. A prototype of this projector was featured at the Air Force Phillips Laboratory's briefing for industry in August 1996.

The compact sources incorporated into the prototype projection display produce speckle-free imagery with colors encompassing essentially the entire gamut. Specifically, operating wavelengths of 457 nm, 532 nm, and 650 nm they provide a gamut which greatly exceeds either the NTSC or the SMPTE 240M color gamuts (as shown in Figure 1). The 1976 CIE u'v' color coordinates for these gamuts and the locus of saturated spectral colors also are shown in Figure 1.

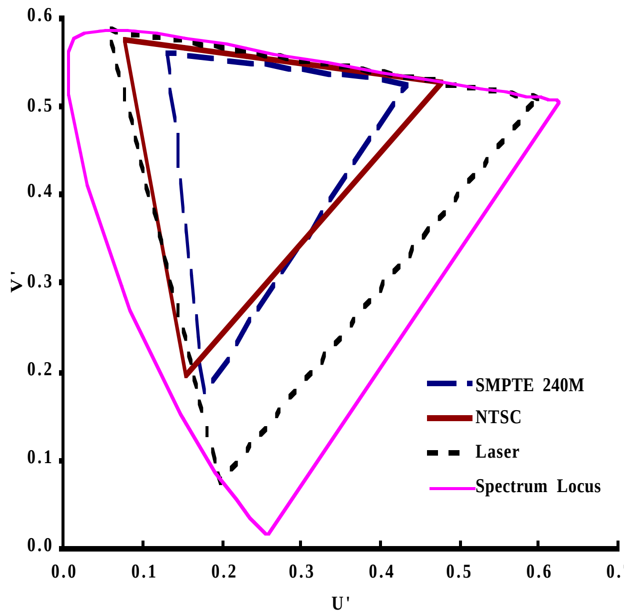

Figure 1. Color gamuts of SMPTE 240M, NTSC, and microlaser-based display.

The characteristics of microlasers insure stable color performance for the lifetime of the laser. Meanwhile, the color fidelity of the primary sources permits digital control of color. This control, in turn, permits colors to be faithfully reproduced both from display to display and with uniformity across the projection area.

Unlike CRT or lamp based displays, microlaser-based displays do not suffer from shifts in color with age. Hence, along with faithful representation of color from display to display, colors can be precisely reproduced over time. Appropriate feedback loops can maintain color balance as laser output powers degrade with time. Along with maintaining color balance, microlaser lifetimes exceed those of typical projection lamps by a factor of 10 or more. The combination of long lifetime and stable color provided by microlasers is particularly germane to color critical display applications.

While extending the gamut, LPC also has concentrated on the development of ultra-high resolution displays. Direct write systems offer multiple resolution performance as well as the ability to address various display gamuts. A breadboard for a direct write projector which is compatible with 1280 by 1024 resolution at an interlaced frame rate of 60 Hz is due to be completed in early 1998. Systems currently under development are capable of resolutions up to 5000 by 4000 with 8-bit intensity per channel.

Implications of the Expanded Gamut

The extensive gamut, when combined with digital control, allows microlaser-based displays to reproduce colors with a high degree of accuracy. Also, since microlaser displays provide highly uniform intensity across the projected image, they avoid the roll-off which is typical of CRT and lamp-based projectors. In addition, they provide the color scientist with a means for testing the psychovisual effects associated with saturated, intense colors. The color gamut available may, in fact, exceed that of surface colors.[2] As a consequence, such displays may be useful in the graphic arts and print industries, allowing an additive representation of the surface colors producible with inks. Figure 2 shows the spectrum locus and typical gamuts for a monitor, a printer, and a laser display in 1976 CIE coordinates.

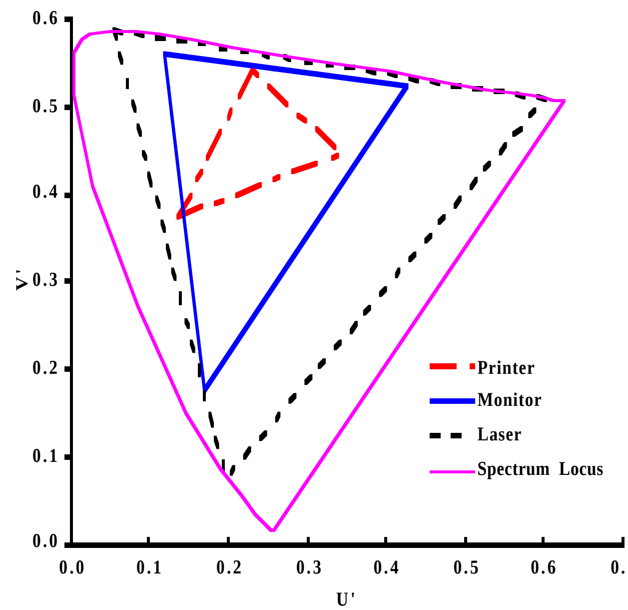

Figure 2. Color gamuts of typical printer, monitor, and microlaser-based display.

The expanded gamut provided by microlasers is compatible with multiple display formats and with color gamuts such as NTSC, HDTV with SMPTE 240M, and PAL/SECAM in addition to VGA or XVGA. This versatility in display format allows the user more freedom to choose media for presentation without the limitations normally imposed by format compatibility and by gamut compression.

Conclusions

Use of lasers in displays has finally become a reality with the successful development of red, green, and blue microlasers. These compact, efficient, high power sources operating at visible wavelengths provide the ultimate sources for projection displays. Displays employing such sources are capable of high luminances, high resolution, and extensive color gamuts with digitally accurate color reproduction.

It is of note that microlaser-based displays can provide users with a wider choice of media and can enhance applications relying upon high performance displays. The extended gamut allows the presentation of highly saturated colors at high luminances, as well as at low luminances similar to real scenery with colored shadows, making picture window imagery a possibility. Observer reactions to such imagery have been favorable.

As a final comment, microlaser displays have the unique capability of being compatible both with multiple resolutions and with multiple color gamuts. Consequently, as these versatile displays become available, they will extend not only the color gamuts available to users, but also the applications for projection displays.

References

1. K. E. Jachimowicz, *Electro-Optical Displays* (Ed. M. A. Karim) Marcel Dekker, 254-265 (1992).

2. C. M. Howard, *Proceedings of the SPIE 1996,* **2657,** 2-9 (1996).