Green light allows big pictures from small projectors

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Green-laser technology can provide bright, efficient, and high-resolution microprojector products with minimal power consumption for portable devices.

Mobile devices are increasingly being developed with functions beyond their original intended use, such as live television for cell phones. But the small displays on these devices limit the user experience. Miniature projectors have been proposed to address this issue. These devices are expected to be embedded in portable devices such as cell phones and laptop computers to provide images the size of A4 paper and larger in indoor lighting conditions. The challenge is to develop the correct microprojector configuration to balance size, cost, performance, and efficiency. These tradeoffs are primarily driven by the choices of light source and imaging mechanism.

Lasers have a more confined emission cone than LEDs and enable simpler light management using standard lenses. Lasers can be combined with a microelectromechanical systems (MEMS) mirror to assemble a compact projector. Red, blue, and green lasers are made collinear on the MEMS device that scans very fast in two dimensions, akin to the raster scan in conventional cathode-ray tubes. While scanning, the three lasers are turned on and off (modulated) quickly to produce the correct color balance. Lasers provide richer colors than LEDs and enable the microprojector to operate without focusing optics. However, the scanner configuration requires that the lasers are modulated at very high speeds (beyond 50MHz), depending on the image resolution. This eliminates the possibility of employing conventional green laser pointers, as these devices are limited to below 1MHz bandwidth. The modulation requirement is easily met for red and blue devices, since these are derived from semiconductor lasers used in the optical disk-drive industry.

Unfortunately, the unavailability of semiconductor green-laser technology has stunted the growth of the microprojector market. We have addressed this with our G-1000 architecture (see Figure 1), which consists of a semiconductor laser that emits at the 1060nm IR wavelength. The IR power is collimated and focused using a pair of lenses on a lithium niobate (LN) crystal that transforms the incident power into 530nm green light. This process of indirect generation of green light is termed ‘frequency doubling’ or ‘second-harmonic generation (SHG).’ The efficiency of green-light generation in the SHG process is a function of the power density of the IR radiation inside the LN crystal. By confining the IR light within a waveguide
(similar to optical fibers), we provided high conversion efficiency in a very short crystal length, resulting in a compact architecture (0.7 cm$^3$ envelope volume) suitable for integration inside a miniature light engine.

The challenge of launching and maintaining the IR power in the LN waveguide can be overcome using adaptive optics for beam steering. In this configuration, the two lenses are mounted on separate orthogonal, smooth-impact drive mechanism actuators that are constantly adjusted through a closed-loop operation to optimize green power. The actuators reduce assembly cost and allow operation over a wide temperature range and quick recovery from severe mechanical shock. Figure 2 depicts the green-power stability over 10–60°C. The 90mW output power (with 9% wall-plug efficiency, WPE) is sufficient to produce an image brightness of 20 lumens.

The fast modulation required for the scanner-based microprojectors is obtained by modulating the gain section of a distributed-Bragg reflector laser. We have shown that the G-1000 has modulation bandwidth exceeding the 100MHz required to achieve wide video-graphics-array image resolution. Alternate architectures of frequency-doubled green lasers use an intracavity configuration to obtain larger pump-field intensities but suffer from a tradeoff between WPE and modulation bandwidth. In such devices, the modulation speed is typically limited to less than 100MHz to minimize power consumption.

The lack of efficient, high-speed green lasers has limited development of the scanner-based microprojector market. We have shown that the G-1000 is compact, efficient, and can be modulated at very high speeds. Our next generation of green lasers will focus on improving the modulation frequency and efficiency and on further reducing the size. This will open up possibilities for consumer-electronics companies to let users project vivid images with minimal power consumption on their mobile devices.

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Vikram Bhatia is the manager responsible for design integration and product engineering in the New Business Development group, leading the development of the G-1000 green laser. He has authored more than 70 journal publications and conference papers, and is listed as a co-inventor on 10 US patents.

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References