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MICRODISPLAYS: Green, blue InGaN µLED microdisplay delivers video images

Not only is its luminance level several orders of magnitude higher than liquid-crystal-device (LCD) and organic light-emitting diode (OLED) displays, but a new video-capable emissive indium-gallium-nitride (InGaN) micro-LED (µLED)-based microdisplay also has low voltage requirements and is amenable to hybrid complementary metal-oxide semiconductor (CMOS) and IC assembly.[1] The GaN µLED microdisplay —currently operational in monochrome blue or green only, with 640 × 480 pixels and a chip size of 9.6 × 7.2 mm—was demonstrated by scientists from Texas Tech University and III-N Technology (both in Lubbock, TX) and the US Army Night Vision and Electronic Sensors Directorate (Fort Belvoir, VA).

Integration is key

Until now, semiconductor microdisplays were incapable of delivering video images because only one row of a monolithic µLED array could be accessed at any one time, making the task of connecting the huge number of required drive circuits within the array nearly impossible. But these roadblocks were overcome through three key developments: 1) fabrication of low-contact-resistance µLEDs with a 12 µm pixel size; 2) design and fabrication of an active-matrix driver IC through a CMOS process; and 3) hybrid integration of an InGaN µLED array with a silicon CMOS IC chip using flip-chip bonding with tiny 6-µm-diameter indium bumps. Low contact resistance was achieved by using a heavily magnesium-doped, p-type GaN contact layer to improve the III-nitride hole-injection process. The integration steps make possible an active-matrix display wherein each µLED pixel in the array has its own driver circuit that is also capable of storing intensity data.

A grayscale projected image of penguins from a green InGaN microdisplay (having a pixel size of 12 µm, pitch distance of 15 µm, and 19,200 total pixels) operates at a driving current of 1 µA per pixel. The device consists of an InGaN quantum-well active layer embedded between n- and p-type GaN. The InGaN quantum well has an emission wavelength of 517 nm. (*Courtesy of III-N Technology*)

Luminance values from a fully assembled InGaN microdisplay using green µLEDs were 1 mcd/µA for each 12-µm-diameter µLED pixel and increased nearly linearly up to 100 µA. The brightness of a green microdisplay with every pixel operating at 1 µA and a pixel-pitch distance of 15 µm is calculated at 4×10^6 cd/m^2—several orders of magnitude higher than comparable LCD or OLED microdisplays (see figure). Operating at 1 µA per pixel, a 640 × 480-pixel InGaN microdisplay would have a power dissipation of only 0.8 W, which is about two times lower or four times higher, respectively, compared to same-sized LCD or OLED microdisplays that have much lower luminance values.

Applications

Brighter and more energy-efficient microdisplays could not only find applications in mobile devices as displays and picoprojector components but are also valuable as light sources for optogenetic neuromodulation. "GaN microdisplays are expected to be more robust than OLED and LCD displays and are highly suitable for applications where performance, reliability, and lifetime are critical, such as head-up and wearable microdisplays for the military," says Hongxing Jiang, professor at Texas Tech and co-inventor of GaN µLED technology. "Also, SBIR contract support from the US Army Night Vision and Electronic Sensors Directorate made the recent advances possible. The final goal would be to bring the technology from laboratory prototype to mass production," he adds. —*Gail Overton*

REFERENCE

1. J. Day et al., *App. Phys. Lett.*, 99, 031116 (2011).

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