

# THE *Current*

October 21, 2026

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## **Red microLEDs developed at UCSB achieve record efficiency of 20.8%, operate at up to 200°C**

Gallium nitride has made highly efficient blue LEDs possible. Getting the same semiconductor to produce red light efficiently has proved much more difficult.

UC Santa Barbara researchers have now demonstrated red micro-light-emitting diodes, or microLEDs, that achieved an external quantum efficiency of 20.8% and maintained strong performance at temperatures as high as 200 degrees Celsius. The devices, narrower than a human hair, were developed in a study led by [Institute for Energy Efficiency](#) (IEE) doctoral research fellow Roark Chao.

“One material can emit every visible color now, which is advantageous for many reasons,” Chao said. “What we show in this paper is that by having very nice epitaxial growth and then manipulating the optical side of things, we’re able to further enhance the light output and get around 21% efficiency.”

The results, published Oct. 7 in [ACS Photonics](#), represent the highest reported efficiency to date for planar red gallium nitride microLEDs on sapphire substrates, according to the researchers.

“The impact of this research is significant because it brings us closer to producing efficient red, green and blue microLED Displays from gallium nitride,” said [Steven](#)

[DenBaars](#), IEE director and distinguished professor of materials and electrical and computer engineering in UCSB's Robert Mehrabian College of Engineering. "That opens the door to a new generation of energy-efficient displays, from smart glasses to projection systems."

DenBaars was a co-author of the study along with doctoral students Vincent Rienzi, Tanay Tak, Alejandro Quevedo, Kent Nitta and Justin Tan, [Nobel laureate Shuji Nakamura](#) and professors [James Speck](#) and [Jon Schuller](#), who co-advises Chao with DenBaars. The group is also affiliated with UCSB's [Solid State Lighting and Energy Electronics Center](#), which, like IEE, brings together university researchers and industry partners.

Gallium nitride, or GaN, becomes less efficient as researchers move from blue toward green light, a challenge researchers have long called the "green gap." Moving farther toward red compounds the problem.

To shift the color, researchers add increasing amounts of indium to create indium gallium nitride, or InGaN. But at the concentrations required for red light, quantum effects within the material increasingly interfere with its ability to convert electrical current into light.

The UCSB devices emitted light at a wavelength of 619 nanometers. Their performance reflected two complementary advances: the quality of the semiconductor material and a design that improved how efficiently light escaped from it.

Rienzi grew the material through a process called epitaxial growth, in which thin layers of crystalline semiconductor material are grown on top of one another, providing the foundation for efficient red emission. Chao then surrounded each microscopic LED with a ring-shaped structure known as a distributed Bragg reflector, which redirected light that might otherwise remain trapped inside the device, allowing more of it to escape.

"The challenge has been getting red LEDs to produce enough light without losing efficiency or shifting toward blue," said Chao. "What we've demonstrated is that we can achieve all three: high efficiency, greater brightness and stable red emission, even at elevated temperatures."

The devices achieved more than double the peak external quantum efficiency of previous red InGaN microLEDs published by the UCSB group, which had remained below 10%. At 200 degrees Celsius, they maintained more than 74% of their room-temperature light output under high-current operation, with a wavelength shift of less than eight nanometers.

Their high efficiency could also make red microLEDs useful in data centers, where optical interconnects are being developed to replace some of the copper connections between computing components.

“The idea is to use light instead of copper to move information,” Chao said. “Optical interconnects could substantially reduce the power needed for communication and, in turn, the energy required to keep data centers cool. For me, that’s one of the most important applications of this research.”

The advance could also help transform full-color displays, which typically rely on different semiconductor materials to produce red, green and blue light. The UCSB team’s results bring researchers closer to producing all three colors from gallium nitride, potentially simplifying manufacturing and enabling smaller, more energy-efficient devices.

The transparency of the sapphire substrate offers an additional possibility. Chao envisioned devices capable of emitting light from both sides, potentially enabling new kinds of displays.

Chao began working with Schuller, a professor of electrical and computer engineering, as a second-year undergraduate at UCSB, learning to fabricate semiconductor devices and investigate how light behaves at extremely small scales. A course with DenBaars later introduced him to GaN technology and its industrial applications. The two professors became his doctoral co-advisors. Chao credited Schuller with developing his scientific foundation and DenBaars with broadening his understanding of how research could translate into practical technologies.

“It was a real pleasure to mentor Roark as an undergraduate, and at this point he’s mostly the one doing the teaching,” Schuller said. “Advising him jointly with Prof. DenBaars has really helped cohere my group’s research with the cutting edge research coming out of SSLEEC.”

Chao's commitment to energy efficiency was also shaped by his late father, who grew up in the mountains of rural China without ever seeing the ocean. Chao recalled how much his father came to treasure the ocean and the conversations they shared about climate change and preserving the natural world for future generations.

"Technology isn't going to slow down," Chao said. "We're going to keep improving and building things. I want my research to help make that progress more energy efficient, without sacrificing the natural world we have now."

Tags

[Energy Efficiency](#)

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