# Engineers develop enhanced GaN-based LED array visible light communication system

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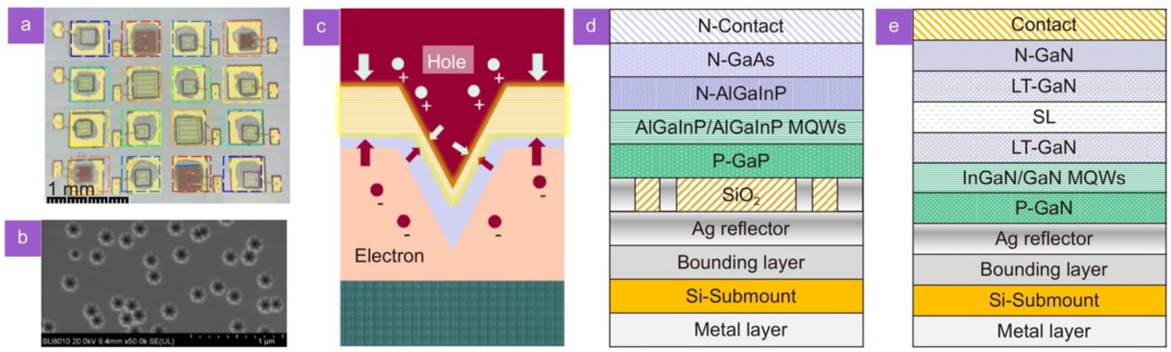


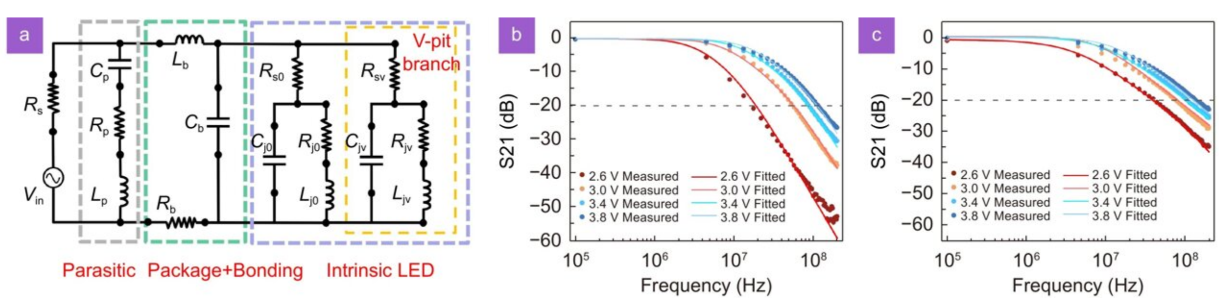

(a) The proposed 8-wavelength 4x4 LED array chip image, the colors of each dash line box represent the color of the LED unit. (b) The scanning electron microscope (SEM) image of the V-pit structure. (c) The vertical profile of the V-pit structure. (d) Layers of the red LED units (660 nm and 620 nm). (e) Layers of the GaN-based LED units (wavelengths from 570 nm to 450 nm). Credit: *Opto-Electronic Science* (2023). DOI: 10.29026/oes.2023.230005

With the large-scale commercial use of 5G, global academia and industry have started research on the next-generation mobile communication technology (6G).

However, the existing RF spectrum resources are seriously depleted to meet the spectrum demand of 6G for ultra-high speed and ultra-large capacity. This severe challenge stimulates researchers to focus on higher frequency bands such as terahertz, infrared and visible light. Among them, visible light communication utilizes the ultra-wide spectrum from 400THz to 800THz, which has the merits of no licensing, high secrecy, environmental-friendly, and no electromagnetic radiation.

At the same time, with the help of commercially available LED technology, visible light communication systems can be integrated with [lighting systems](). However, limited by the electro-optic response performance of LED devices, the actual available bandwidth of the system is very small compared with the frequency band of visible light.

Improving the available bandwidth of LED devices in visible light communication systems becomes an important problem to realize high-speed visible light communication. Micro-LEDs have a GHz-level -3dB device bandwidth. However, as the device size shrinks to tens of microns, the current density of micro-LED devices increases dramatically and is difficult to further improve.




(a) The proposed equivalent circuit for fitting both LEDs with and without V-pits (with tiny V-pits). The branch in the dash yellow box is dedicated to representing the extra current introduced by the V-pit area. And the other branch in the intrinsic LED part represents the flat quantum well region. The fitting result using the proposed equivalent circuit for (b) the sample without V-pits and (c) the sample with V-pits. Credit: *Opto-Electronic Science* (2023). DOI: 10.29026/oes.2023.230005

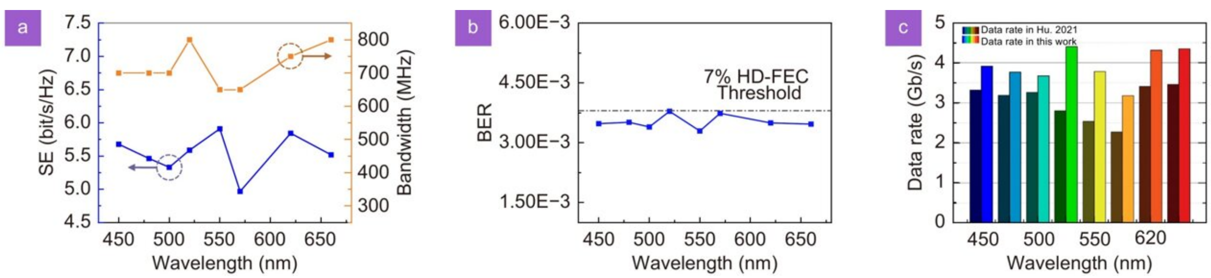
Under the limitation of current density, micro-LED is difficult to achieve watts level optical power, which is not suitable for long-distance and underwater optical communication that requires high-power optical transmitter devices. Therefore, how to improve the communication performance of conventional-size LED is also a key issue at present.

The authors of an article published in *Opto-Electronic Science* studied a wavelength division multiplexing visible light communication system based on multi-color LED. The system uses a Si substrate GaN-based LED with a 3D structured quantum well. In the active layer of this LED, there is a three-dimensional structure ("V" shaped pit, or V-pit) with a hexagonal profile, opening towards the P-type GaN layer.

Generally speaking, for GaN-based LEDs, in order to achieve longer spontaneous emission wavelengths, it is necessary to add a higher indium component in the quantum well, which leads to a serious GaN and InN lattice mismatch problem. However, the V-pit structure helps to screen the dislocations caused by lattice mismatches in GaN-based LEDs, thus significantly improving the quantum well quality and optical efficiency of GaN-based LEDs with long wavelengths (such as yellow-green bands).

The multicolor LED array used in this study contains eight different LED units. Up to eight independent channels for WDM can be used simultaneously. Except for the 660nm and 620nm red LED units, the other six LED units in the 570nm–450nm wavelength band use Si substrate GaN-based LEDs developed by the National Institute of LED on Silicon Substrate, Nanchang University.

Based on the LED array, the Fudan University team built a communication system and wrote advanced digital signal processing technology programs required for the system, including bit-power loading DMT modulation/demodulation program, DZN digital preequalizer, and software post-equalizer based on recurrent neural network. This communication system achieves a 31.38Gb/s total transmission rate.




Summary of the communication rate. (a) The spectrum efficiency (SE) and modulation bandwidth of the proposed 8-wavelength WDM system. (b) The BER of each channel, all the BERs are lower than the 7% HD-FEC threshold. (c) Comparison in data rate with the original design. The total data rate of the proposed size-improved design device is 31.38 Gb/s. Credit: *Opto-Electronic Science* (2023). DOI: 10.29026/oes.2023.230005

The authors also explain the principle of the V-pit combining physical model simulation and equivalent circuit modeling. During [model simulations](), the authors found that the V-pit strongly enhanced the current density in its vicinity. A great number of carriers flooded into the V-pit, and next, they were horizontally transported in the quantum well to the neighboring flat area.

According to this phenomenon, a special branch representing quantum wells was added nearby the V-pit in the LED equivalent model. This new circuit model successfully fits the response curve of the device. The model shows that the V-shaped pit effectively reduces the series resistance of the device and enhances the response of the device to high-frequency signals. This means that the V-pit brings higher electro-optic conversion efficiency and larger device bandwidth. Thus, the positive effect of the V-pit structure on the communication performance of LED devices is preliminarily explained in theory.

**More information:** Zengyi Xu et al, 31.38 Gb/s GaN-based LED array visible light communication system enhanced with V-pit and sidewall quantum well structure, *Opto-Electronic Science* (2023). DOI: 10.29026/oes.2023.230005

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