Integrated Metasurface-Freeform System Enabled Multi-Focal Planes Augmented Reality Display

A new publication DOI 10.29026/oes.2026.250031, discusses an integrated metasurface-freeform system enabled multi-focal planes augmented reality display.

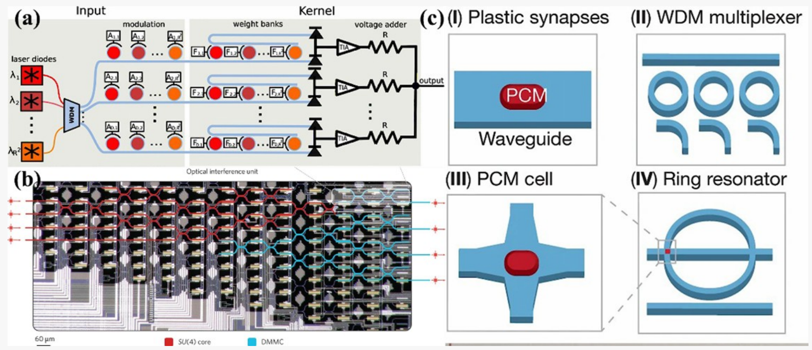

Fig. 1 Schematic of the hybrid optical meta-freeform system for real-time multi-focal planes AR display. (a) The novel AR system integrates a display screen, a multiplexing metasurface, and a freeform lens simultaneously. (b) Catadioptric birdbath structu

SHANNON, CLARE, IRELAND, February 5, 2026 /EINPresswire.com/ -- A new publication from Opto-Electronic Sciences; DOI 10.29026/oes.2026.250031, discusses an integrated metasurface-freeform system enabled multi-focal planes augmented reality display.

Driven by the advancement of artificial intelligence, augmented reality (AR) display technology is undergoing a leap from laboratory research to commercial application, poised to give rise to new forms of next-generation mobile terminals and usher in a new era of intelligent perception and spatial computing. However, the current approaches to real-time AR display technology are predominantly focused on single-focus plane displays, which lead to accommodation-vergence conflicts and are not conducive to long-duration use.

To address this issue, multi-focal AR display technology has emerged. By generating multiple discrete or continuous virtual focal planes that simulate the depth information of real objects, it has become a key technological pathway for enhancing user experience. Nevertheless, existing solutions struggle to simultaneously meet the optical requirements for multi-depth projection, and the demands for compact form factor and affordable expense. To achieve the natural integration of three-dimensional (3D) digital scenes with real physical environments, there remains a need to explore new optical materials, innovative optical system designs, and novel technological paths.

In response to the aforementioned challenges, Professor Wang Yongtian, Professor Huang Lingling, Associate Professor Yang Tong, and their team from Beijing Institute of Technology, in collaboration with Beijing NED+ AR Ltd., the Institute of Physics of the Chinese Academy of Sciences, and the National University of Singapore, proposed an innovative multi-focal plane AR display system that integrates a non-orthogonal polarization-multiplexing metasurface, freeform optical elements, and an OLED display screen. This work, titled "Integrated Metasurface-Freeform System Enabled Multi-Focal Planes Augmented Reality Display," was published in the first issue of Opto-Electronic Science in 2026 and was selected as the cover article.

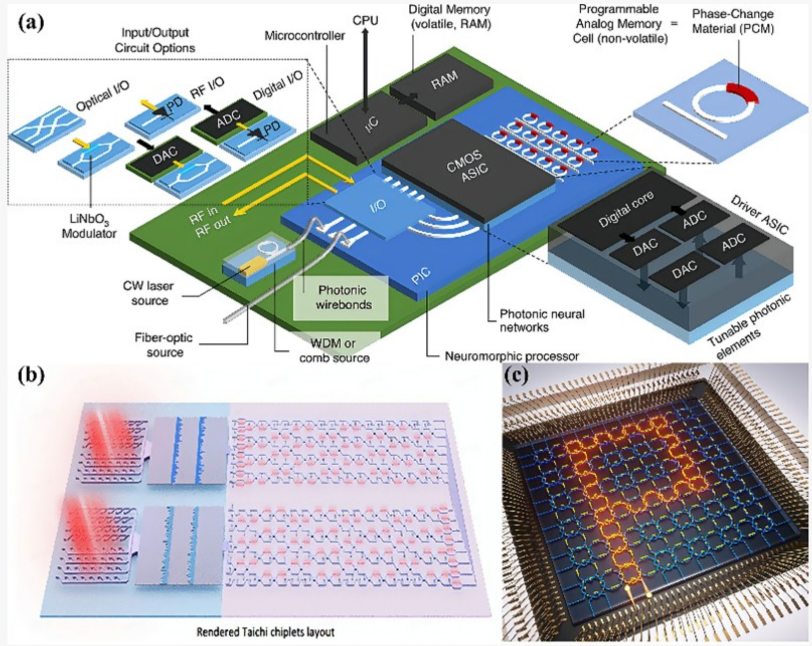

Fig.2 Multi-focal plane display of prototype at three distinct distances simultaneously. The image that is outlined by a white frame correspond to different virtual image distances. Both the real and digital scene can be seamlessly transitioned in real ti

In this work, the multi-focal plane AR visual effect is realized by the compact and multiplexing metasurface, which performs distinct phase functions across diverse polarization channels. Meanwhile, freeform surfaces offer ample design flexibility for the system. Based on a joint optimization design method combining ray tracing and diffraction theory, the multi-focal-plane digital scenes and see-through paths are synergistically optimized. While maintaining a slim and compact system form factor, good display performance is realized at each focal plane, and the system distortion is well controlled.

The research team successfully developed a solid-state AR prototype system with dimensions of 9.3 cm × 4.5 cm × 4.9 cm, demonstrating excellent compactness. Experimental results show that the system is capable of simultaneously rendering clear digital images on three independent focal planes at distances of 0.7 m, 1.5 m, and 3 m, while achieving seamless integration with the real-world environment. When the observation focus is adjusted to a specific depth, the image on the corresponding focal plane remains sharp, while those on other focal planes exhibit natural defocusing effects, delivering a realistic three-dimensional visual experience. With its compactness, high frame rate, pure solid-state design, and true 3D display capability, the system exhibits significant potential for future applications in mobile intelligent terminals, immersive interactions, industrial visualization, and other scenarios, providing an innovative technical pathway for the development of next-generation high-performance AR display devices.

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Keywords: augmented reality, metasurface-freeform, multi-focal planes display, non-orthogonal polarization-multiplexing, metasurfaces

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