Chip-scale metamicroscope for high-performance imaging

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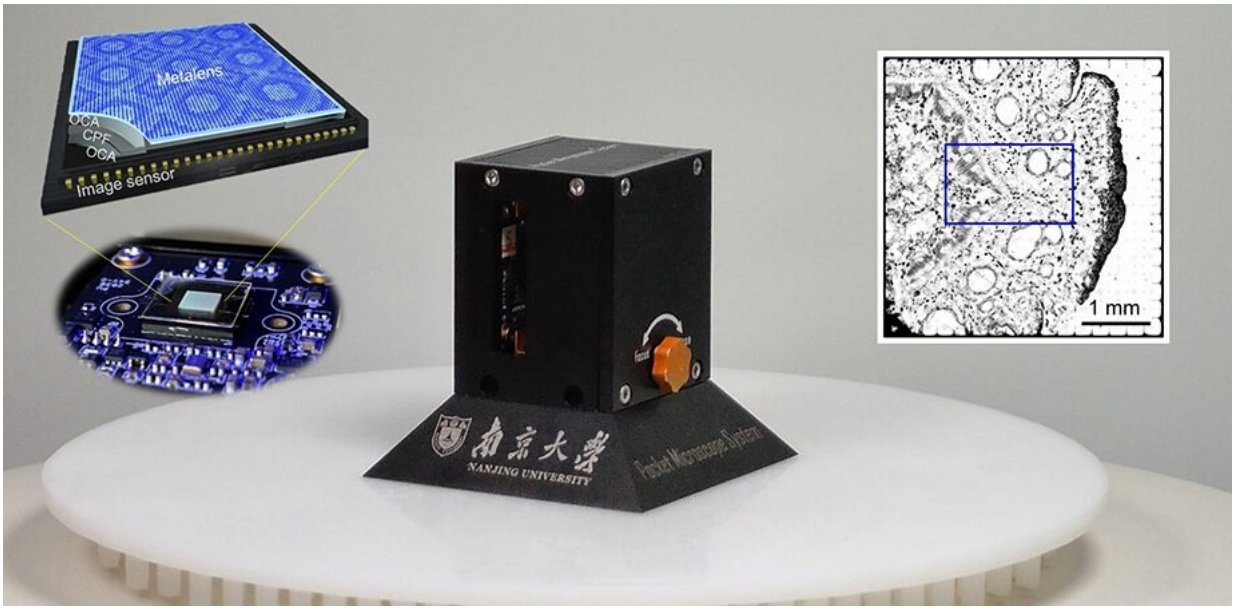
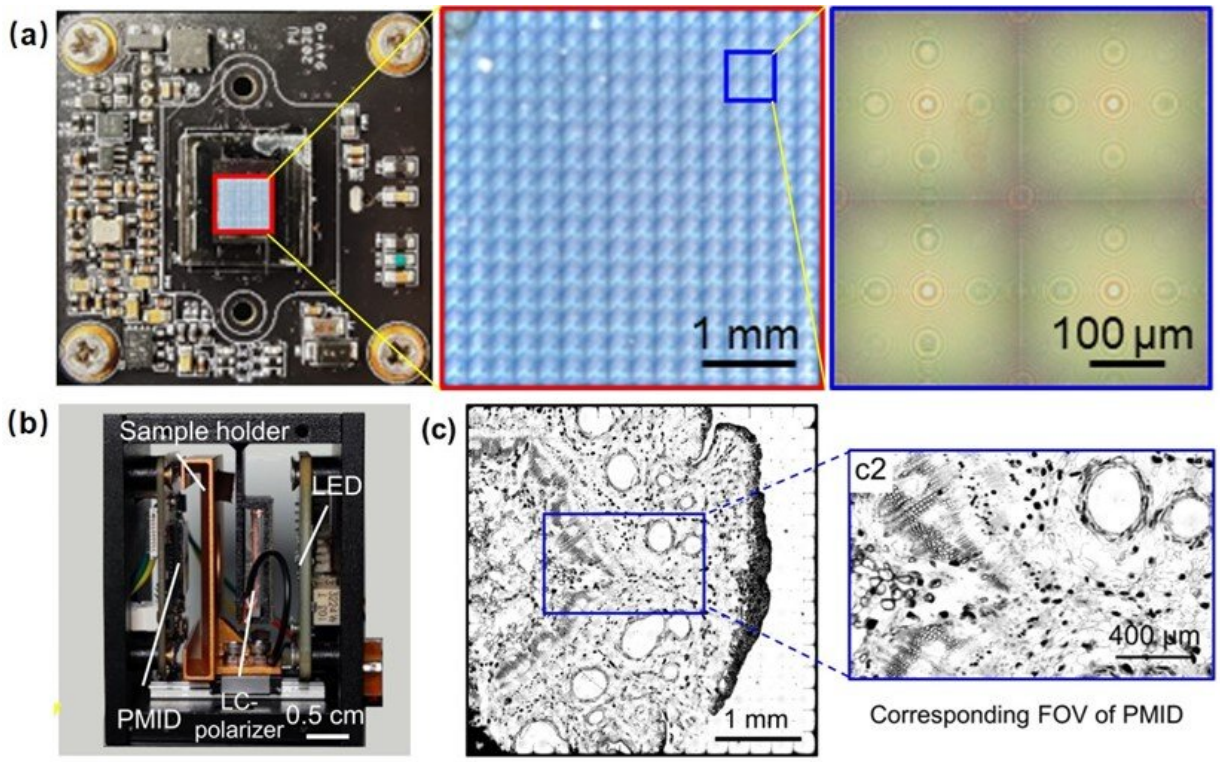


A chip-scale metalens array makes this microscope system ultracompact. Credit: Tao Li, Nanjing University.

The microscope effectively expands human eyesight to the microworld. It supports wide applications in scientific research, biomedical diagnosis, industry, and beyond. The ultimate goal is superresolution, yet along the way researchers are working to achieve compact, miniature devices with comprehensive performance for wide field-of-view (FOV), large depth-of-field (DOF), and high throughput.

Traditional optical microscopes are based on refractive optical elements, which are usually bulky and heavy with limitations in FOV and DOF, though they have been substantially developed. Flat diffractive lenses seemed to offer a possible solution to miniaturize imaging systems, but they achieve low efficiency and poor imaging quality. Recent lensless imaging technology considerably revolutionizes imaging technology and enables highly compact imaging devices, but it strongly depends on postprocessing computation, which is resource-intensive and risks distortion.

Metalens technology opens a new way to achieve ultracompact and lightweight optical imaging systems. A metalens is a kind of metasurface composed of subwavelength units with powerful capability for manipulating light. An innovative polarization multiplexed metalens array (based on silicon nanoposts) was proposed to realize a compact and wide-field microscope that breaks conventional FOV constraints, but the imaging quality is relatively poor due to its low efficiency with background noise, and the overall FOV is still smaller than that of traditional microscope with the same resolution.



Chip-scale metalens array for polarization-embedded metalens imaging device (PMID) and compact portable microscope system (PMS): (a) chip-scale metalens array integrated in the CMOS image sensor with zoom-in images; (b) the PMS with compact size of 3×3.5×4 cm3 by integrating the PMID, sample holder, LC-polarizer and LED source; and (c) wide-field microscopic image for a bio-specimen of the pine stem cross section covering a 4×4-mm2 FOV with 1.74-μm resolution. The blue box area is the recorded FOV of a traditional microscope. Credit: Ye et al.

Significantly improved imaging quality is now possible with higher-resolution imaging, thanks to researchers from Nanjing University who developed a polarizer-embedded metalens imaging device (PMID). As reported in *Advanced Photonics*, the PMID is implemented based on a silicon nitride metasurface mounted on a CMOS image sensor with a fixed circular-polarization filter inserted between the two. It eliminates

background noises, and even enables zoom-in imaging.

The system is based on a special co-and-cross-multiplexed metalens array and embedded polarizer. By integrating them to a chip-scale CMOS sensor, the researchers successfully developed a high-quality wide FOV and large DOF microscopy technique. Significantly high performances are achieved, with a 4×4-mm^2 FOV, a 1.74-μm resolution (limited by the CMOS pixel size), and a ~200-μm DOF (450-510-nm wavelength range). This FOV is around 5 to 7 times that of a traditional microscope with the same resolution. The team demonstrated the outstanding microscopy performance by imaging a large number of bio-specimens.

According to senior author Tao Li, principal investigator at Nanjing University's National Laboratory of Solid-State Microstructures, "To the best of our knowledge, this is the first time a metalens imager has accessed a larger FOV than a traditional microscope with similar imaging quality. By sweeping the illumination wavelength, the device is able to achieve large depth-of-field imaging simultaneously, thanks to the large dispersive nature of the metalens." Li further remarks, "This chip-scale PMID enables the implementation of miniaturized portable microscope system, with a thousand-fold reduction in volume and weight compared to a traditional microscope."

This chip-scale microscope promises to revolutionize traditional optical devices, presenting a new horizon of ultracompact imaging devices powered by metatechnology.

More information: Xin Ye et al, Chip-scale metalens microscope for wide-field and depth-of-field imaging, *Advanced Photonics* (2022). DOI: 10.1117/1.AP.4.4.046006