# Ansys + Sun Yat-Sen University

"Ansys Lumerical's finite-difference time-domain (FDTD) simulation software was the ideal tool to reach our research goals into metalens design quickly and with confidence. It offers unprecedented accuracy, providing simulation results that closely matched measured results and with the performance needed for our optimization platform."

**Haowen Liang**

Lead Investigator / Sun Yat-Sen University

CASE STUDY

# An Ultra-high Numerical Aperature Metalens at Visible Wavelengths

## / Research Summary


The State Key Laboratory of Optoelectronic Materials & Technology at Sun Yat-sen University set out to develop a metalens with ultra-high numerical aperture (NA) when front-immersed in oil, enabling subwavelength imaging with higher resolution. A novel hybrid optimization algorithm (HOA) was used to find optimal designs by iteratively simulating with the finite-difference time-domain (FDTD) method to determine transmission rate and absorption, as well as evaluating each candidate with a figure of merit focused on maximizing transverse electric and magnetic (TE/TM) transmission while minimizing the discrepancy between the simulated and target phase. Crystalline silicon (c-Si) on sapphire was used as the target fabrication process rather than the typical titanium dioxide (TiO2) to further increase NA while remaining compatible with a standard CMOS process. The goal of the research was to develop a better metalens with a higher NA and demonstrate that this could be achieved automatically via an optimization platform.


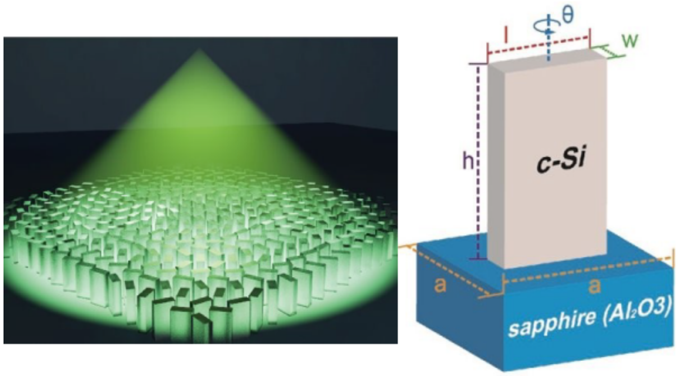


Figure 1. The metalens developed at Sun Yat-Sen University (left) was developed by individually optimizing individual "nanobrick" elements (right) using Ansys Lumerical FDTD.

## / Results

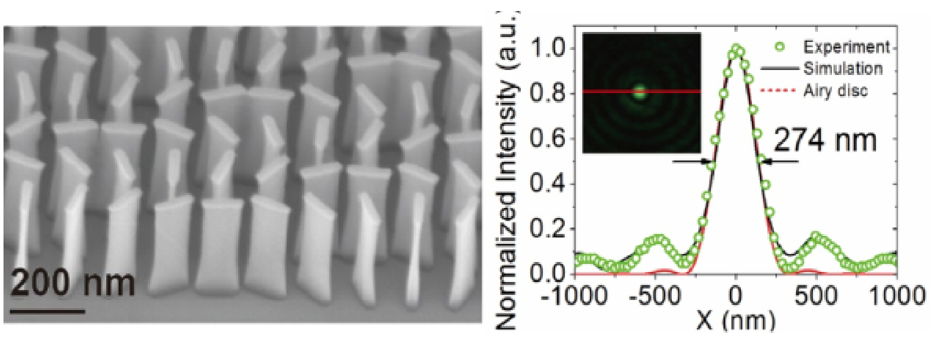


Figure 2. Scanning electron microscope (SEM) image (left) and measured performance of the metalens developed at Sun Yat-Sen University (right). The experimental results agree well with the predictions from FDTD simulations.

After performing optimization using their HOA platform, the group at Sun Yat-Sen manufactured their design via patterning in a negative resist by electron beam lithography (EBL) and etched by inductively coupled plasma (ICP). Figure 2 shows the fabricated metalens as shown by a scanning electron microscope (SEM). Also shown in Figure 2 is a comparison between the measured and simulated results of the normalized intensity distribution of the focal spot in air. As shown in this figure, the optimization solution based on Ansys Lumerical FDTD resulted in a metalens design with measurements that closely match simulation results in terms of focused spot size and efficiency.

The final metalens design achieved an NA of 0.98 in air, a bandwidth (FWHM) of 274 nm, and a focusing efficiency of 67% at a 532-nm wavelength. This result was close to the transmission performance possible with existing TiO2 metalenses; however, it was particularly exceptional when front-immersed in oil. In this case, the optimized design was shown through experiments to achieve an ultra-high NA of 1.48. The authors of this research speculate that the level of NA they were able to achieve with the help of Lumerical FDTD has the potential to push the use of metasurfaces into application spaces such as high-resolution, low-cost confocal microscopy and achromatic lenses.

The simulation approach for metalens design used by the Sun Yat-Sen group is similar to one of the metalens examples provided in Lumerical's application gallery.

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