

Design and Analysis of Achromatic Metalenses in the Visible Regime

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INTRODUCTION & AIM

Metasurface metalenses enable compact wavefront control using subwavelength nanostructures. Compared with conventional optics, they offer ultra-thin structures and high integration capability.

However, metalenses in the visible spectrum suffer from strong chromatic aberration due to wavelength-dependent phase responses, leading to focal length variations across wavelengths.

To design a visible achromatic metalens based on Si_3N_4 dielectric metasurfaces using an interleaved phase-compensation strategy that suppresses chromatic focal shift while maintaining high transmission efficiency.

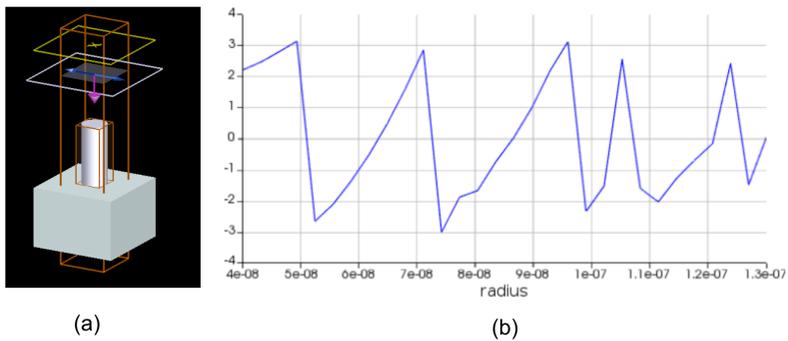
METHOD

Metalens Design

The metalens consists of Si_3N_4 nanopillars on a SiO_2 substrate. Phase control is achieved through propagation-phase modulation, enabling polarization-independent operation.

Phase Library

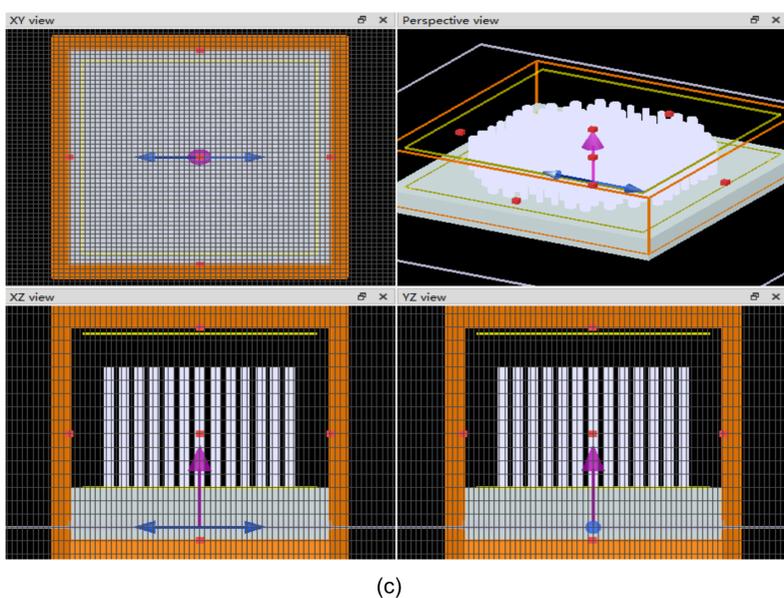
A unit-cell phase library is constructed using FDTD simulations by scanning nanopillar radii to obtain transmission phase responses at multiple visible wavelengths.



Figure(a). Single superatom design Figure(b). Radius and Phase Variation Diagram

Interleaved Strategy

Meta-atoms optimized for different wavelengths are spatially interleaved across the metalens aperture. This arrangement approximates the required phase profiles for multiple wavelengths simultaneously and enables multi-wavelength phase compensation.



Figure(c). Interlocking superatomic arrangement and design

RESULTS & DISCUSSION

In this work, we present the design and analysis of a visible achromatic metalens based on Si_3N_4 dielectric metasurfaces.

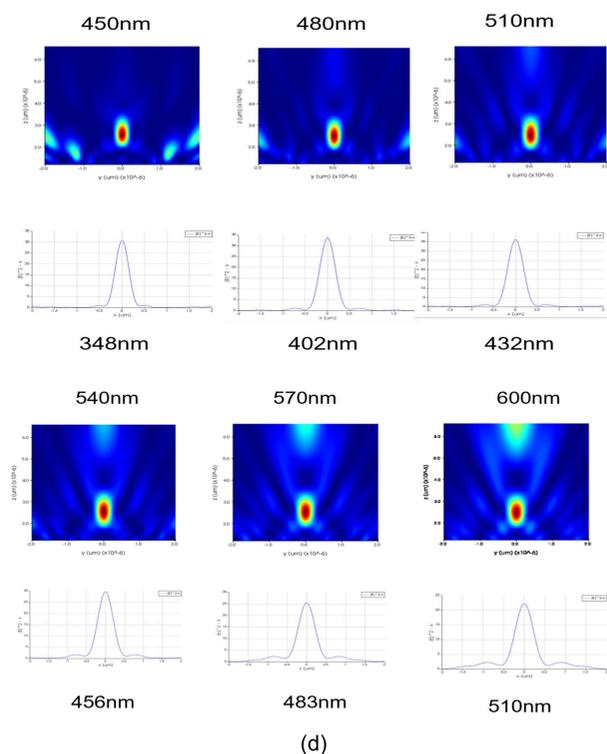
By combining propagation-phase modulation with an interleaved meta-atom arrangement, the proposed design successfully suppresses chromatic focal shift while maintaining stable focusing behavior.

Numerical simulations demonstrate nearly coincident focal positions across the visible wavelength range.

Compared with conventional single-wavelength metalenses:

- Chromatic focal shift is significantly reduced
- Focal spots remain symmetric and stable
- Focal sizes are consistent across wavelengths
- High transmission efficiency is maintained

These results indicate that the interleaved metasurface design effectively mitigates wavelength-dependent phase variations, improving chromatic tolerance.



Figure(d). Changes in focal point and FWHM when light of different wavelengths is incident

CONCLUSION

In this work, we present the design and analysis of a visible achromatic metalens based on Si_3N_4 dielectric metasurfaces.

By combining propagation-phase modulation with an interleaved meta-atom arrangement, the proposed design successfully suppresses chromatic focal shift while maintaining stable focusing behavior.

Numerical simulations verify that the metalens achieves consistent focal positions and symmetric focal spots across multiple visible wavelengths.

The proposed approach provides a practical and scalable solution for achromatic metalenses, which may enable applications in compact imaging systems, integrated photonics, and visible-light optical devices.

FUTURE WORK

Future research will focus on:

- Experimental fabrication of the proposed metalens structure
- Optimization of the interleaving strategy for broader bandwidth
- Integration into compact optical imaging systems
- Investigation of polarization-insensitive broadband designs

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