He et al. *Light: Advanced Manufacturing* (2026) 7: 65
https://doi.org/10.37188/lam.2026.065 www.light-am.com

News & Views Open Access

Minimalist optical achromatic meta-imaging with extended field of view

Boping He[1], Shuming Wang[1,2,*] and You Zhou[3,*]

Abstract

A minimalist optical system based on a monolithic integrated meta-axicon cluster achieves achromatic imaging over an extended field of view without relying on conventional dispersion engineering. By harnessing the inherent broadband consistency of Bessel beams and combining it with non-blind image restoration, the design circumvents the strict phase-matching constraints that have traditionally limited large-aperture meta-optics. This work establishes a promising paradigm for combining physics-driven optical elements with computational reconstruction, paving the way toward scalable, high-performance meta-imaging systems.

Keywords: Minimalist optical system, Achromatic metalenses, Extended field of view, Meta-imaging

Metalenses are revolutionizing frontier fields from consumer products to biological microscopy and astronomical observation[1–5] through their ultrathin planar structures and multidimensional wavefront control, yet large-scale fabrication and broadband achromatism each remain significant challenges, and achieving both simultaneously proves even more demanding[6]. Although traditional phase dispersion engineering is heavily constrained by the aspect ratio limits of nanofabrication[7–11], recent developments in large-aperture meta devices have demonstrated significant progress. By expanding beyond strict continuous phase matching toward more flexible physical modeling and optimization driven design strategies, researchers have successfully scaled achromatic or quasi achromatic performance for continuous broadband light[12–19]. Nevertheless, these advancements often necessitate inherent physical trade-offs including diminished focusing efficiency, heightened fabrication complexity, or residual chromatic aberration.

Against this backdrop, the recent work by Wang and colleagues[20] makes a significant contribution by proposing a minimalist optical system design. The research team shifts their core optical element from the conventional hyperbolic phase metalens (Fig. 1a) to the meta axicon (Fig. 1b). This choice is rooted in the physical constraints of the optical grating equation. Unlike traditional focusing lenses, the relative intensity distribution of a zero order Bessel beam generated by a meta axicon is fundamentally independent of the incident wavelength. By leveraging this natural dispersion law, the system obtains a point spread function (PSF) that exhibits extraordinarily high spatial consistency across the entire visible spectrum. This strategic shift transfers the burden of chromatic aberration correction from complex dispersion engineering to a physical design that prioritizes wavelength-invariant PSFs jointly with computational algorithms.

However, achieving high-resolution imaging with a wide field of view (FOV) remains a significant challenge. Traditional meta axicons are highly sensitive to incident angles, where oblique light disrupts wavefront symmetry

---

Correspondence: Shuming Wang (wangshuming@nju.edu.cn) or You Zhou (zhouyou@nju.edu.cn)
[1]National Laboratory of Solid State Microstructures, School of Physics, Nanjing University, Nanjing 210093, China
[2]Collaborative Innovation Center of Advanced Microstructures, Nanjing 210093, China
Full list of author information is available at the end of the article.

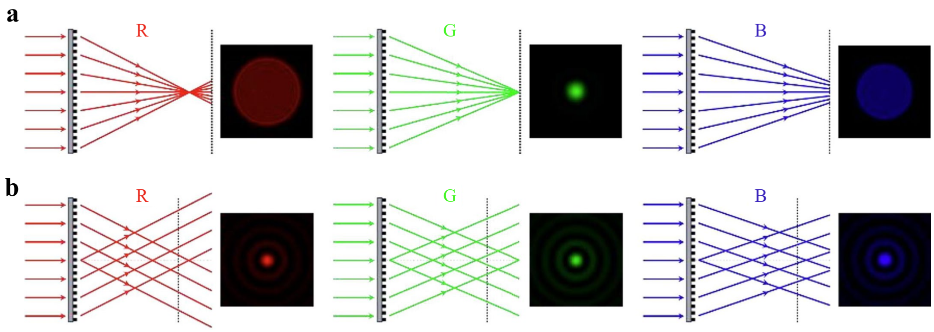

Fig. 1 **a** Ray tracing and PSF illustration of monochromatic metalenses. **b** Ray tracing and PSF illustration of meta-axicons[20].

and introduces off-axis aberrations that restrict the effective FOV. To overcome this limitation, the researchers[20] developed an array of off-axis meta axicons featuring eccentric conical phases. Instead of relying on conventional global phase profiles, they applied a local optical path constraint to ensure that obliquely incident light is converted into uniform and co-propagating Bessel beams. Their experimental system uses a monolithic metasurface integrated with nine distinct elements, including a central 4 mm meta axicon surrounded by eight 3 mm off axis versions.

Each element is responsible for capturing a specific angular region of the field. The system then employs a non-blind deconvolution technique based on total variation (TV) regularization to perform independent, high quality image reconstruction for each region. These local optical fields are fused into a seamless 10-degree FOV, maintaining an angular resolution limit of at least 80% compared to a traditional diffraction limited lens of an equivalent aperture. Table 1 presents main performance comparison for metasurface achromatic imaging research[7–20].

Beyond the conceptual breakthrough, this work points toward a feasible path for developing large-aperture computational imaging systems. However, transitioning from the laboratory to real world applications involves physical challenges. While current performance is validated under specific angles, the system's robustness in complex scattering environments requires further testing. A critical challenge remains in the trade-off regarding the numerical aperture (NA). Because axicons inherently possess a smaller equivalent NA than traditional lenses, increasing light gathering capability while maintaining consistent broadband PSF is a demanding task. Future research should also focus on quantifying the effective depth of field of the meta-imaging system and improving

Table 1 Main performance comparison for metasurface achromatic imaging research.

Achromatic design method	Bandwidth (nm)	Aperture (μm)	NA	Resolution (lp/mm)
Ideal wideband phase matching[7]	400~600	50	0.106	228
Ideal wideband phase matching[8]	470~670	220	0.02	≈ 40
Ideal wideband phase matching[9]	400~660	21.65	0.216	256
Ideal wideband phase matching[10]	650~1,000	30	0.24	228
Ideal wideband phase matching[11]	460~650	30	0.155	228
Multi-layer topology optimization[19]	400~800	20	0.5	80.6
Asymptotic phase compensation[12]	400~1,000	50	0.164	57
Phase dispersion compensation[13]	1,000~1,800	300	0.02	40.3
Dispersion-matched layers[14]	400~700	400	0.02	57
End-to-end learning reconstruction[15]	450~650	10,000	0.25	≈ 113
Frequency-domain coherence optimization[16]	400~1,100	10,000	0.1	≈ 150
Cubic phase for extended-depth-of-focus[17]	400~700	200	0.45	≈ 250
Vortex Bessel beam imaging[18]	450~700	350	0.2	≈ 50
Multi-field Bessel beam imaging[20]	**450~700**	**4,000**	**0.067**	**244**

the algorithm's robustness to fabrication errors.

More broadly, these results arrive as researchers in meta-optics focus on how metasurfaces and algorithms can work together. The design, simple yet sophisticated, shows a new way to combine the natural physical laws with computational imaging capabilities. By moving past conventional engineering constraints, this work suggests a practical future for large FOV and large aperture meta cameras. This successful synergy between physical mechanisms and algorithmic reconstruction will likely lead to further investigation into next-generation intelligent imaging systems.

Author details

[1]National Laboratory of Solid State Microstructures, School of Physics, Nanjing University, Nanjing 210093, China. [2]Collaborative Innovation Center of Advanced Microstructures, Nanjing 210093, China. [3]Medical School, Nanjing University, Nanjing 210093, China

Data availability

All data are available from the corresponding authors upon reasonable request.

Conflict of interest

The author declares no competing interests.

Received: 28 March 2026 Revised: 10 April 2026 Accepted: 13 April 2026

References

1. Arbabi, A. & Faraon, A. Advances in optical metalenses. *Nature Photonics* **17**, 16-25 (2023).
2. Wang, X. W. et al. Advances in information processing and biological imaging using flat optics. *Nature Reviews Electrical Engineering* **1**, 391-411 (2024).
3. Wang, J. L. et al. Portable astronomical observation system based on large-aperture concentric-ring metalens. *Light: Science & Applications* **14**, 2 (2025).
4. Park, J. S. et al. All-glass 100 mm diameter visible metalens for imaging the cosmos. *ACS Nano* **18**, 3187-3198 (2024).
5. He, B. P. et al. Achromatic metalens for three-dimensional depth sensing. *ACS Photonics* **13**, 1303-1309 (2026).
6. Chen, W. T., Zhu, A. Y. & Capasso, F. Flat optics with dispersion-engineered metasurfaces. *Nature Reviews Materials* **5**, 604-620 (2020).
7. Wang, S. M. et al. A broadband achromatic metalens in the visible. *Nature Nanotechnology* **13**, 227-232 (2018).
8. Chen, W. T. et al. A broadband achromatic metalens for focusing and imaging in the visible. *Nature Nanotechnology* **13**, 220-226 (2018).
9. Lin, R. J. et al. Achromatic metalens array for full-colour light-field imaging. *Nature Nanotechnology* **14**, 227-231 (2019).
10. Wang, Y. J. et al. High-efficiency broadband achromatic metalens for near-IR biological imaging window. *Nature Communications* **12**, 5560 (2021).
11. Zhang, Y. et al. On-chip integration of achromatic metalens arrays. *Nature Communications* **16**, 7485 (2025).
12. Hu, Y. Q. et al. Asymptotic dispersion engineering for ultra-broadband meta-optics. *Nature Communications* **14**, 6649 (2023).
13. Balli, F. et al. A hybrid achromatic metalens. *Nature Communications* **11**, 3892 (2020).
14. Chang, S. Y. et al. Achromatic metalenses for full visible spectrum with extended group delay control via dispersion-matched layers. *Nature Communications* **15**, 9627 (2024).
15. Fröch, J. E. et al. Beating spectral bandwidth limits for large aperture broadband nano-optics. *Nature Communications* **16**, 3025 (2025).
16. Xiao, X. J. et al. Large-scale achromatic flat lens by light frequency-domain coherence optimization. *Light: Science & Applications* **11**, 323 (2022).
17. Colburn, S., Zhan, A. & Majumdar, A. Metasurface optics for full-color computational imaging. *Science Advances* **4**, eaar2114 (2018).
18. Du, X. M. et al. Full-color quasi-achromatic imaging with a dual-functional metasurface. *Nano Letters* **25**, 8143-8150 (2025).
19. Pan, C. F. et al. 3D-printed multilayer structures for high–numerical aperture achromatic metalenses. *Science Advances* **9**, eadj9262 (2023).
20. Wang, J. L. et al. Minimalist optical system for achromatic imaging within extended field of view based on monolithic integrated meta-axicon cluster. *Light: Science & Applications* **15**, 202 (2026).