NanoOpto Group

Achromatic Flat Lenses: Do They Improve Imaging Performance?

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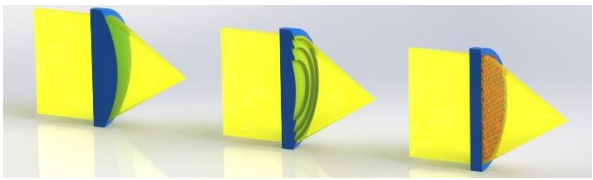
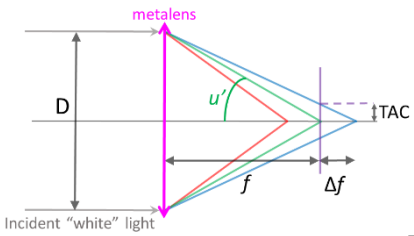
We introduce a metric for evaluation of overall metalens performance and use it to compare published achromatic flat lens (AFL) designs to equivalent chromatic flat lenses (CFL).



1. Chromatic aberration

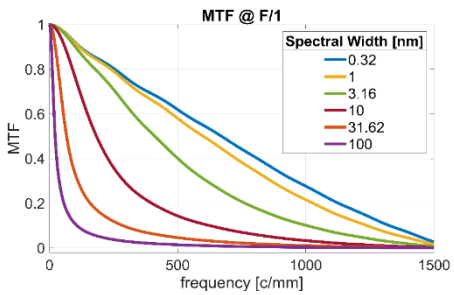


Longitudinal chromatic aberration:

$$\Delta f = f\frac{\Delta\lambda}{\lambda}$$

$$TAC = \Delta f tan(u') = \Delta f \frac{D}{2f} = \frac{\Delta\lambda}{\lambda}\cdot\frac{D}{2}$$

MTF for different spectral ranges

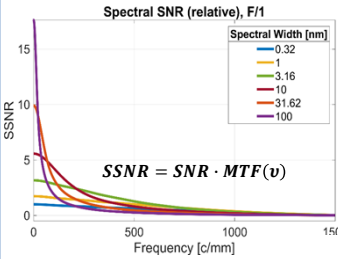


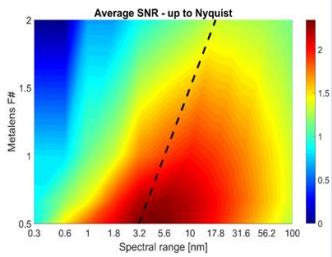
2. SNR

$$SNR = \frac{S}{\sqrt{S}} = \sqrt{S} \propto D\sqrt{\Delta\lambda}$$

3. System performance metric

Low freq. SNR improves as aperture and Δλ increase, while MTF degrades





Performance metric: $$ISNR = SNR\int_0^{f_{nq}} MTF(v)dv$$

4. Lens performance metric

Same first-order parameters:

$$OPM = \frac{\eta}{\sqrt{T}} * Strehl$$

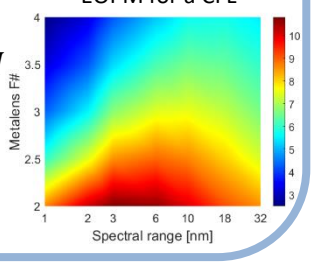
Different first order parameters:

$$EOPM = FN\sqrt{\frac{\Delta\lambda}{\lambda}}\cdot OPM$$

FN – Fresnel number:

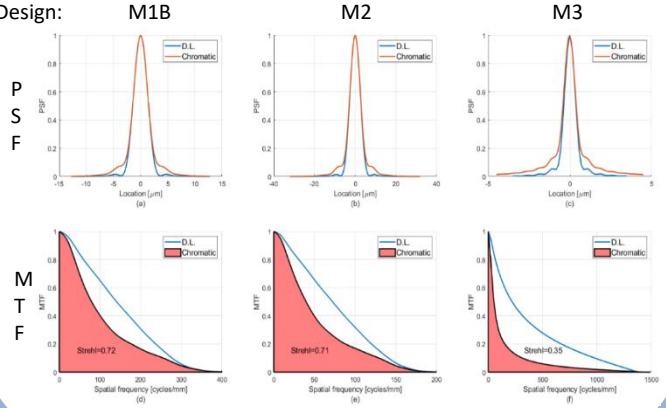
$$FN \approx \frac{f\cdot NA^2}{\lambda}$$

EOPM for a CFL



5. Equivalent CFL performance

Design: M1B M2 M3



Resolution of CFLs equivalent to AFLs of [3]

6. AFL-CFL performance comparison

Design	M1B		M2		M3	
λmin [μm]	1.2		1.2		1.2	
λmax [μm]	1.65		1.65		1.4	
NA	0.24		0.13		0.88	
EFL [μm]	200		800		30	
Dia. [μm]	100		210		111	
Fresnel no.	8		10		51	
Airy rad [μm]	3.6		6.7		0.9	
Chr. rad [μm]	7.8		16.6		4.3	
	AML	CDL	AML	CDL	AML	CDL
Efficiency	0.35	0.78	0.35	0.87	?	0.05
2D Strehl	0.85	0.57	0.85	0.61	?	0.16
1D Strehl	~0.93	0.72	~0.93	0.71	?	0.35
OPM	0.55	0.64	0.55	0.66		0.08
EOPM	2.6	3.0	3	3.6		1.5

Performance comparison of AFL designs presented in [3], to equivalent CFL designs

References:

1. J. Engelberg, U. Levy, "Optimizing the Spectral Range of Diffractive Metalenses for Polychromatic Imaging Applications," Opt. Express 25, 18 (2017).
2. J. Engelberg et al., "How good is your metalens? Experimental verification of metalens performance criterion," Opt. Lett. 45, 2–5 (2020).
3. S. Shrestha, A. C. Overvig, M. Lu, A. Stein, and N. Yu, "Broadband achromatic dielectric metalenses," Light Sci. Appl. 7, 85 (2018).

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