Large field-of-view polychromatic metalens for full-color scanning fiber endoscopy: Supporting information

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I Ray tracing simulation results

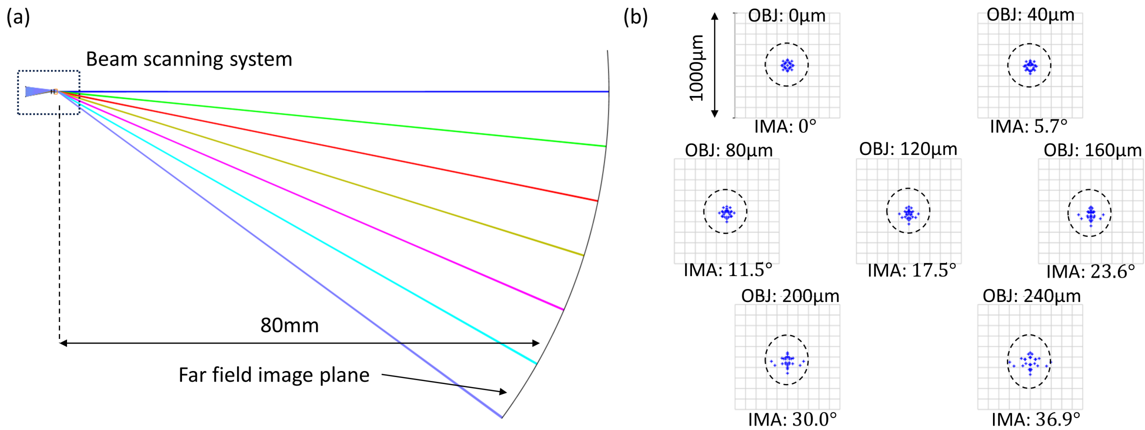

Fig S1 **(a)** Cross-section of the ray tracing simulation of the beam scanning system in SFE. **(b)** The spot diagram of the images of 7 point sources on the image plane. The dashed lines indicate the beam spots with a radius of the diffraction limited FWHMs.

beam	1	2	3	4	5	6	7
source y position on object plane (µm)	0	40	80	120	160	200	240
beam y position on metalens (µm)	0	44	89	133	177	222	266
beam steering angle θ (°)	0.0	5.7	11.5	17.5	23.6	30	36.9

Table S1 The position of the point source and the beam steering angle in the ray tracing simulation in Zemax.

The radius of the incident beams on the metalens is 72 µm.

II Simulated beam intensity distribution on the optical plane

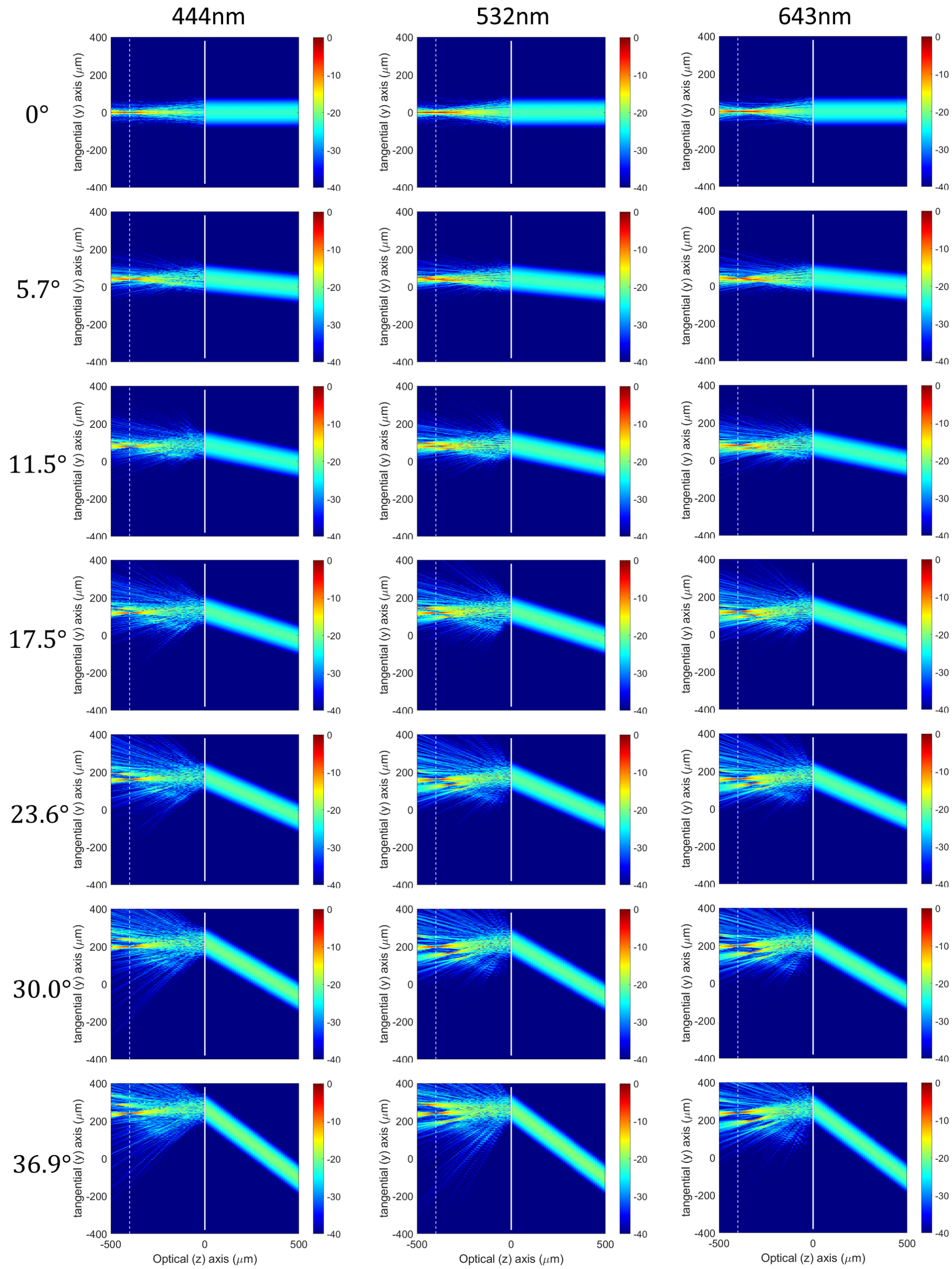

Fig S2 Optical (yz) plane intensity distribution of the beams propagating backward in the inverse design of the metalens, simulated via angular spectrum method. The beams are incident on the metalens (solid white line) at 7 different angles and positions, which are obtained in the ray-tracing simulation of the system.

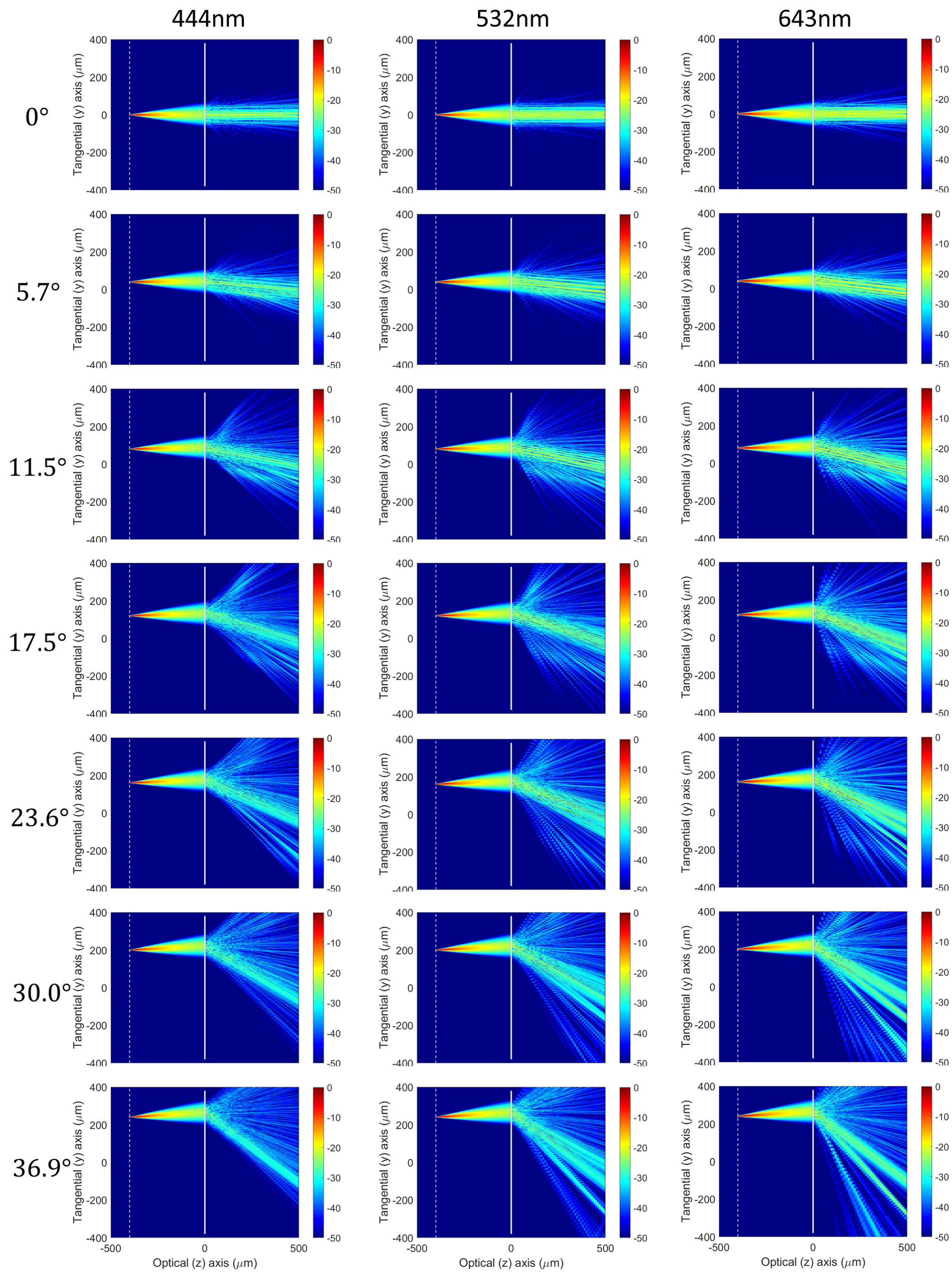

Fig S3 Optical (yz) plane intensity distribution of the beams propagating forward in the functionality authentication of the metalens. The beams emit from fiber tips at 7 different positions on the focal plane (dashed white line).

III The meta-atom library

The target phase profile at a particular radial position, denoted as $\psi(r, \lambda_i)$, can be visualized as a point in a 3D space. The collective target phase profile can be conceptualized as a series of points within a cube in 3D space. If the phase response library of meta-atom covers the entire three-dimensional cube with a side length of 2π, and the transmission of meta-atoms is always 1, it enables independent control over the phase profile at three distinct wavelengths. However, the distribution of points of the phase response and transmission library is constrained by factors such as limitations in refractive index, thickness, and fabrication constraints, thus the efficiency of the lens is lower. Fig. S4 plots the phase response and transmission library of the $750\,\mathrm{nm}$ height Si_3N_4 meta-atoms.

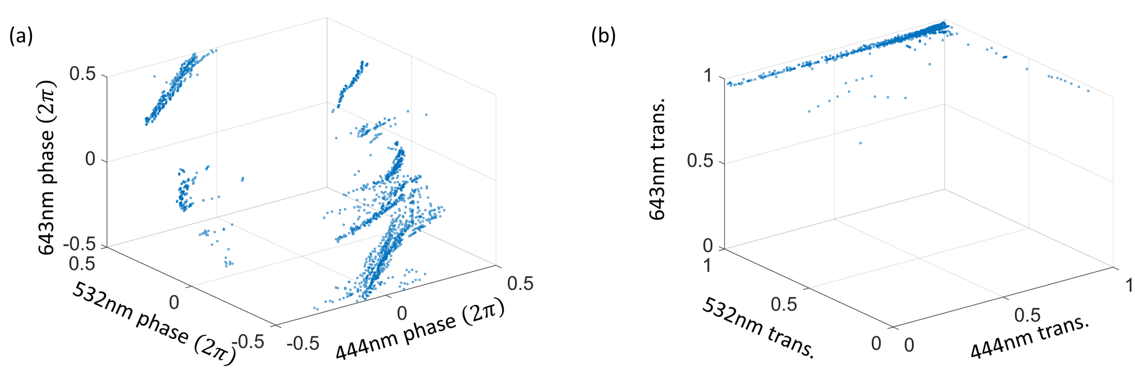

Fig S4 (a,b) The phase response (a) and transmission (b) distribution of meta-atoms with $80\,\mathrm{nm} \leq a \leq b \leq 260\,\mathrm{nm}$ at 3 design wavelengths obtained via FDTD simulation. **(c,d)** The comparison of FDTD and DNN meta-model obtained phase response (a) and transmission (b) of meta-atoms at 3 design wavelengths.

IV Calculation of the diffraction limited angular intensity distribution of the steered beam

The diffraction limited angular intensity distribution can be calculated by assuming that the beams after transmitting through the metalens are Gaussian beams with their beam waists positioned at the metalens. The amplitude profiles of these Gaussian beams are assumed to be equal to the incident beams on the metalens:

$$w_0 = r_b = 40\,\mu\mathrm{m} \tag{S1}$$

where w_0 is the width of the incident Gaussian beam on the metalens, and $2w_0 = 80\,\mu\mathrm{m}$ is the diameter of the incident beam on the metalens, which can be viewed as the effective aperture.

$$w_S = w_0 \tag{S2}$$

$$w_T = w_0 \cos\theta \tag{S3}$$

where w_S (w_T) is the sagittal (tangential) Gaussian beam width after transmitting through the metalens.

$$\delta_S = \lambda/(\pi w_S) \tag{S4}$$

$$\delta_T = \lambda/(\pi w_T) \tag{S5}$$

$$r_S = \mathrm{FWHM}_S = \sqrt{2\ln 2}\delta_S \tag{S6}$$

$$r_T = \mathrm{FWHM}_T = \sqrt{2\ln 2}\delta_T \tag{S7}$$

where δ_S (δ_T) is the sagittal (tangential) diffraction limited diverging angle of the collimated beam, and r_S (r_T) is the sagittal (tangential) diffraction limited beam angular radius.

V Simulated performance of polychromatic metalens with higher efficiency

Meta-atoms with larger height or using higher index materials have a more diverse phase response distributions. Fig. S5 shows that the metalens using larger height ($1500\,\mathrm{nm}$ height SiN) or higher index material ($750\,\mathrm{nm}$ height TiO_2) has a significant higher efficiency than the fabricated metalens in this paper ($750\,\mathrm{nm}$ height SiN).

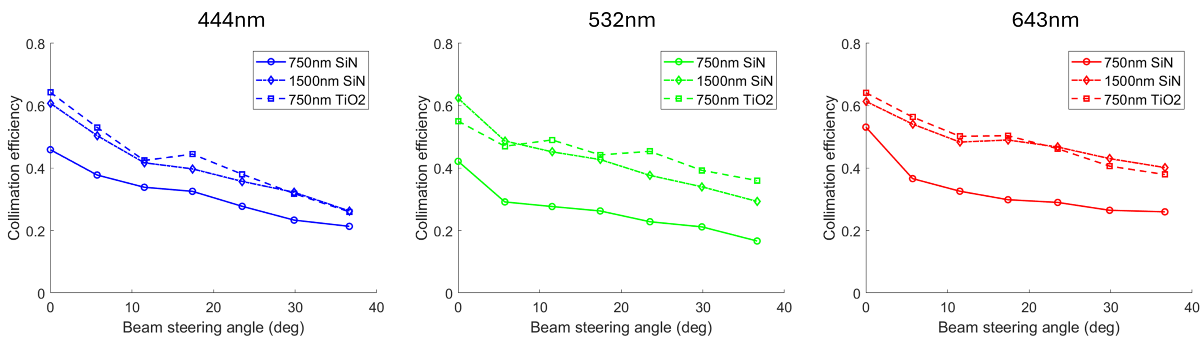

Fig S5 Simulated collimation efficiency of polychromatic metalens designed with $750\,\mathrm{nm}$ height SiN, $1500\,\mathrm{nm}$ height SiN or $750\,\mathrm{nm}$ height TiO_2 meta-atoms.

39 # VI Sensor image at multiple wavelengths and steering angles

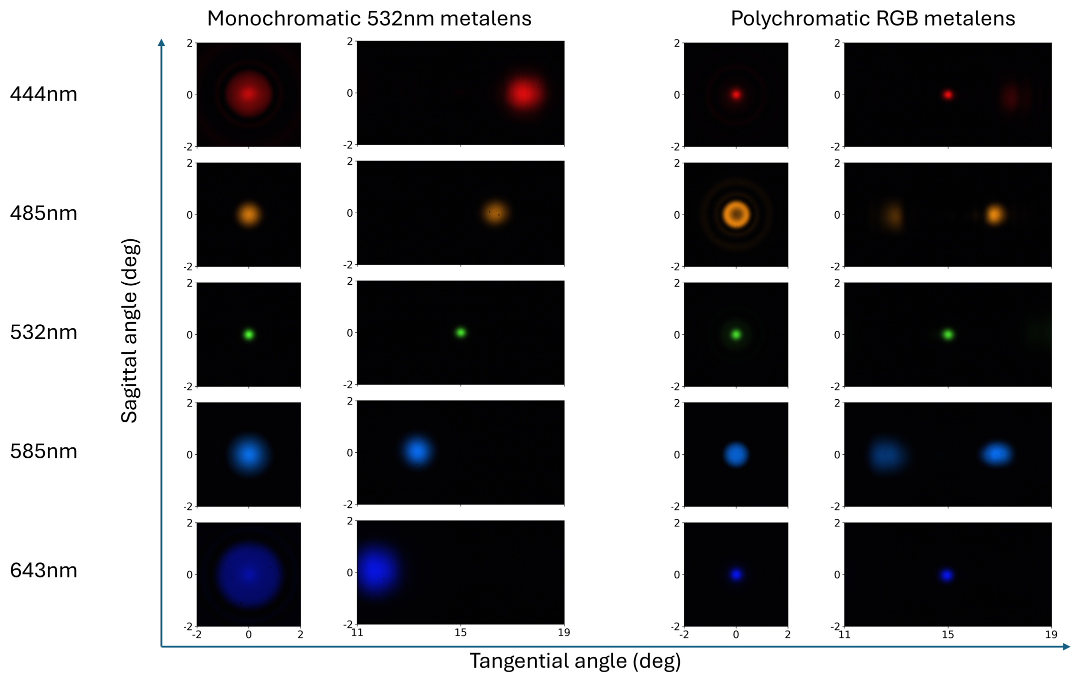

Fig S6 Images directly captured by light sensor at various wavelengths and beam steering angles. $\theta = 0°, 15°$

VII Intensity distribution of beams steered to different angles at RGB wavelength

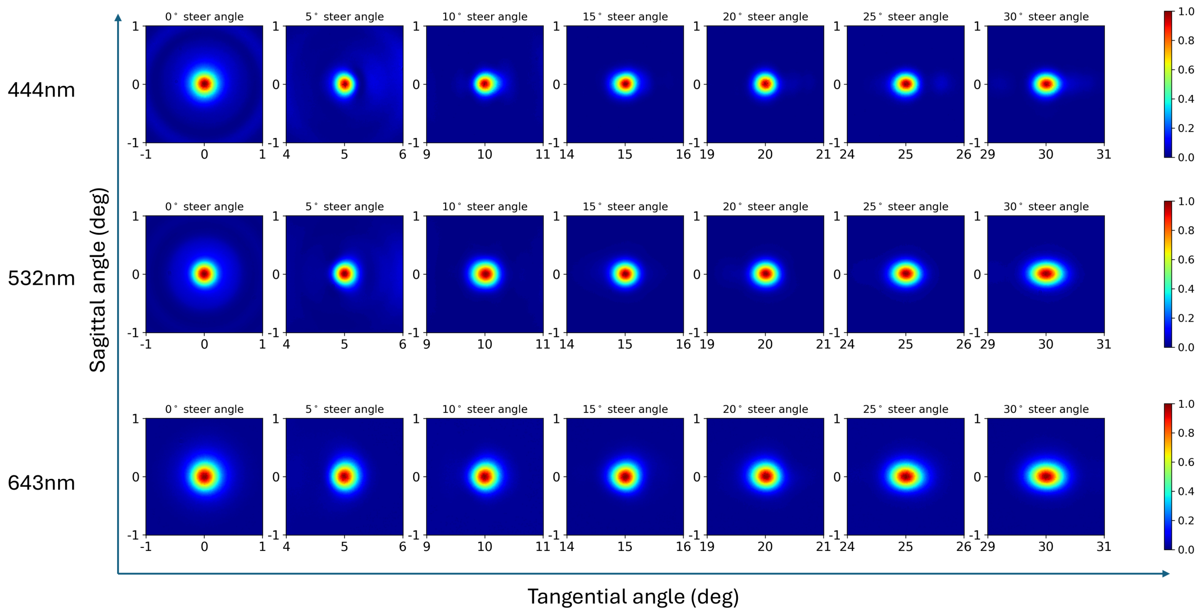

Fig S7 Angular intensity distribution of the beam steered to $\theta = 0$ - 30° at the three designed wavelengths.

41 ## VIII SFE images of a checkboard test pattern

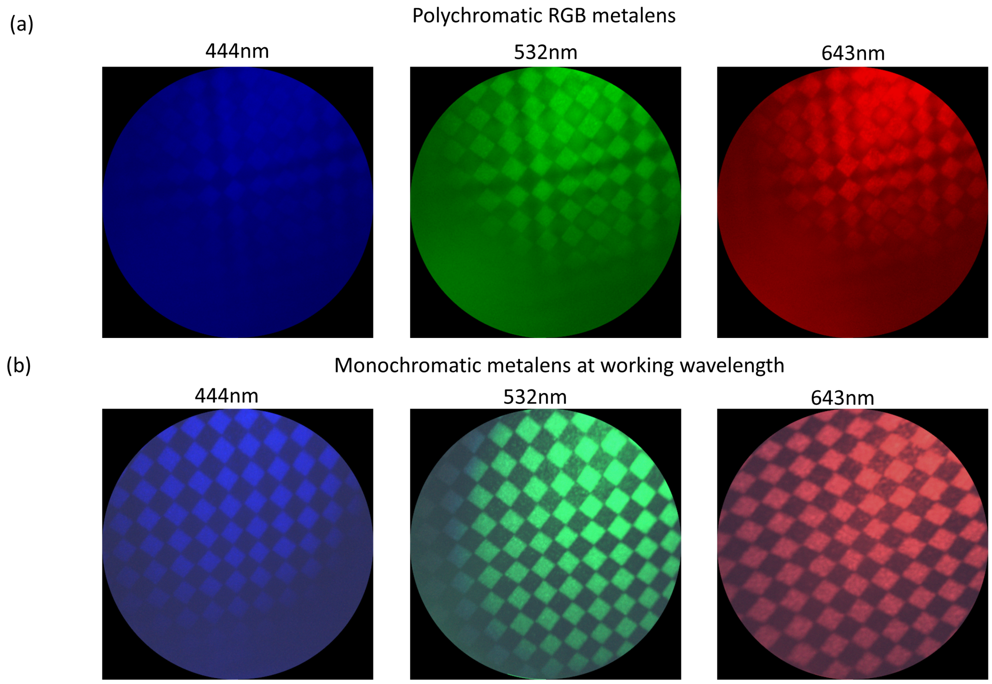

Fig S8 Unprocessed image taken by the SFE platform using the polychromatic RGB metalens at 3 color channels **(a)** and 3 monochromatic metalenses designed at corresponding wavelengths **(b)**. The imaging distance is $14.5\,\mathrm{mm}$, the blocks of the checkerboard have a side length of $1.1\,\mathrm{mm}$, and the angular FOV of this SFE platform is $54°$.