Broadband high-efficiency and polarization-insensitive metasurfaces

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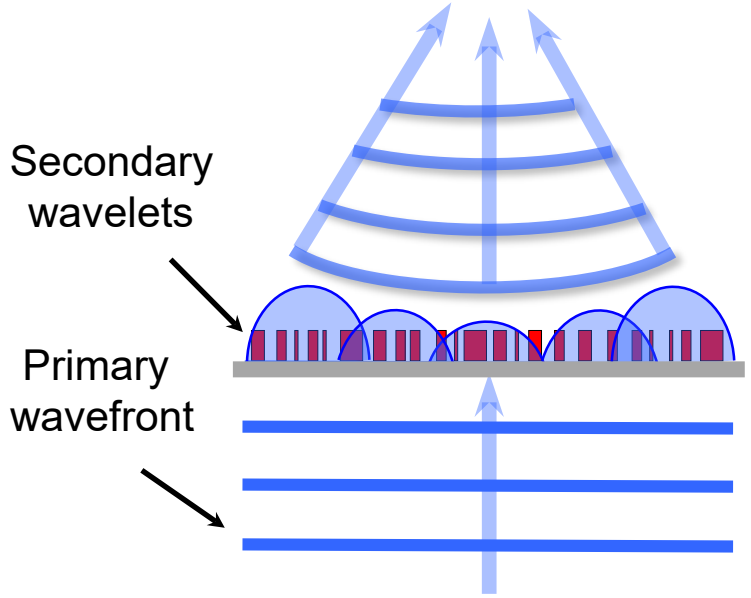
Introduction to metasurfaces

- **Metasurfaces**: nano-structured surfaces with tailored functionalities
- Control Amplitude, phase, polarization and wavenumber of incident light

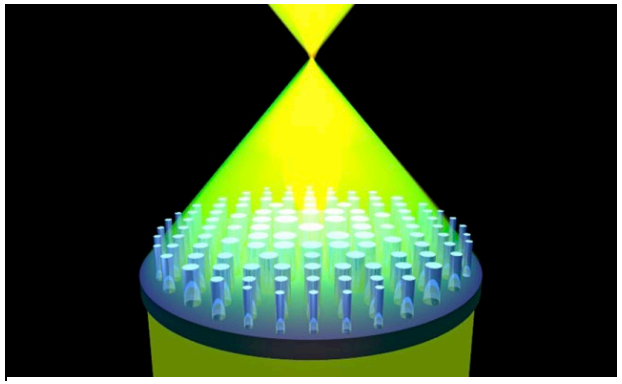
$$\vec{E} = A \cdot \exp^{i(k_z \cdot z + \varphi(\omega))} \hat{y}$$

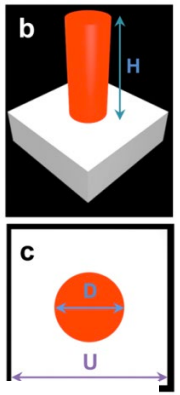
- Previous designs of metalenses suffer from efficiency loss, leading to poor imagining quality

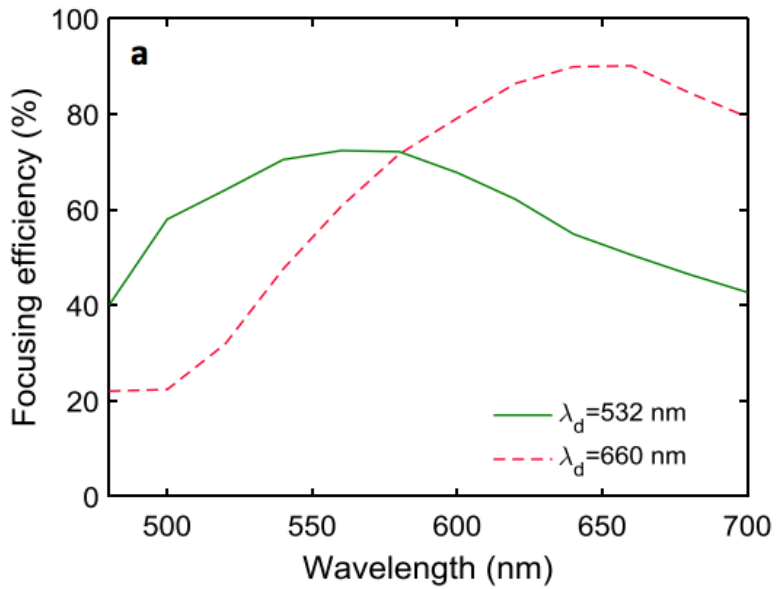


Past work

Circular Pillars

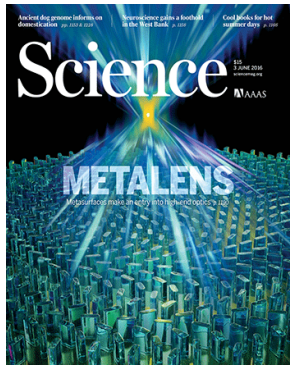


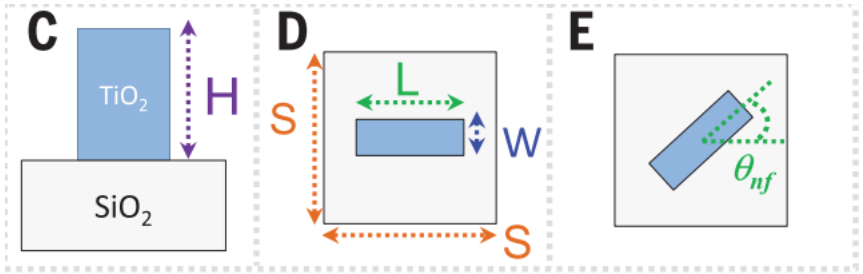


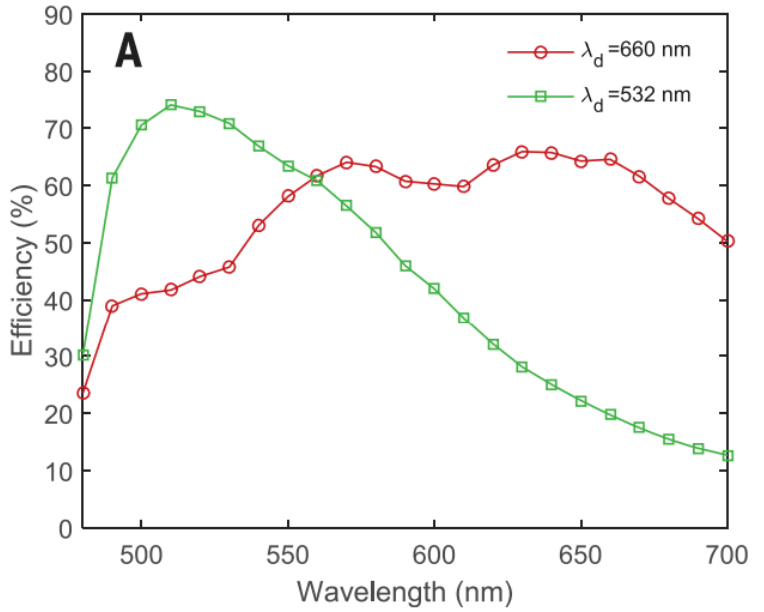


M. Khorasaninejad et al. (Nano Letters) 2016

Rectangular Nanofins

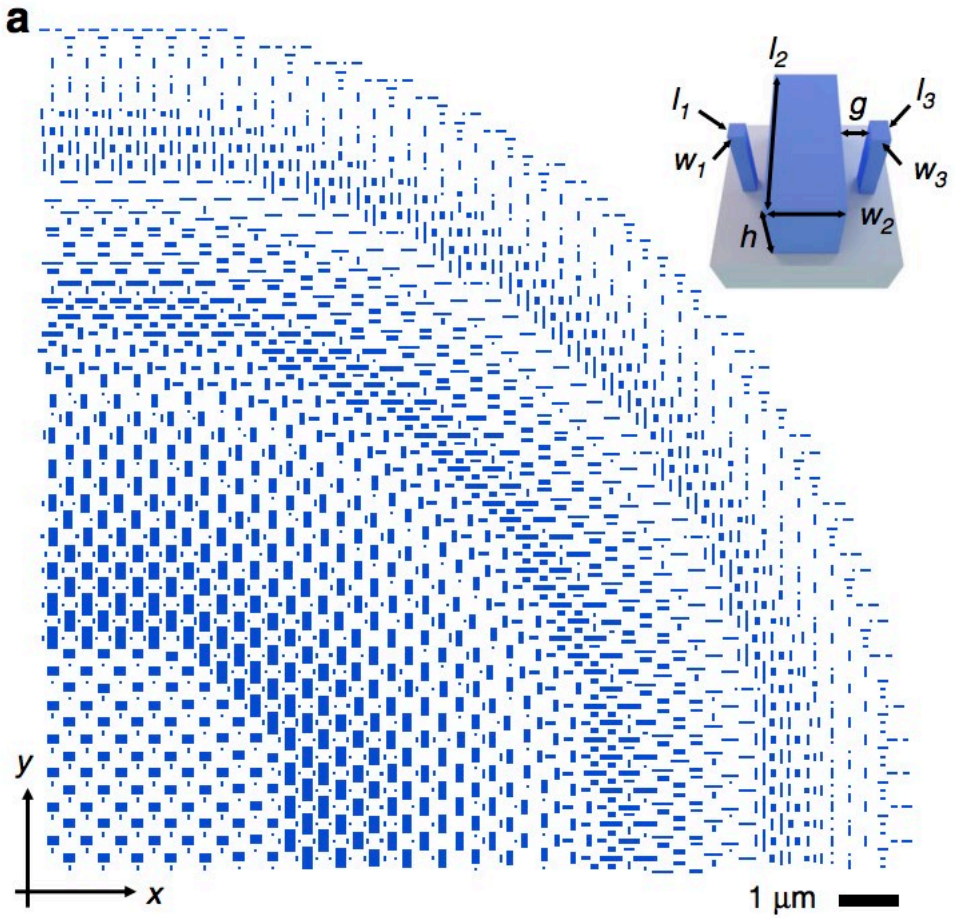






M. Khorasaninejad et al. (Science) 2016

Anisotropic nanostructures



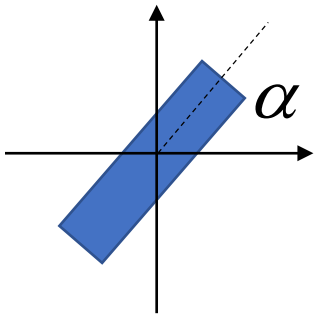
WT Chen et al. (Nature Communications) 2019

- High tunability of design parameters
- **>20,000** elements in the library

- Algorithm to optimize efficiency
- Improve efficiency by studying **gratings**

Polarization-insensitivity

- Achieve polarization-insensitivity with **anisotropic** nanostructures

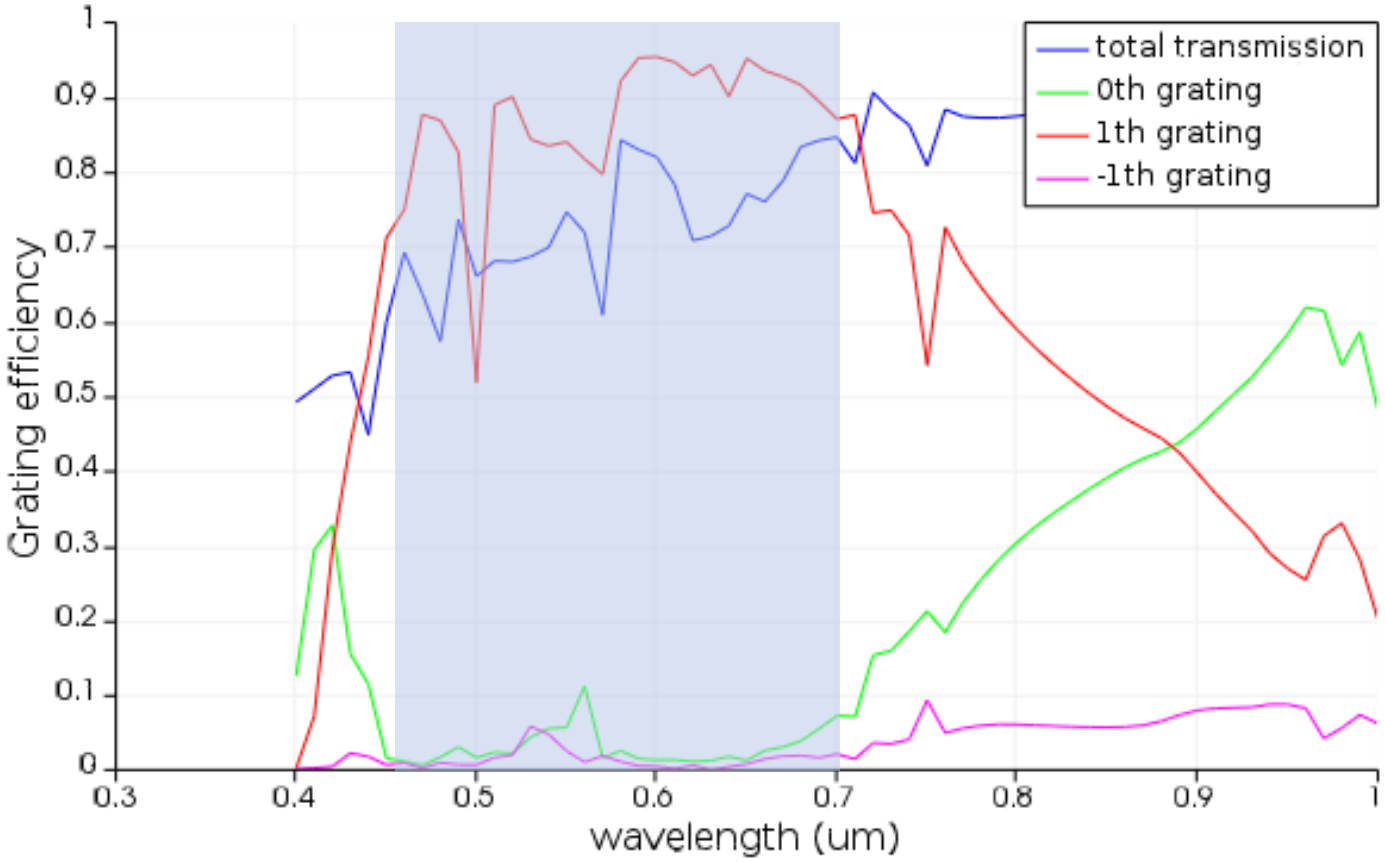


$$\begin{bmatrix} \tilde{E}_x \\ \tilde{E}_y \end{bmatrix} = \frac{\tilde{t}_l + \tilde{t}_s}{2} \begin{bmatrix} 1 \\ \pm i \end{bmatrix} + \frac{\tilde{t}_l - \tilde{t}_s}{2} \exp^{\pm i2\alpha} \begin{bmatrix} 1 \\ \mp i \end{bmatrix}$$

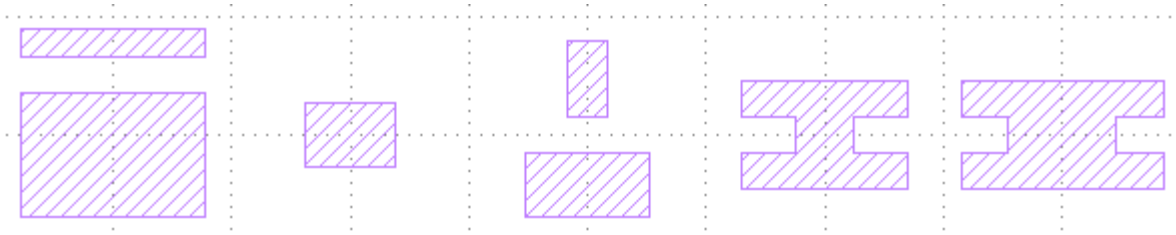
Geometric phase

- When $\alpha = 0°$ or $90°$, the geometric phase becomes the same for both RCP and LCP incidences → polarization-insensitive
- An advantage = a knob for tuning phase by π without changing dispersion

Promising simulation results



Average 1st order efficiency from 450nm to 700nm = **86.6 %**



- H = 600nm
- Unit cell size = 400nm

- **Grating efficiency** is defined as the fraction of transmitted light that gets diffracted to a particular order

Summary

- **Metasurfaces** enable the miniaturization and integration of optical components into a single device with **multi-functionalities**


Grating


Lens

Waveplate

Polarizer


Splitter

Filter

- The **high-efficiency surfaces** have extensive and promising applications in microscopy, imaging, and other technologies

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