Nanostructured Ultra-Lightweight Lenses for Earth Observation

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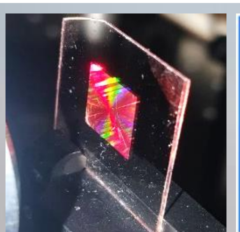
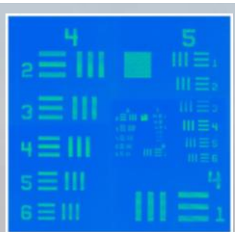
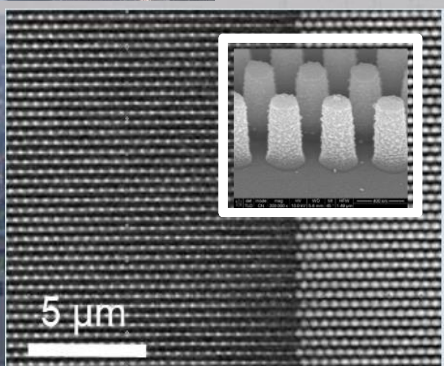
NCEO-CEOI e-Conference

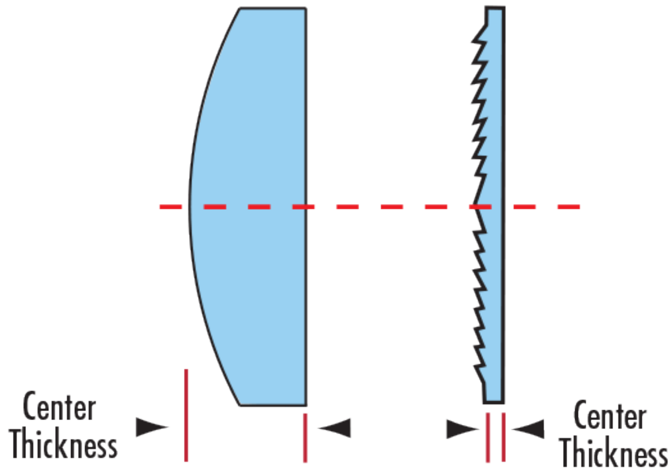




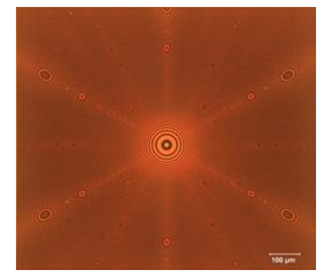


24th June 2020

What are Ultrathin lenses?



- Lenses focus incident light to a point either behind (reflective) or in-front of the incidence (transmissive)
- Path length of light in different parts of the lens leads to focussing
- Path length → Phase difference
- *Similar idea used by Fresnel lenses*

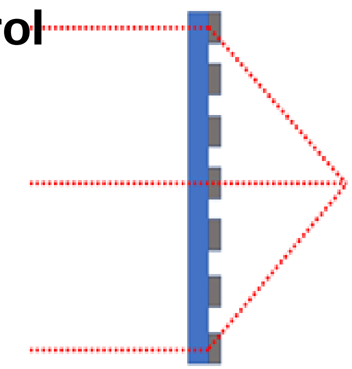


- Phase is *cyclic* → after 360°, phase is “identical” → split lens into *“zones”*

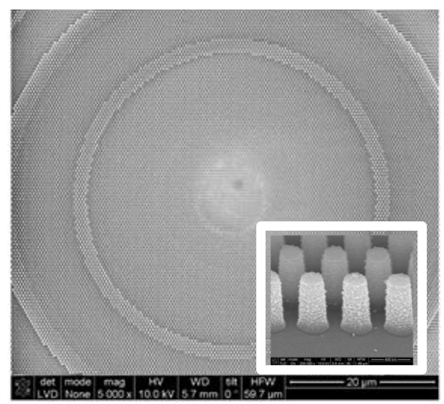
- **Use nanostructures to control local phase**
  → size and width determined

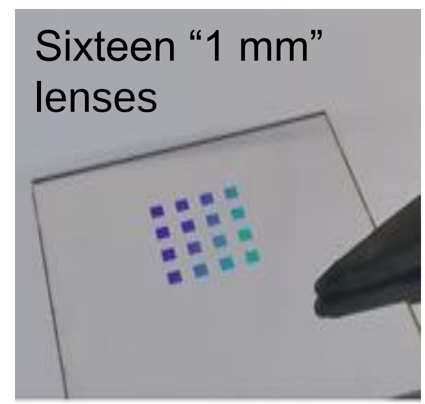
$$\varphi = \frac{2\pi}{\lambda}\left(\sqrt{f^2 + x^2 + y^2} - f\right)$$

- Choose wavelength and focal length



Ultra-Thin Lens (UTL)
(metasurface lens/metalens

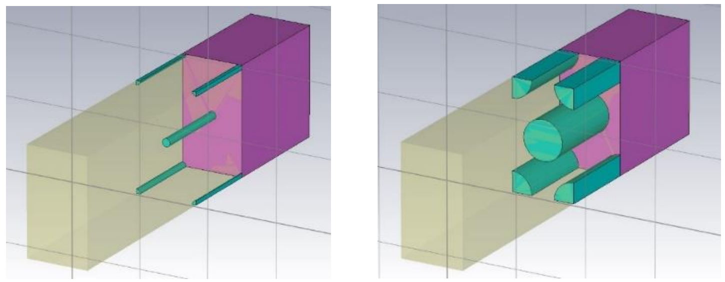




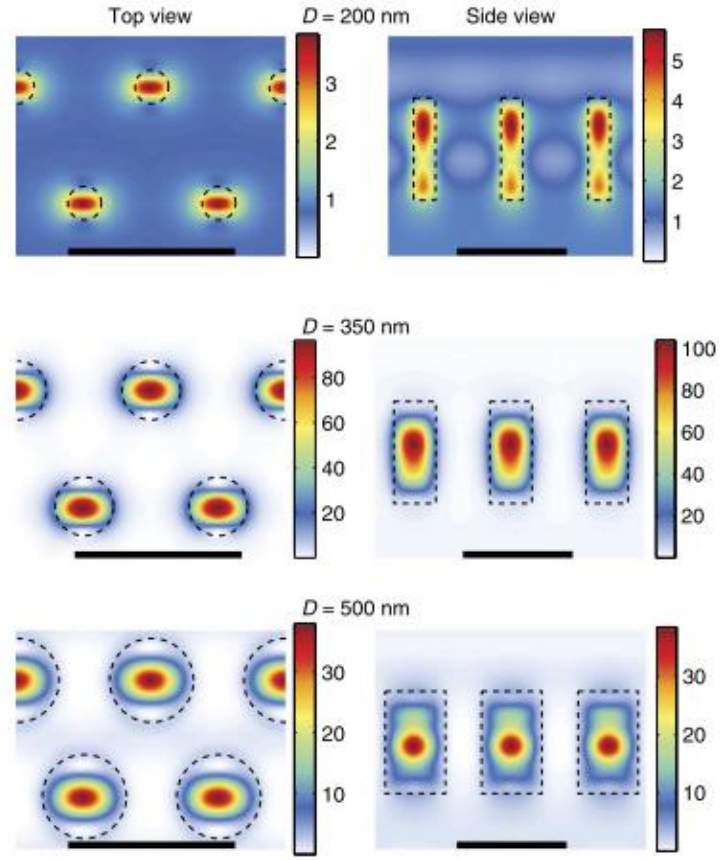
How do they work?

- Use dielectric pillars (a-Si), on a transparent substrate (fused silica glass)
  → a-Si has high refractive index & transmission in Infrared (n ~ 3.2)

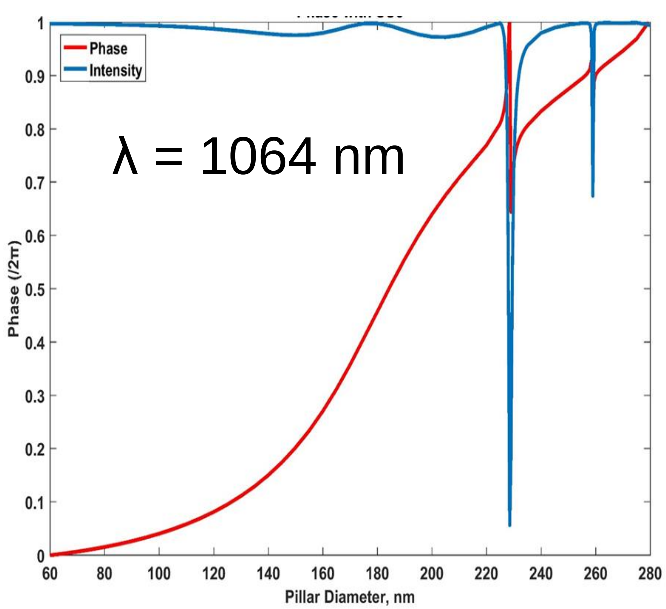
- Pillars act like *waveguides*, "squeezing" light inside



"effective index" effect



Faraon *et al*, Nat. Comms. **6**, 7069 (2015)



→ Smooth phase and intensity with varying diameters

Map diameters onto phase φ for specific x and y coordinates

$$\varphi = \frac{2\pi}{\lambda}\left(\sqrt{f^2 + x^2 + y^2} - f\right)$$

Optical Characterisation

- Fabricate 1 - 10mm UTLs using a-Si film deposition, E-beam Lithography, and plasma etching.

  → Designed at both SWIR and MWIR wavelengths

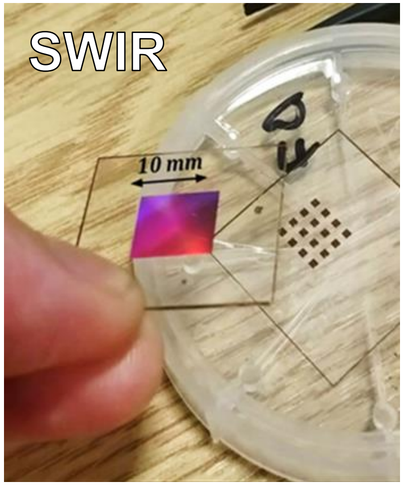
- Characterise these using two setups (only SWIR shown)
  → Beam expander needed for 10mm lenses

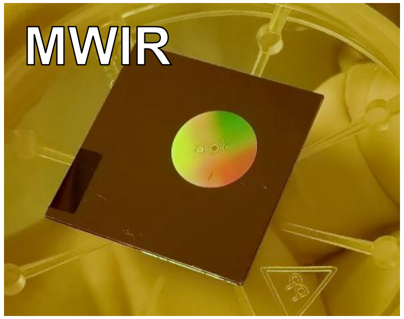
- Measure beam profile of lens using microscope objective and IR camera

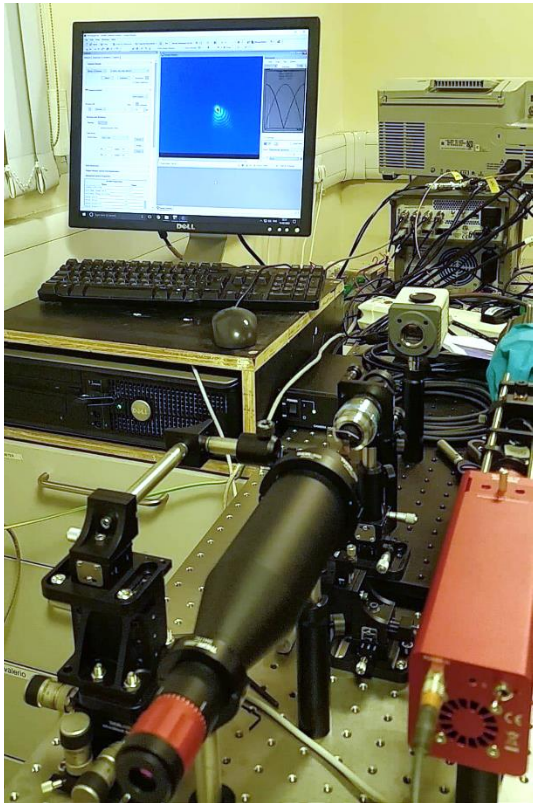
- F#1 10mm SWIR lens gives a spot size of ~1.8μm.

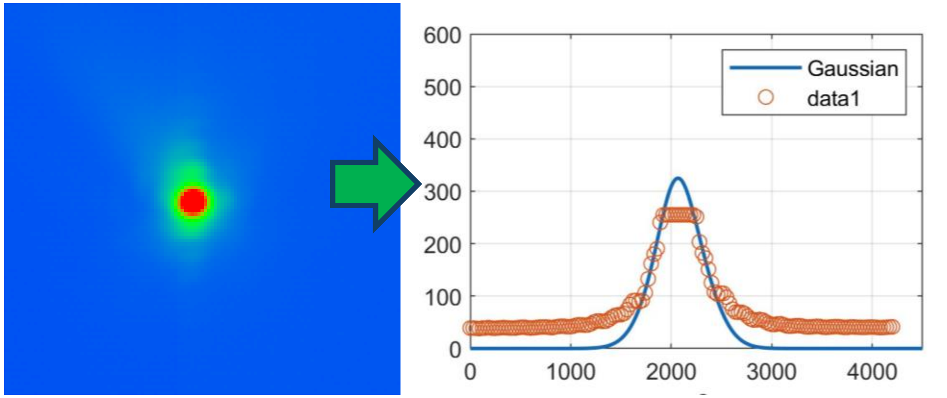
$$SS = \lambda / (2 \cdot NA)$$

- Theory = 1.19μm
  Close to diffraction limited









Efficiency & Imaging Performance

F#1 efficiency

Use ThorLabs Thermopile power meter to measure UTL focussing efficiency

Averaged power of laser = 0.298mW

Averaged power after substrate only = 0.287mW

Averaged power after UTL = 0.207mW

Power transmitted through substrate = 96.5%

Efficiency of metalens with respect to substrate = 73.4%

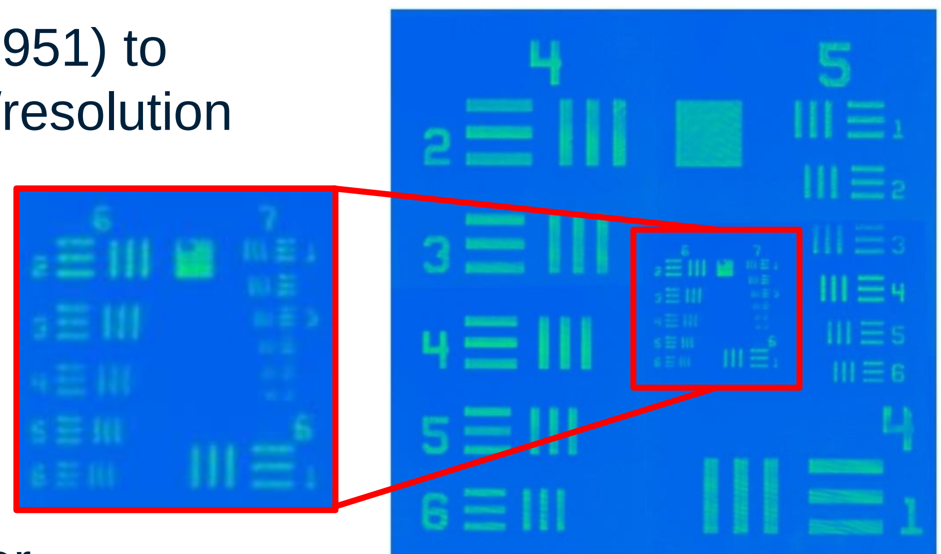
Absolute efficiency of metalens = 69.7%

Imaging

US Airforce Target (USAF 1951) to measure imaging capability/resolution

Image full USAF, stitch together to make full picture

→ Able to resolve Group 7 Element 4
→ Resolution: 2.8μm



Close to diffraction limited resolving power

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Due to COVID, project halted near end
Close to finishing MWIR lenses

Thank you for your attention