Increasing photodetector light collection with

Metalenses

Chris Stanford
Harvard University
Guenette Group

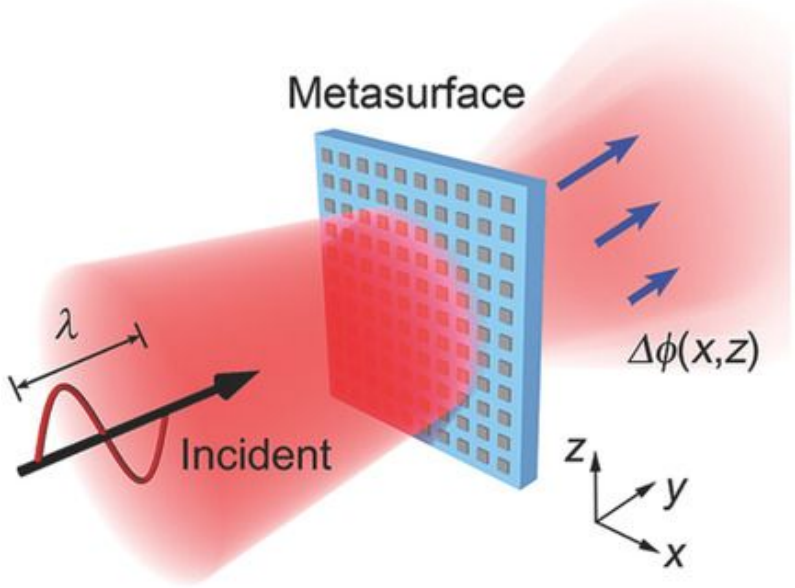
CPAD - 3/18/2021

Outline

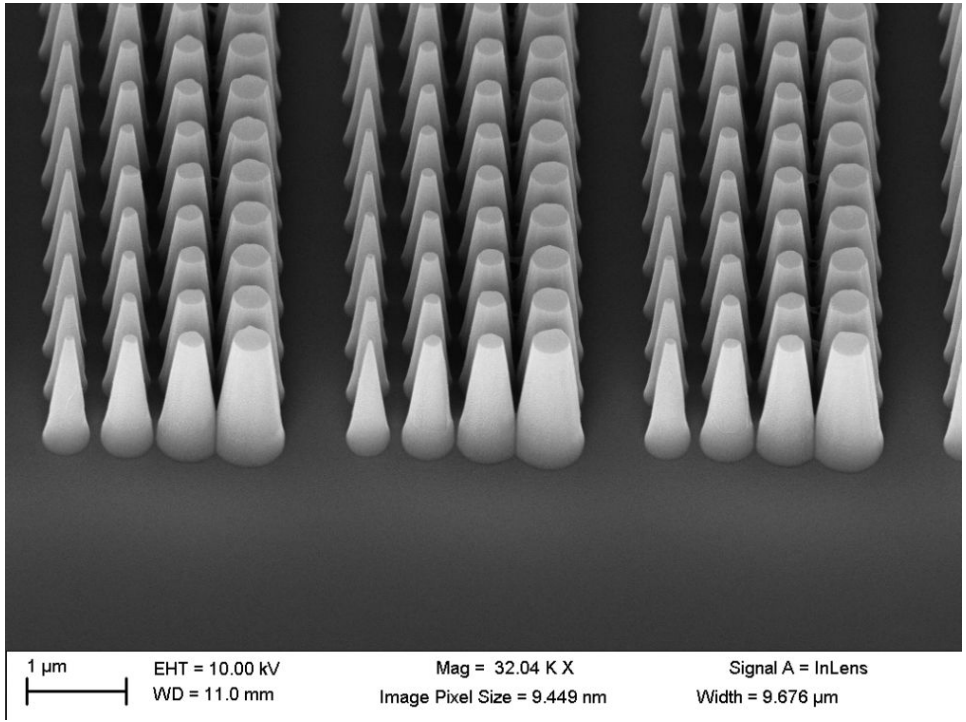
1. What are metalenses?
2. Importance to instrumentation
3. Current state of our research

What are metalenses?

A metalens is a type of metasurface

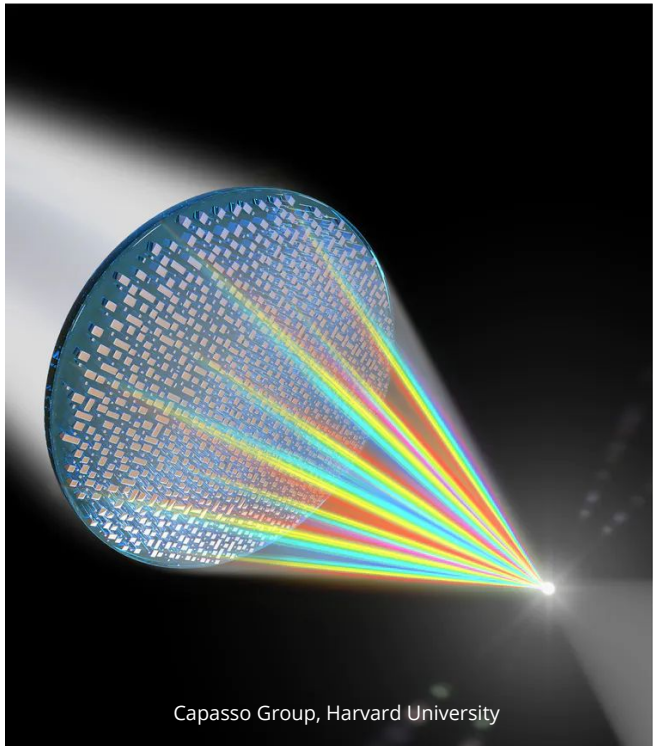


Kim, K.-H., Jung, G.-H., Lee, S.-J., Park, H.-G. and Park, Q.-H. (2016), Ultrathin Capacitive Metasurfaces for Strong Electric Response. Advanced Optical Materials, 4: 1501-1506. https://doi.org/10.1002/adom.201600146



What are metalenses?

Metalenses are designed to focus light, much like traditional lenses



Metalenses have seen some big developments in the last few years, with the Capasso Group at Harvard University at the forefront of that development.

- (2016) M. Khorasaninejad et al., Metalenses at visible wavelengths: Diffraction-limited focusing and subwavelength resolution imaging. *Science* **352**, 1190–1194.

- (2018) Chen, W.T., Zhu, A.Y., Sanjeev, V. et al. A broadband achromatic metalens for focusing and imaging in the visible. *Nature Nanotech* **13**, 220–226

- (2021) Intel, 3M, and others announced a $10 million dollar investment to expand the capabilities of the Capasso laboratory to further the innovation and move toward large scale fabrication.

Importance to instrumentation

Experiments live or die by their light yield

Light collection is arguably the single biggest factor when it comes to shaping the design of modern-day large-scale physics detectors, and determines what physics can be done

- Detectors are getting larger
- SiPMs/PMTs are expensive/radioactive
- Number of readout channels is growing unmanageable

Concessions must be made: sacrifice light collection and physics reach in order to build affordable and practical detectors.

Importance to instrumentation

Experiments live or die by their light yield

Light collection is arguably the single biggest factor when it comes to shaping the design of modern-day large-scale physics detectors, and determines what physics can be done

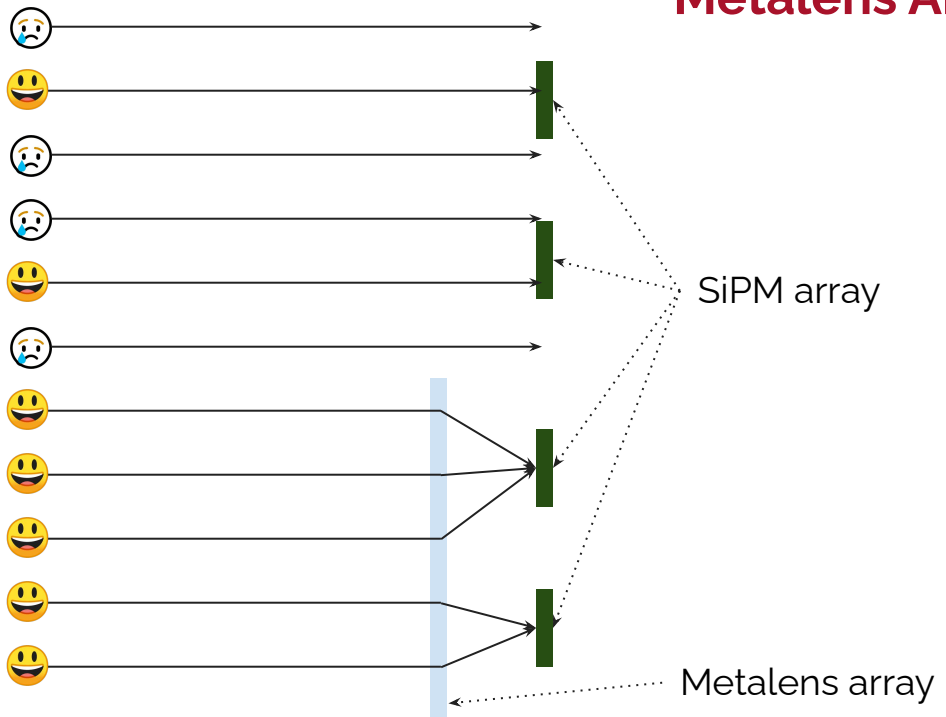
- Detectors are getting larger
- SiPMs/PMTs are expensive/radioactive
- Number of readout channels is growing unmanageable

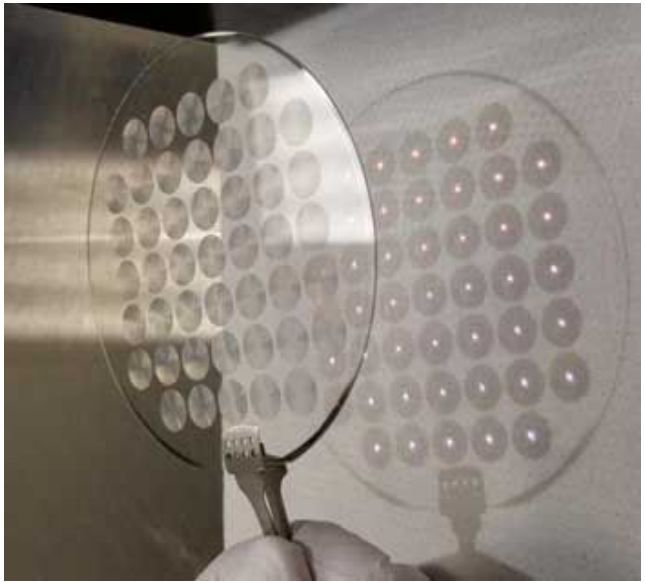
~~Concessions must be made: sacrifice light collection and physics reach in order to build affordable and practical detectors.~~

Metalenses offer a low-cost way to increase light collection in a detector without increasing the number of channels

Importance to instrumentation

Metalens Array

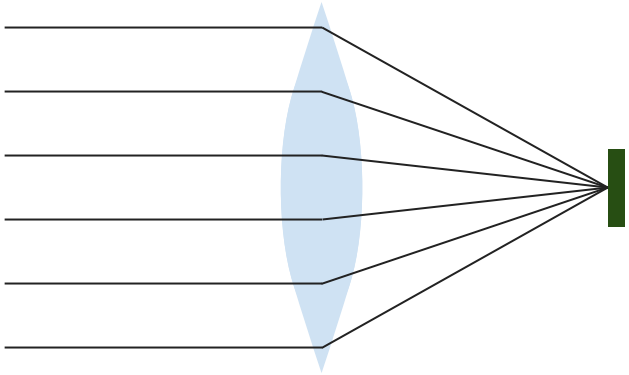




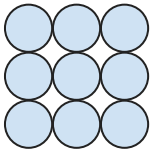
Capasso Group, Harvard University

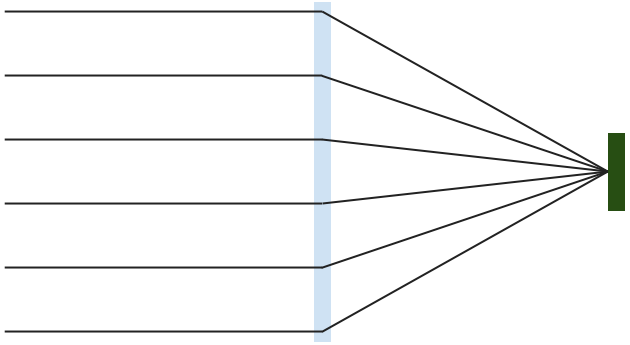
Importance to instrumentation

Traditional vs **Meta**

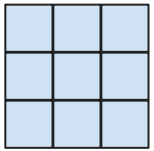


- Bulky
- Expensive
- Optical limitations



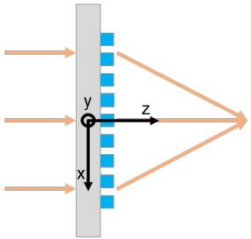


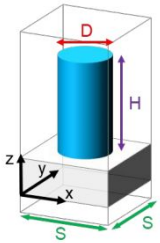
- Thin and lightweight
- Cheap, easy to mass-produce
- More flexible



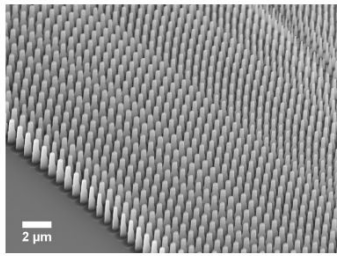
Current state of our research

A.A. Loya Villalpando *et al* 2020 *JINST* 15 P11021

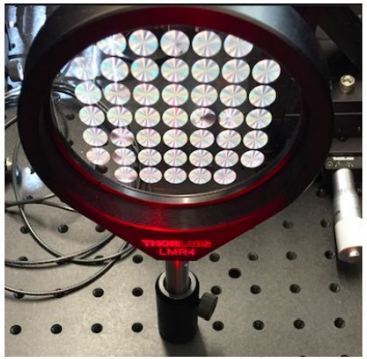




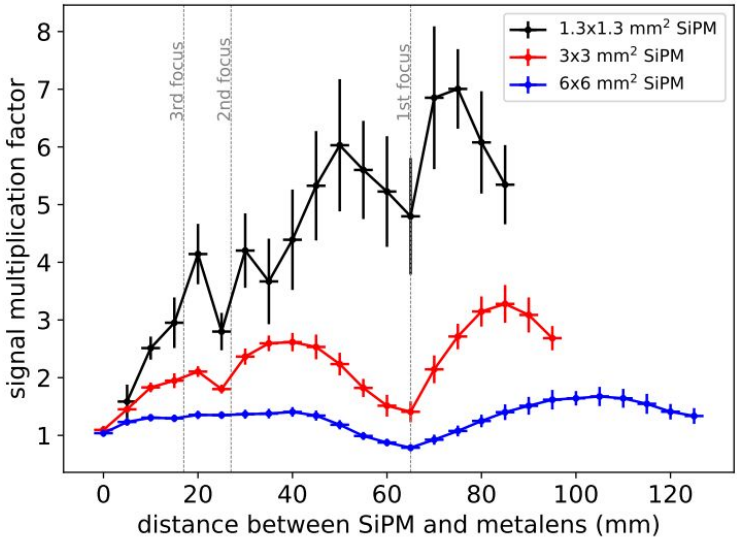
(a) Schematic representation of a metalens nanostructures.



(b) SEM image of our metalens nanostructures.

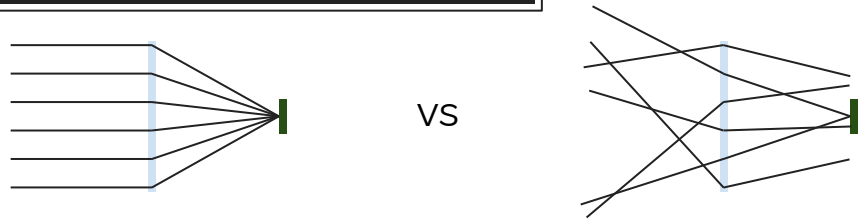


(c) Array of identically fabricated metalenses composed of the nanostructures in (b). Each metalens has a diameter of 10 mm and was designed at 630 nm with a numerical aperture of 0.1.



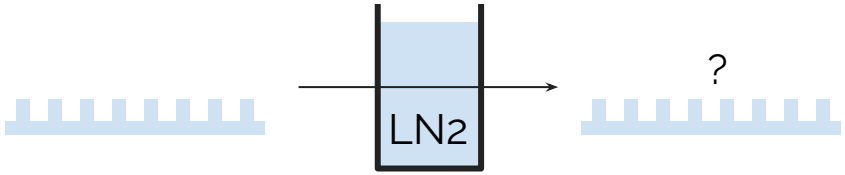
Future plans

Angular efficiency studies



Submersion studies

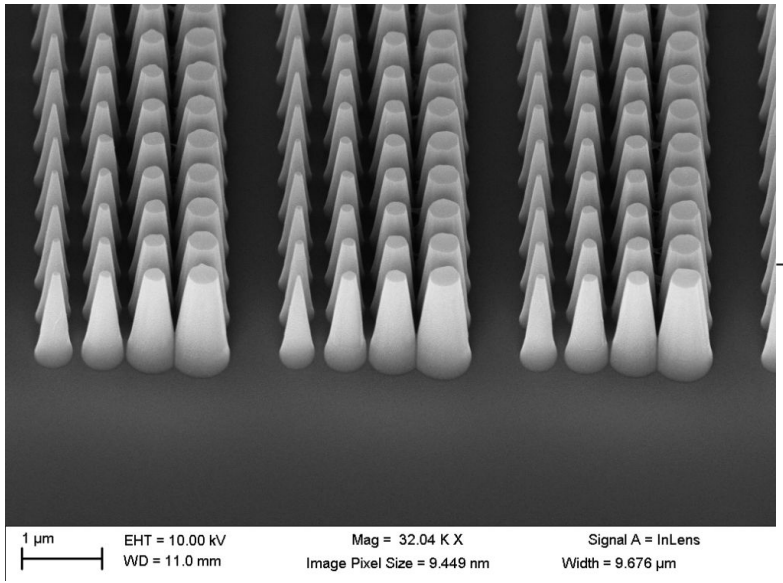
Cryogenic temperature studies

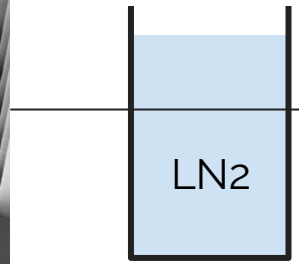


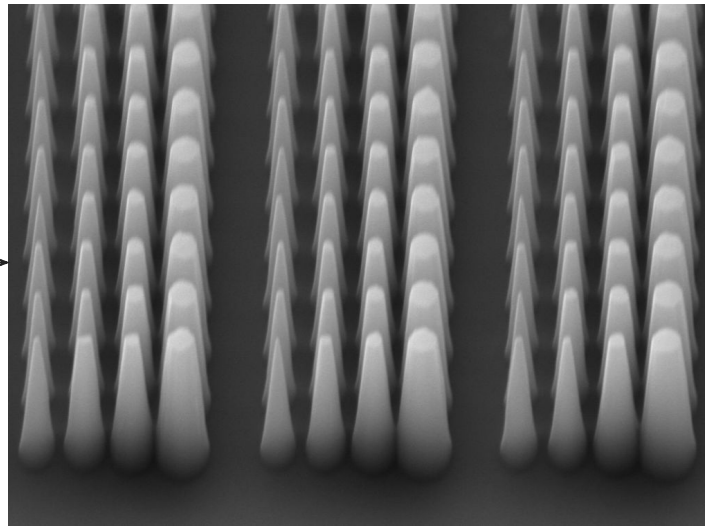
VUV Metalenses

LN2 Submersion

Nanopillars have proven durable under LN2 submersion

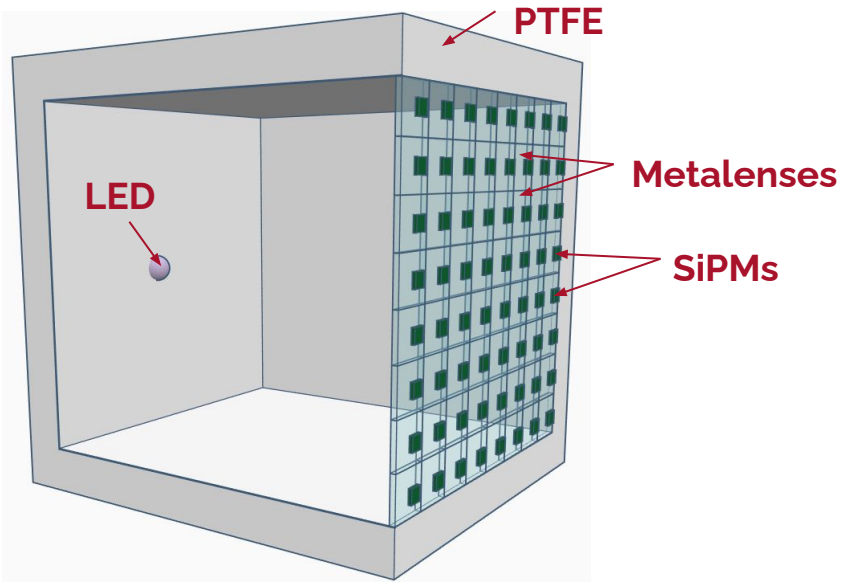




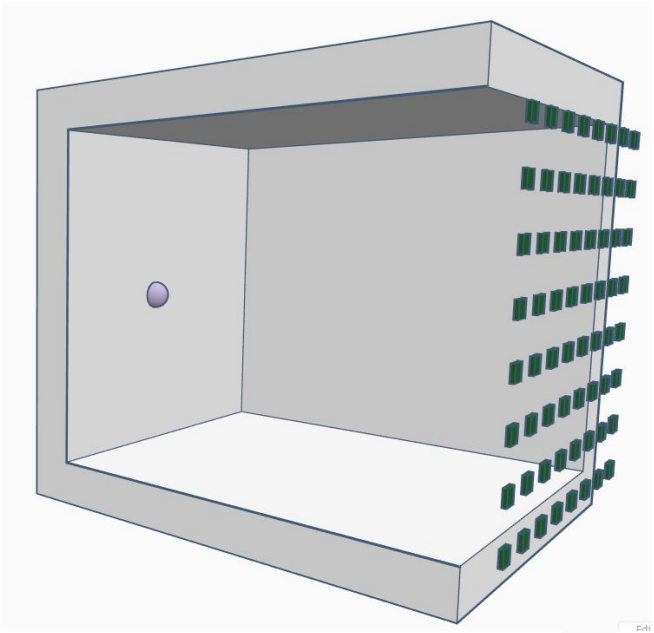


Questions

Extra Slides



With Metalens Array



Without Metalens Array