Designing Metasurface Optics

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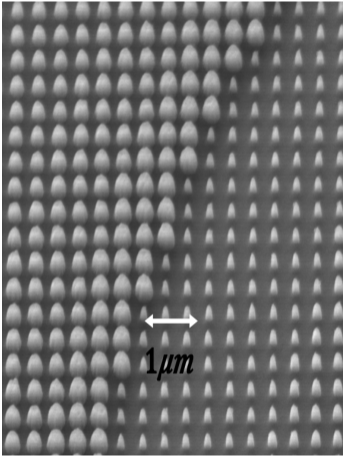
August 15, 2018

Outline

- Intro to metasurfaces
- Problem with traditional refractive optics
- Diffractive optics and metasurface approach
- Designing u shaped scatterers
- Simulating metasurfaces
- Continuing work

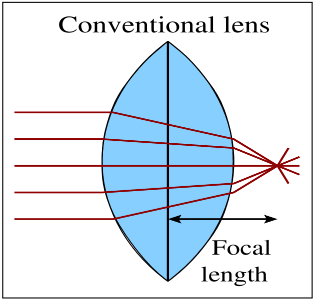
Metasurface (MS) Introduction

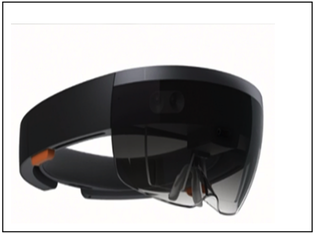
- Subwavelength diffractive optics
  - No higher order diffraction
- Periodic array of scatterers
- Arbitrary phase transformations
- Currently our lab works with cylindrical scatterers



Problems with Traditional Optical Elements

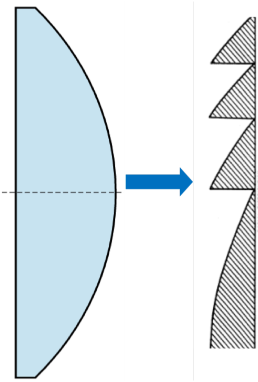
- Depends on shape and extent of optics
- Electronics miniaturization limited by optics size
  - The Internet of things
  - Alternate and virtual reality
- Focal length lower limit
- Single function





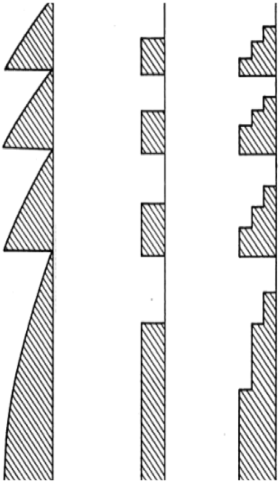
Diffractive Optics

- Transforms light through diffractive effects
- Smaller than traditional refractive optics
- Curvature imparts different phase transformation to different points on lens
  - Unable to fabricate e beam lithography



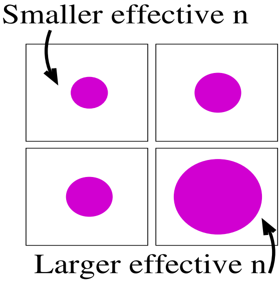
Metasurface Solution to Curvature

- Stepped height has similar performance and fabrication concerns
- Want constant thickness optics
  - Easy to fabricate structures



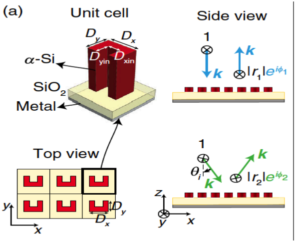
Metasurface phase transformation

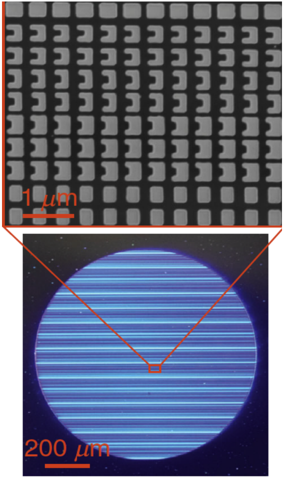
- Effective refractive index achieved by varying in plane scatterer dimensions
- Lenses on the scale of tens to hundreds of μm radius and thickness of a few μm



My Contribution: U Shaped Scatterer MS

- Multi functionality demonstrated by Andrei Faraon's lab
    - Different phase shifts for different incident angles
- Coupled cavities with u shaped scatterer metasurface mirrors





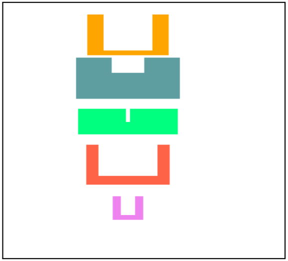
Faraon group: Angle-Multiplexed Metasurfaces

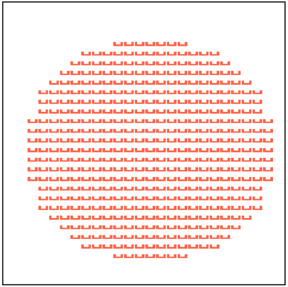
Simulation of Metasurface

- No closed form solution to Maxwell's equations
- Trial and error simulation
- Simulation process includes:
  - Initial dimension scanning simulation
  - Phase to dimension mapping
  - Final MS design simulation

Rigorous Coupled Wave Analysis (RCWA)

- Assumes constant scatterer dimension
- Wavelength, angle, and scattering shape specific
- Outputs phase and transmission with corresponding scatterer dimensions



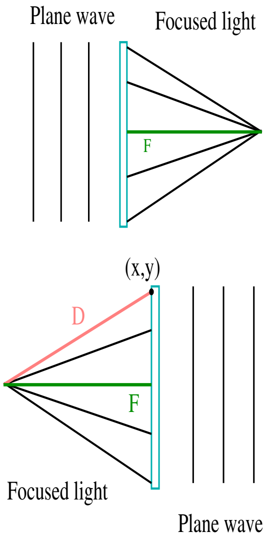


Phase Profile

- Find desired phase at each point on surface and map to dimension

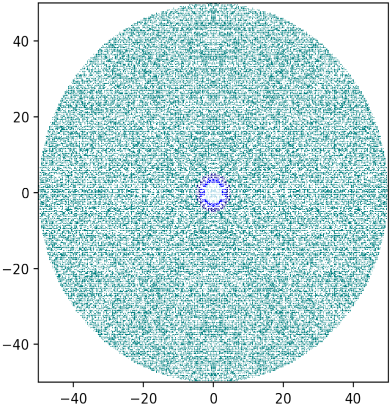
$$E = E_0 e^{i\varphi}$$
$$\varphi = kx - wt$$
$$\varphi = kD$$
$$\varphi = k\sqrt{F^2 + x^2 + y^2}$$

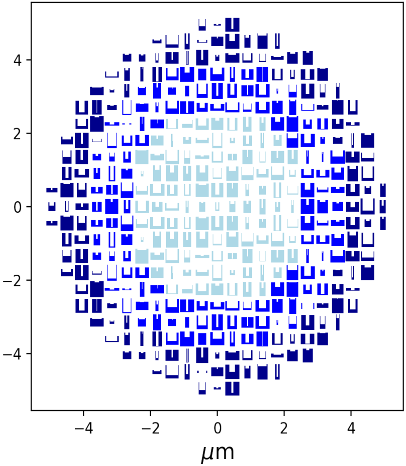
- Minimize the difference between the ideal and simulation phases



Simulation Parameters and MS Design

- 800,000 u dimensions
- 30,000 lattice points
- Normal incidence, 45 degree reflection





Finite Difference Time Domain Simulation

- Final simulation to test metasurface layout
  - Uses a leapfrog approach to solve time dependent Maxwell's equations
  - Much longer runtime
  - Does not assume uniform scatterers
- Last step before designing mask for fabrication

Future Work

- Complete MS design check in FDTD
- Fabricate metasurface and test the reflection and focusing power
- Further explore the multi functional capabilities of u scatterers

Acknowledgements

- Dr. Arka Majumdar, Albert Ryou, James Whitehead, and Luocheng Huang
- NSF and the UW INT REU Program
- Deep, Gray, Linda, and Cheryl