Tunable Dielectric Huygens Source Metasurfaces

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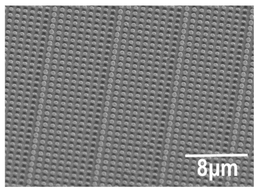
SMART SUMMER MATERIALS RESEARCH @ TULANE

Abstract

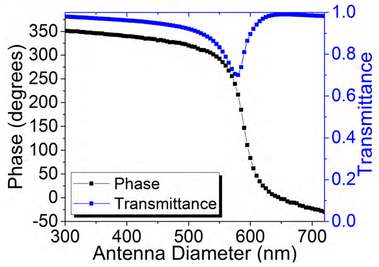
- Dielectric Huygens metasurfaces are comprised of nanoantenna elements
- Each element supports spectrally overlapping electric and magnetic dipole resonances
- Provides a platform for optical tunability through manipulation of nanoantenna geometry or material properties
- Potential for sensing applications and reconfigurable optics
- Metasurfaces can be designed for manipulation of any wavelength

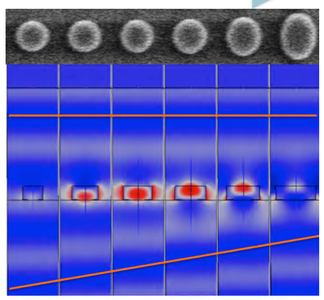
Huygens Metasurfaces

- Consist of microarrays of nanoantenna elements
- Manipulation of light through abrupt phase discontinuities on a subwavelength scale; can be designed for any wavelength
- Efficient wavefront manipulation tunable through changing geometric or material properties of nanoantenna elements



Increasing Diameter

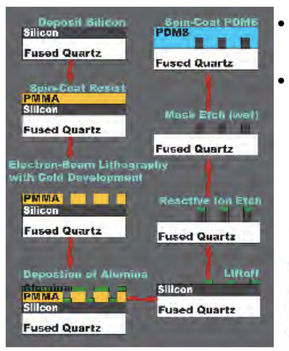




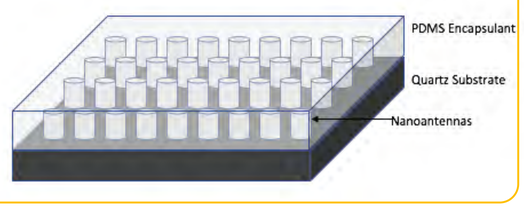
- Each nanoantenna element is treated as a discrete radiator
- Nanoantennas span a full 2π phase shift range with equal amplitude transmittance
- Varying the nanoantenna diameter controls the transmitted phase

- Dynamically tunable metasurfaces will allow the creation of tunable and reconfigurable optics; leading to the creation of flat optics for cameras, optical based sensing, and much more

Fabrication of Metasurfaces



- Fabrication process involves electron beam lithography and anisotropic reactive ion etch
- Fabrication method can be adapted to make metasurface antenna elements with different materials



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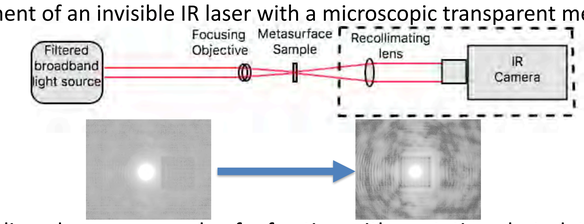
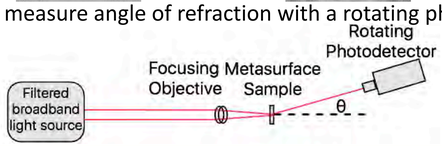
Metasurface Alignment And Characterization

- Alignment of an invisible IR laser with a microscopic transparent metasurface

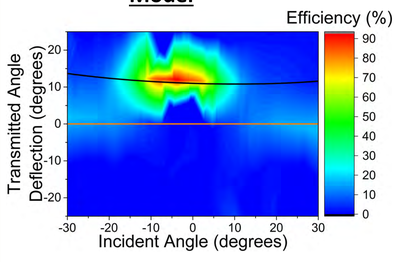


- Once aligned, measure angle of refraction with a rotating photodetector

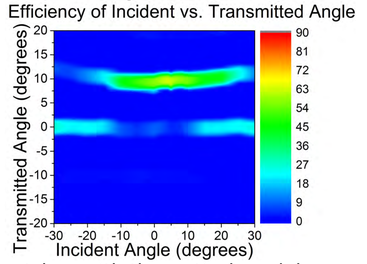


Theoretical Models and Experimental Results of Static Silicon Metasurfaces

Model

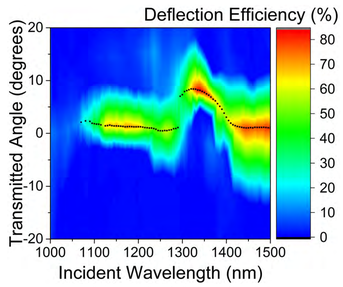


Experimental

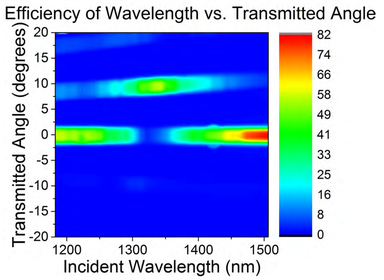


- Measured incident angle range of 30° matches with theoretical model
- Average angle of anomalous refraction is 9.5° vs. a predicted 12°

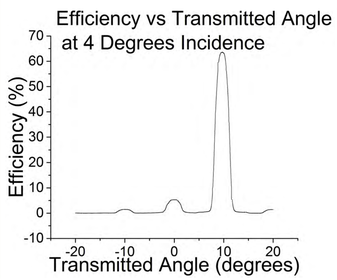
Model



Experimental



- Measured bandwidth of ~80nm matches theoretical model
- Average measured efficiency >60% vs. a predicted >90% efficiency

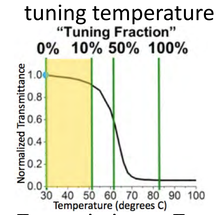


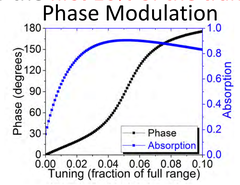
- Maximum measured efficiency of 63.55% transmitted at an angle of 9.642° at 4° laser incidence

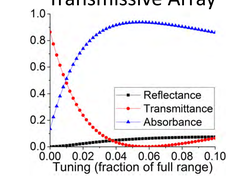
	Model (Incident Angle 4.2°, 1340nm)	Experimental (Incident Angle 4°, 1342.61nm)
Efficiency	92.4%	63.55%
Deflection Angle	12.06°	9.642°
Acceptance Angle	30°	30°
Bandwidth	80nm	80nm

Dynamic Vanadium Dioxide Metasurfaces

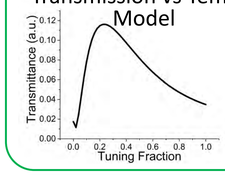
- Vanadium Dioxide (VO_2), a Transition Metal Oxide (TMO), can be tuned by external stimulus (temperature variation, electric field, intense illumination, pressure/strain)
- These external stimuli induce the reversible insulator to metal transition of VO_2
- VO_2 has a transition temperature of 70°C, resulting in decreased refractive index and increased conductivity and absorbance
- Modeling results show modulation of transmitted phase and transmittance by tuning temperature over the first 10% of the transition.

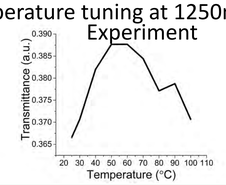




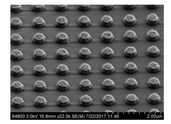


Transmission vs Temperature tuning at 1250nm





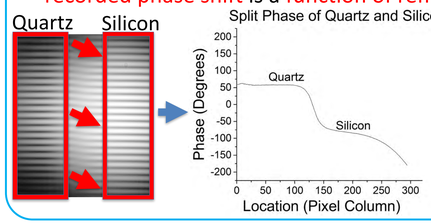
- Results shown left are from a VO_2 metasurface



Interferometry

- Superposition of electromagnetic waves produce interference fringes from which data such as induced phase shift and refractive index can be extracted
- This technique will be used to characterize silicon and VO_2 metasurfaces based on the measured phase shift

- Will measure the refractive index of VO_2 as a function of temperature; the recorded phase shift is a function of refractive index and thickness of material



- With a film thickness of 215.6nm and incident wavelength of 1342.7nm, we experimentally measured a refractive index of 3.489 compared to the literature accepted value of 3.501.

Conclusions

- Wavefront manipulation of incident light is achieved using arrays of dielectric Huygens source nanoantennas
- The transmitted phase of the wave can be changed by tuning the diameter of the nanoantenna elements
- VO_2 metasurfaces can manipulate the transmission, reflection, absorption, and transmitted phase of incident light as a function of temperature
- Experimental demonstration of a home-built interferometer for measuring relative phase shift and extracting accurate refractive index of thin films

Acknowledgements

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