Ultrafast Effects in 3D Metamaterial

Nkorni Katte

Wilberforce University, Electrical Engineering Wilberforce, Ohio

nkatte@wilberforce.edu / (937) 829-7956

Philip G. Evans

Oak Ridge National Laboratory, Quantum Information Science Oak Ridge, Tennessee (ORNL)

evanspg@ornl.gov / (865) 576-9447

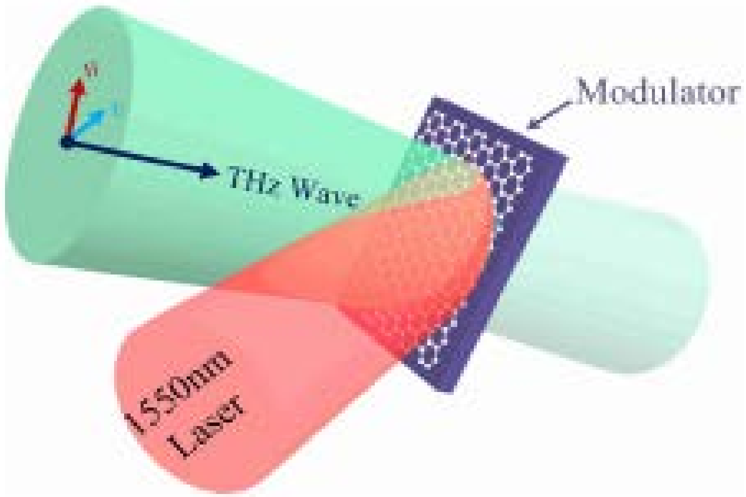
COMSOL CONFERENCE
2015 BOSTON

Introduction and Motivation

- The ultrafast modulation of light with light has been a long sought goal for researchers and remains a difficult task, especially in the IR and Terahertz frequency region.
- This is essentially so because the optical nonlinearities in conventional nonlinear materials are generally too weak to alter the intensity of light significantly on a sub-wavelength scale.
- The typical nonlinearities in these case are usually higher than those of common semiconductor such as Si and GaAs that are popular in the optoelectronics industry.

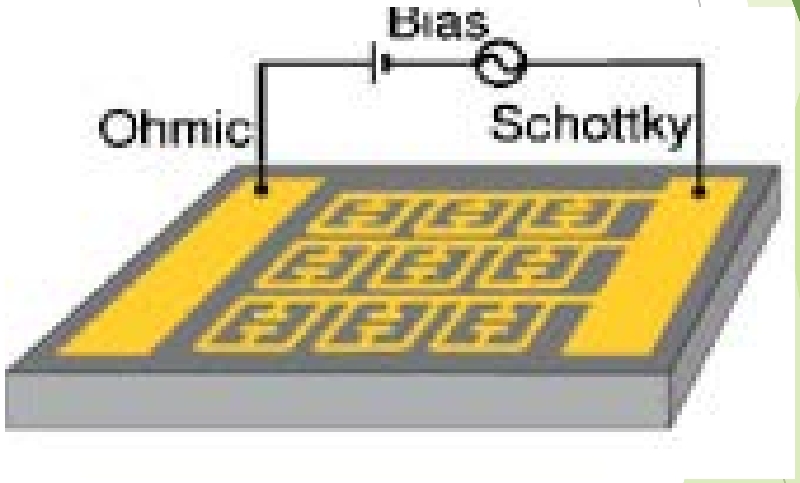
Typical Application for Spatial light Modulation

1-Optically controlled SLM



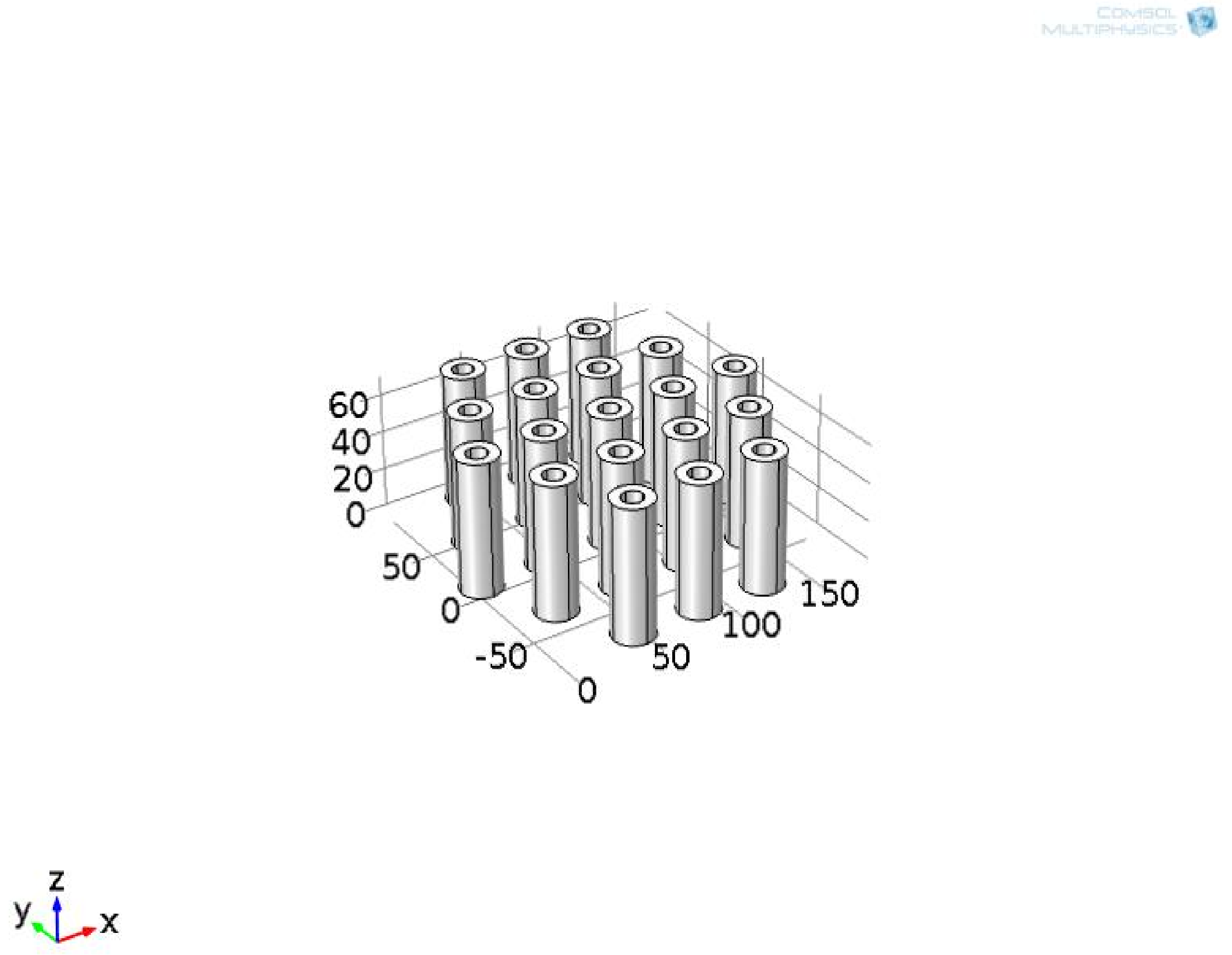
1-Nurbek Kakenov, Taylan Takan, Vedat Ali Ozkan, Osman Balc, Emre O. Polat, Hakan Altan, and Coskun Kocabas, "Graphene-enabled electrically controlled terahertz spatial light modulators," Opt. Lett. 40, 1984-1987 (2015).

2-Electrically controlled SLM



2-Wai Lam Chan, Hou-Tong Chen, Antoinette J. Taylor, Igal Brener, Michael J. Cich, and Daniel M. Mittleman “A spatial light modulator for terahertz beams,” APPLIED PHYSICS LETTERS **94**, 213511 2009

Hex Design



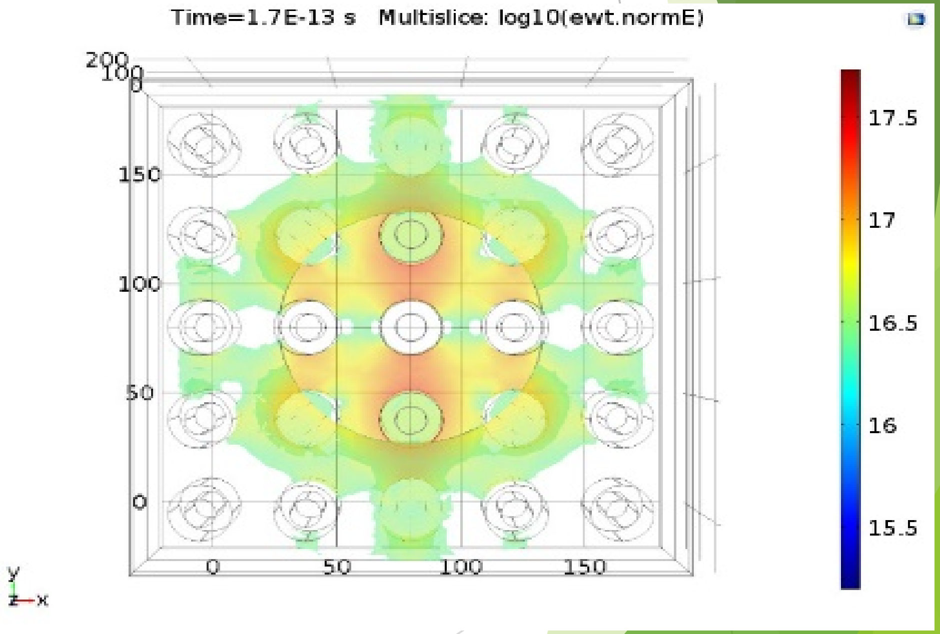
Rect Design

Introduce Chirality to Enhance third order nonlinearity

$$\nabla \times \frac{1}{\mu_r}(\nabla \times \mathbf{A}) + \mu_0 \sigma \frac{\partial \mathbf{A}}{\partial t} + \mu_0 \frac{\partial}{\partial t}(\varepsilon_0 \frac{\partial \mathbf{A}}{\partial t} - \mathbf{P}) = 0$$

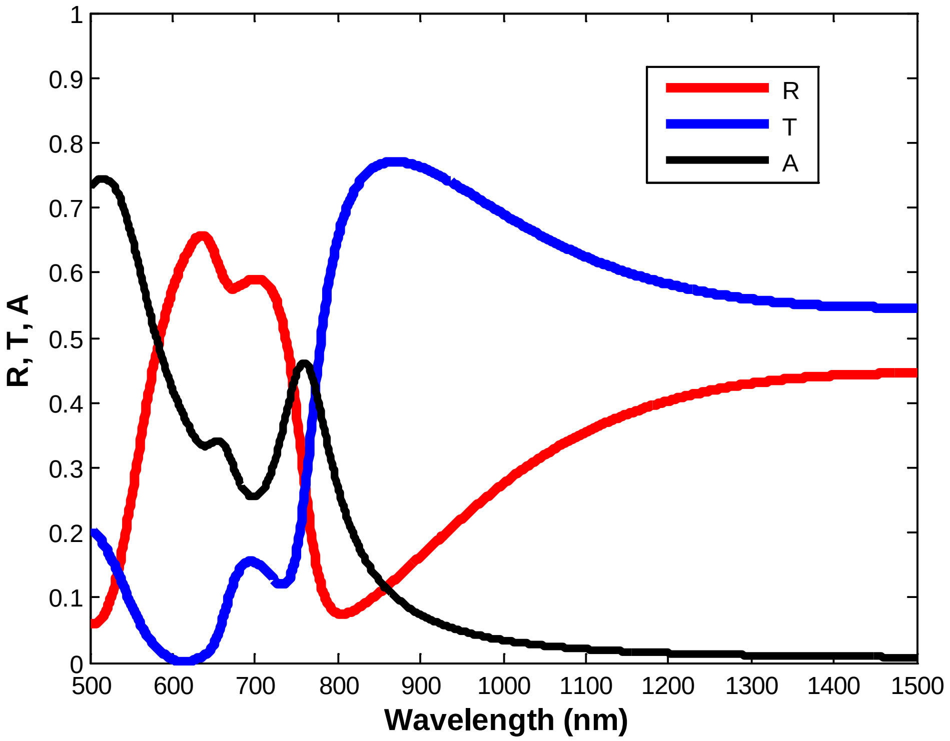
$$\mathbf{P} = \varepsilon_0 \chi^{(1)} \mathbf{E} + \varepsilon_0 \chi^{(3)} |\mathbf{E}|^2 \mathbf{E}$$

$$\mathbf{E} = -\nabla V - \frac{\partial \mathbf{A}}{\partial t}$$

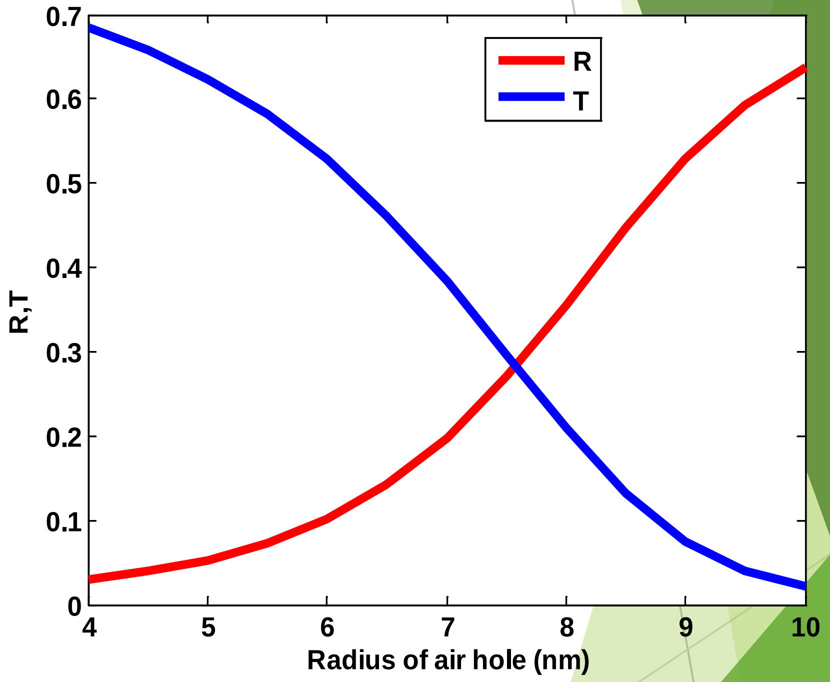


Chirality: Mirror image cannot be superimposed. So a Hemisphere on the rods will make the designs chiral. These structural designs have been shown to increase the third order nonlinear tensor.

Linear Optics results



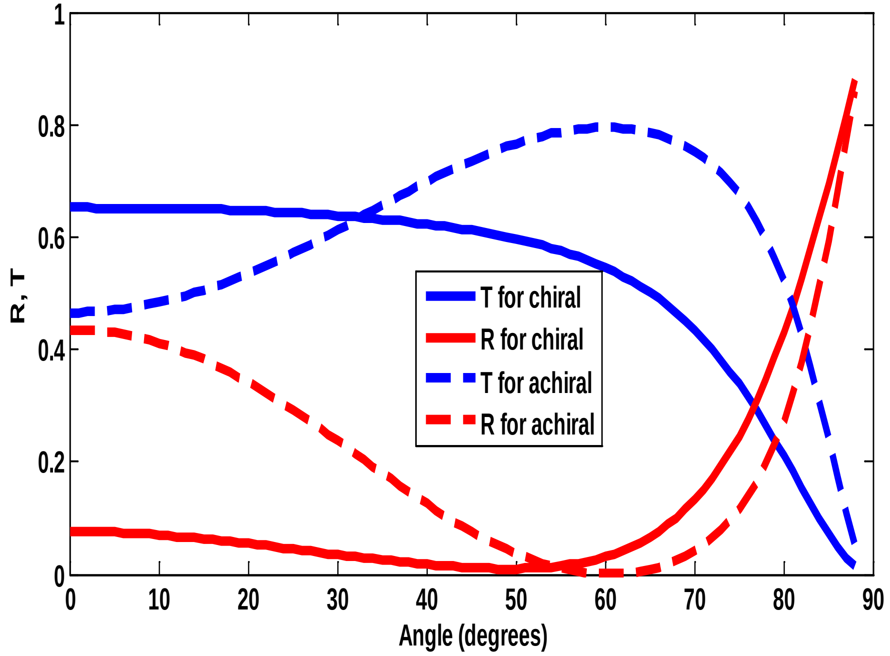
Transmission, Reflection and Absorption versus wavelength for a chiral MM, with a hemisphere radius of 50nm at zero degree incident.



Shows the Transmission and Reflection versus the Radius of air, when the incident angle is 0, degree at an operating wavelength of 800nm, for the achiral MM.

Linear Optics Results

Incident at angles to excite high energy plasmons



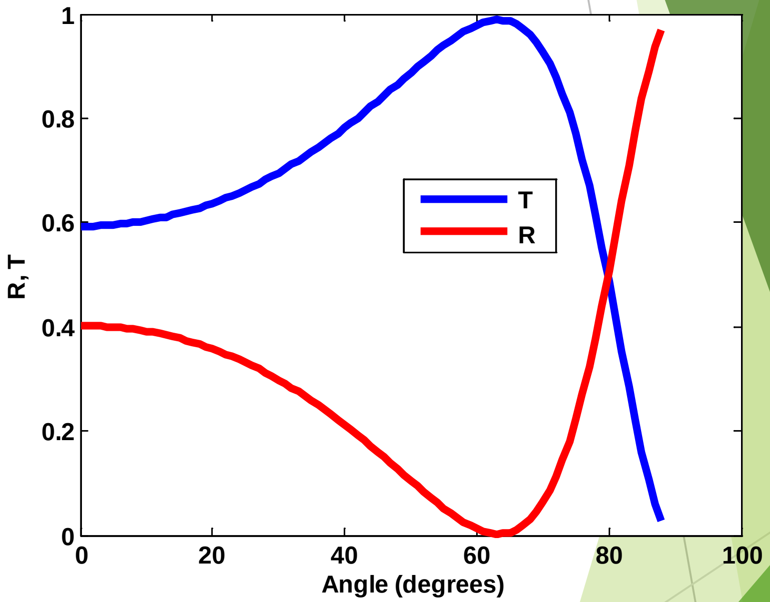


Figure (left): This figure shows the Transmission and Reflection versus angle of incidence for both achiral rectangular MM and the chiral rectangular MM at a wavelength of 800nm. Figure (right): This figure shows the Transmission and reflection versus angle of incidence for the chiral MM at a wavelength of 2000nm.

Nonlinear Optics Results

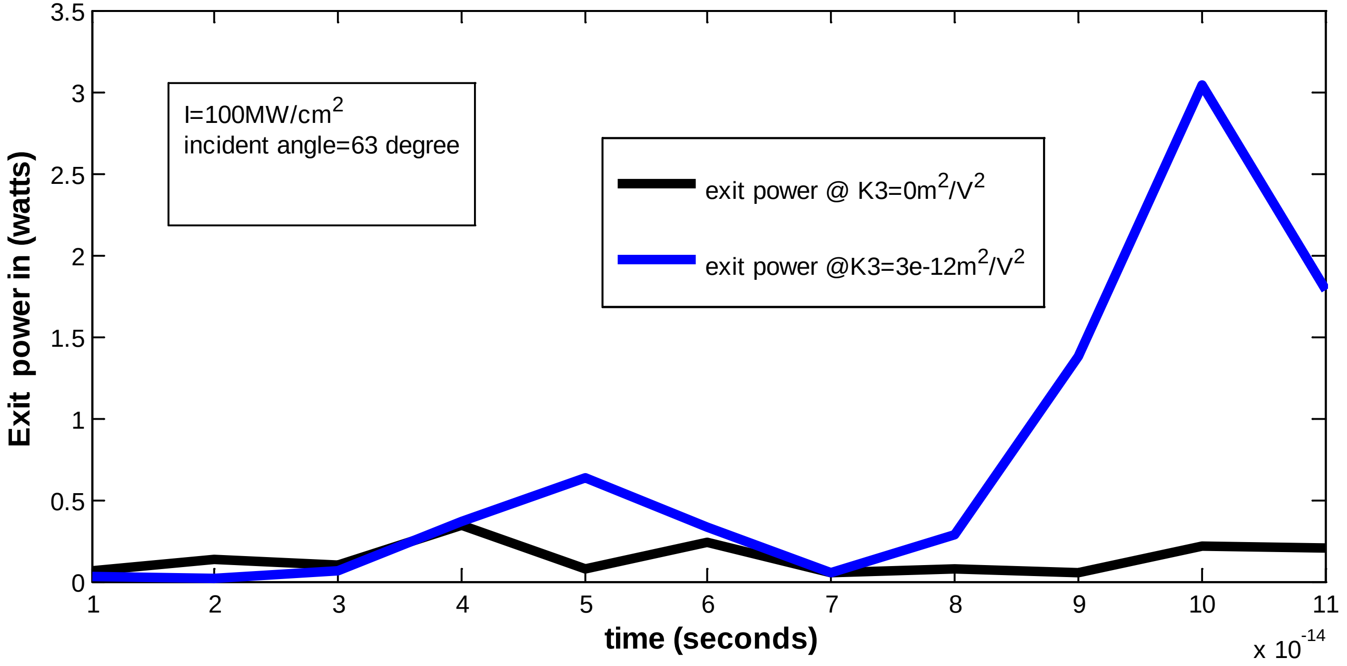


Figure : Shows the exit powers as function of time. The blue line represents the case when nonlinear effects are present, and the black line represents the case when, no nonlinearities are exited.

Conclusion and Future Work

- -Observed regions of field enhancement within MM
- -Transmission is sensitive to metallic filled volume and wavelength which can be
- optimized.
- The field enhancement and nonlinearity is very sensitive to incident angle
- -Possible to tune R,T and A for wavelengths, far into the infrared.

Future Work

- -Pump probe simulations
- Experimental measurements of third order nonlinearity
- -Apply appropriate design to design Optical switches and modulators
- Q&A