Ultrafast Effects in 3D Metamaterials

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1 Introduction: The extraordinary electromagnetic response of nanostructured material, usually made up of a metallic structures distributed in within a dielectric matrix has attracted a lot of interest in recent years. These materials are technically called metamaterial (MM) since they possess different properties from their constituent materials. Several applications of metamaterials have already been demonstrated ranging from super-resolution imaging, invisibility cloaking. Our study seeks to explore the ultrafast response of MM which will find applications in Optical switching and limiting, IR and Terahertz Spatial light modulation.

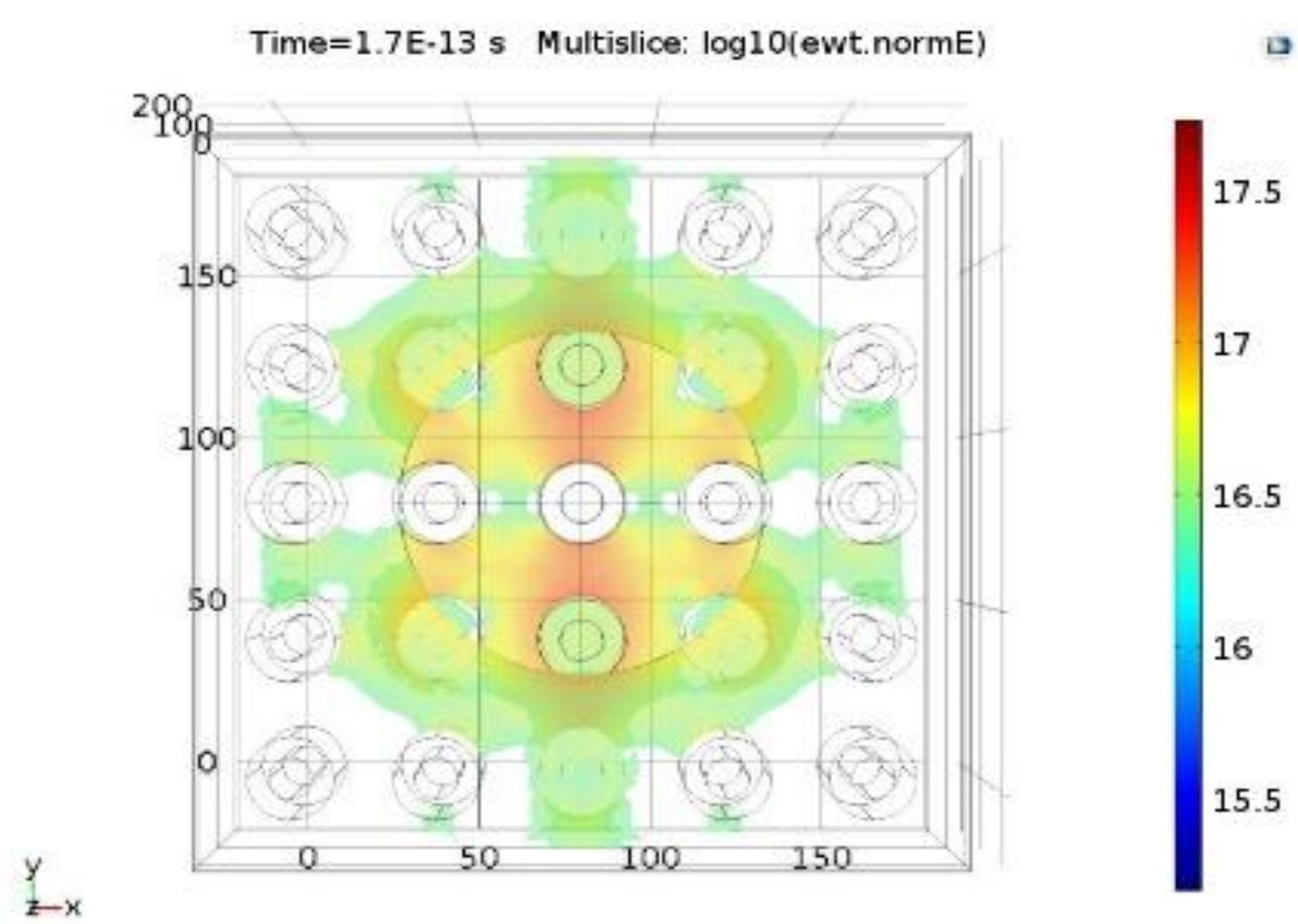


Fig1: Rectangular MM cell.

1 Computational Method

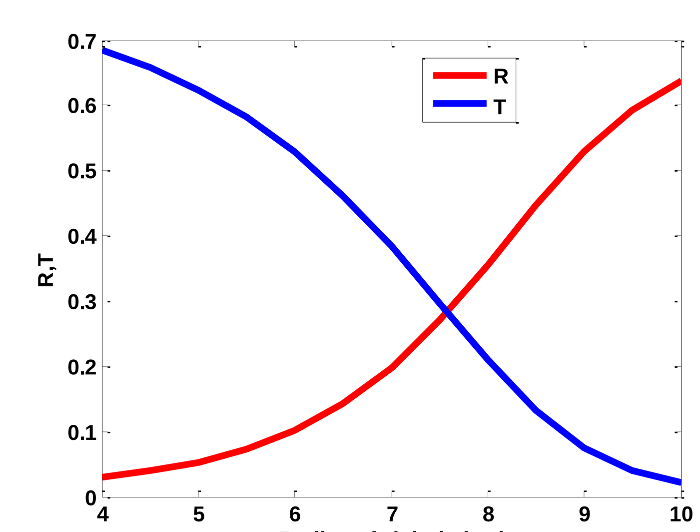
$$\nabla \times \frac{1}{\mu_r}(\nabla \times \mathbf{A}) + \mu_0 \sigma \frac{\partial \mathbf{A}}{\partial t} + \mu_0 \frac{\partial}{\partial t}(\varepsilon_0 \frac{\partial \mathbf{A}}{\partial t} - \mathbf{P}) = 0$$

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

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

Chirality has been shown to provide high Nonlinear optical activity such as polarization rotation in molecules and high concentration of electric field.
Examined the Reflectance and Transmittance as a function of geometrical parameters such as, air hole radius and metallic hemispherical radius which provides chirality[1].
Introduce nonlinearities, found in literature within the metallic nanostructures and observe changes in the Transmission functions [1,2].

3 Results



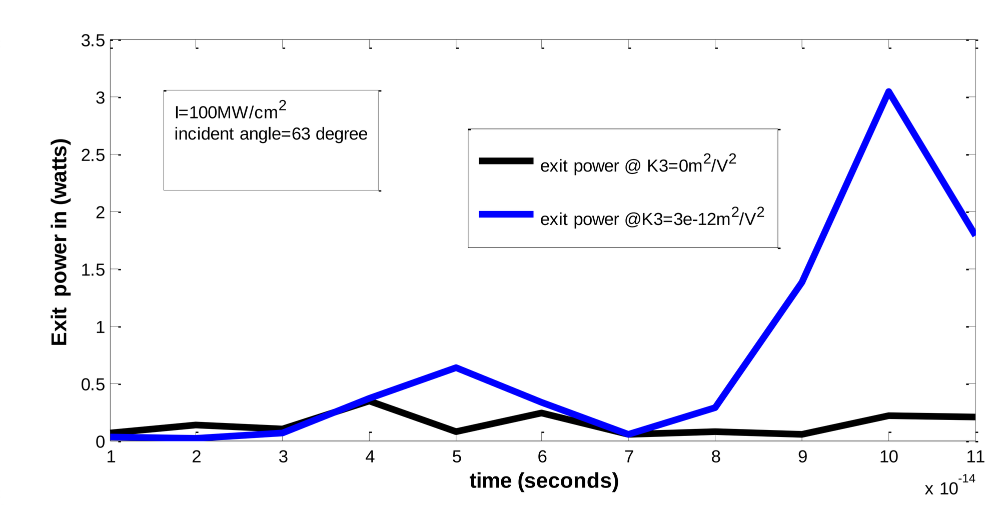
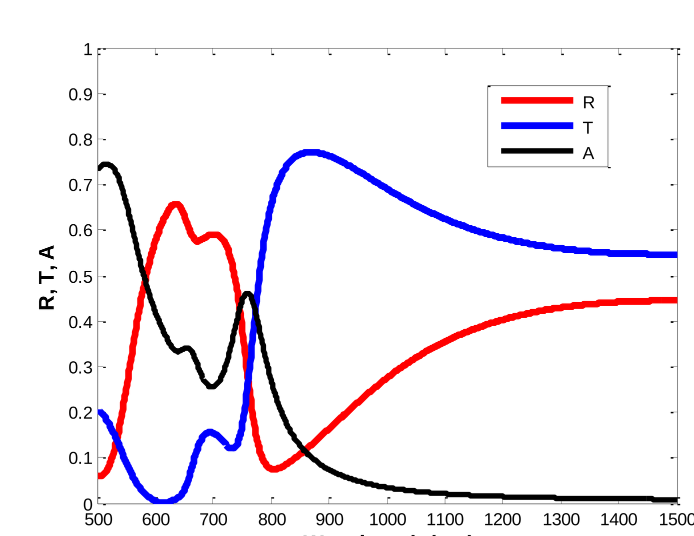


Fig 2 (Left): Au MM @ 0 degree incidence, as the radius of cylindrical air pore is varied, when wavelength=800nm.
Fig 3 (Right) Exit power as function of time at 2000nm incident wavelength.



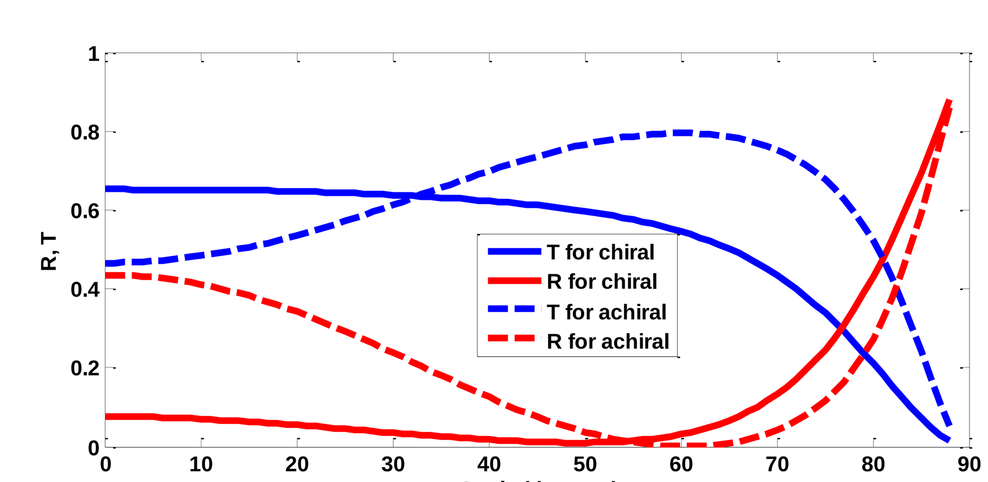


Fig 4 (Left): Chiral AuMM @ 0 incidence, Fig 5 (Right) : AuMM , Comparing achiral and chiral designs for different incident angles.@wvl=800nm.

4 Conclusions/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
Experimental measurements of third order nonlinearity
-Apply appropriate design to design Optical switches and modulators

Acknowledgements
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References

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[2] Jun-Yu Ou, E. Plum, J. Zhang, and N. I. Zheludev 2015 “Modulating light with light via giant nano-opto-mechanical nonlinearity of plasmonic metamaterial” arxiv.org/pdf/1506.05852.