ND*nano* Undergraduate Research Fellowship (NURF)
2013 Project Summary

1) Student name: *Yogita Guttikonda*
2) Faculty mentor name: *Prof. Lei Liu*
3) Project title: *Dynamically tunable THz devices based on magnetic carbon nano fibers.*

4) New skills acquired during summer research:
During my summer research I acquired a variety of skills. I learnt the importance of frequency domain THz spectroscopy instrument and to handle it. Secondly, I learnt the use of a waveguide and a lock-in amplifier and how to use them. Finally I learnt the fabrication of magnetic carbon nano fibers and their importance in the field of terahertz.

5) Practical application/end use of your research:
Manufacture and demonstrate dynamically tunable THz polarizers controlled by an external magnetic field. This approach would help us produce cost-effective, environmental friendly and potentially high-performance THz quasi-optical components (polarizers) which are of immense interest for advanced technological applications.

Terahertz Gap (0.1-10THz) is the least explored and developed frequency range in the entire spectrum. In the recent times, THz waves have attracted much interest owing to their applications in fields such as astronomy, security screening, sensing and imaging, etc. Conventional methods for realizing dynamically tunable THz quasi-optical components, THz polarizers, filters, attenuators and shielding devices, require complex and costly microfabrication processes, such as lithography or chemical etching. We propose to explore an alternative approach for cost-effective manufacturing of dynamically tunable THz quasi-optical devices and components relying on magnetic tuning of nanoparticle-filled CNF composite coatings. Our collaborator at the University of Illinois, Chicago has synthesized magnetic CNF powders consisting of CNFs intercalated with 10nm-dia. Fe_3O_4 superparamagnetic nanoparticles. On the basis of the novel composite materials, we will manufacture and demonstrate dynamically tunable THz polarizers controlled by an external magnetic field.

In this NURF project, the frequency domain terahertz spectroscopy and imaging system (Fig. 1) was optimized and applied for characterizing the magnetic CNF composite coatings in the frequency range of 570-630 GHz. As shown in Fig. 2 (a), shielding effectiveness for different CNF loadings were measured, giving a highest value of ~5dB for the sample containing mixed-CNF in PMMA substrate of regular thickness as compared to the samples of mixed-CNF in PMMA substrate of thinner dimensions. It can also be seen that the attenuation of unloaded PMMA samples is low compared to magnetic CNF loaded PMMA samples. Linearly patterned CNF coating samples behave as polarizers, allowing maximum transmission for perpendicularly polarized E-field and showing strong absorption for parallel polarization. As shown from Fig. 2 (b), the attenuation decreases with angle of orientation of the magnetic CNF composites, i.e., the THz absorption was seen to increase monotonically as the polarization angle decreased from 90degrees to 15degree. The anisotropic polarization with respect to the CNF alignment direction, thus offers fabrication of quasi-optical THz devices relying on such metamaterials. Metamaterials, artificially engineered structures with properties unattainable in nature, have opened up a new era in electromagnetic device design. Dynamically tunable metamaterials offer unique solutions for efficiently manipulating electromagnetic waves, particularly THz waves, which has been difficult due to the fact that naturally occurring materials rarely respond to THz frequencies in a controlled manner.

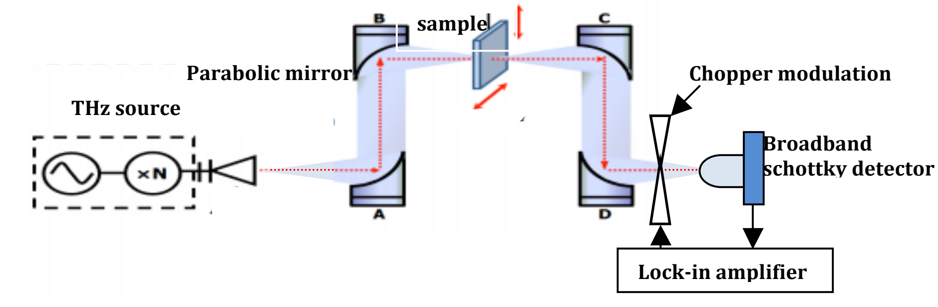
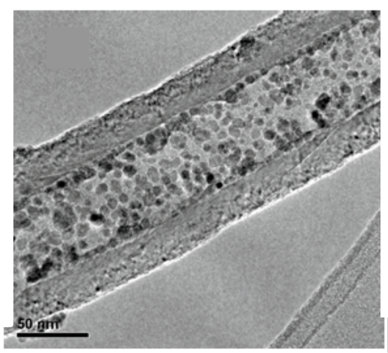


Fig. 1 The frequency domain terahertz spectroscopy and imaging system based on broadband quasi-optical Schottky diode detectors. Mirrors A and B collimate and then focus the THz beam through the sample. Mirrors C and D collimate the transmitted signal again and focus it on to the detector. The sample under test is placed at the focal point of the THz beam between mirrors B and C.



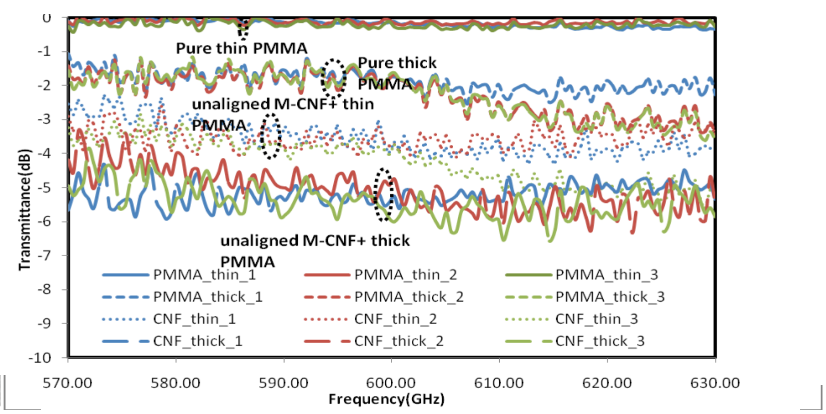


Fig. 2(a) CNF filled with magnetic Fe_3O_4. Graph showing attenuation which increases with CNF loading and thickness of the PMMA substrate.

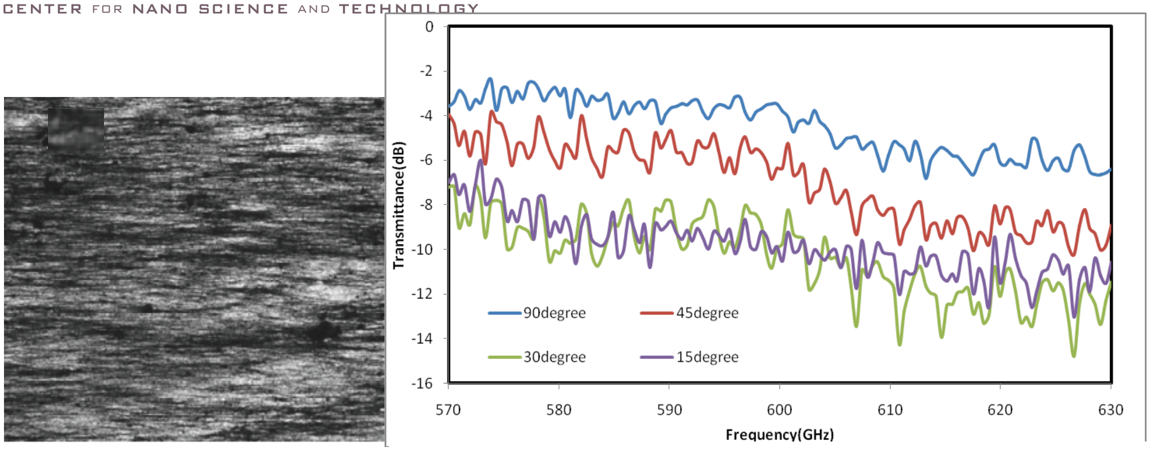


Fig. 2(b) CNF oriented in a PMMA solution that was dried to form the solid film shown. Dark areas in that image correspond to many overlapping CNFs. The external magnetic field was horizontal in this case, and resulted in alignment of the magnetic CNFs in that direction. Transmittance curves for polarizer at various angles of polarization