NDnano Undergraduate Research Fellowship (NURF)
2014 Project Summary

1. Student name: Sakshi Singh

2. Faculty mentor name: Lei Liu

3. Project title: Photo-induced tunable zone plates for terahertz beam focusing

4. Briefly describe any new skills you acquired during your summer research:
Through my summer research, I got introduced to the Terahertz (THz) domain and learned to work with quasi-optical components and THz sources and detectors. I learned how photo-induced masks can be employed for THz beam manipulation applications such as beam steering and focusing to achieve universal tunability. Apart from technical expertise, I also gained valuable experience in working with a research group and performing high-end research in an organized and efficient manner. Furthermore, I developed my presentation skills by making and presenting a poster at the Summer Undergraduate Research Symposium 2014.

5. Briefly share a practical application/end use of your research:

With rapid developments in THz sources and Detectors, there is an increasing demand for tunable quasi-optical components. Photo-induced Fresnel zone plates offer advantages such as universal tunability, low cost, compactness and dynamic beam focusing (not requiring mechanical movement) over the conventional methods employed for beam focusing. They may find direct applications in various fields including THz Spectroscopy, THz imaging for different layers and THz pharmaceutical tablet quality monitoring.

Project Summary:

The terahertz (THz) region (0.1-10 THz) in the electromagnetic spectrum has become increasingly important for a wide range of applications including package inspection, quality control, security screening, defence, medical imaging and diagnostics, non-destructive evaluation and spectroscopic characterization of materials. While Terahertz sources and detectors have been highly developed, techniques for terahertz beam manipulation still have a wide scope for research. The conventional method for focusing THz beams employs gold-plating parabolic mirrors, which are not only bulky and very expensive but also have fixed quasi-optical parameters such as focal lengths and beam waists. In this research project, a novel technique for beam focusing has been explored that overcomes the above shortcomings by employing photo-induced Fresnel zone plates.

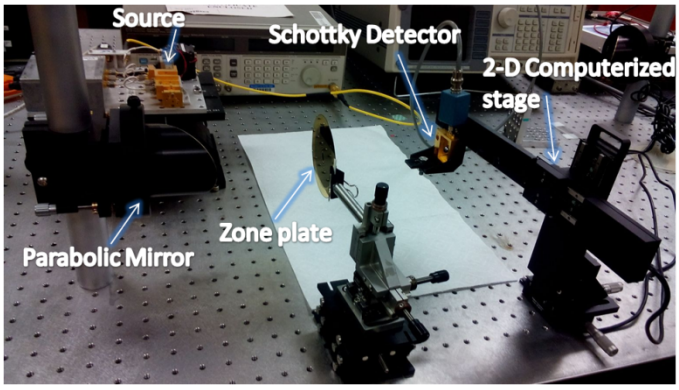

Fig.1. Setup for initial zone-plate-focusing demonstration using a physical zone plate

For initial demonstrations of the focusing behavior of a zone plate, a physical zone plate was fabricated and used for beam focusing. This zone plate was designed on a high-resistivity silicon wafer by using gold plating to demarcate the Fresnel zone pattern. Fig.1 shows the setup for this experiment. A Schottky detector, mounted on a two-dimensional computerized stage was used to map the zone-plate-focused beam image. A Labview code was written to automate the mapping process and a 50mm X 50mm beam mapping was performed to generate the beam images. To analyze the focusing effect, unfocused THz beam (620 GHz) and zone-plate-focused beam images were compared. A comparative study was also done between beams focused with parabolic mirrors and those focused with zone plate. Some of the images obtained are shown in Fig.2. Fig. 2(a) shows a focusing trend as the detector moves closer to the focal point of the zone plate, demonstrating the zone plate's focusing effect. A comparison between unfocused and focused beam images in case of parabolic mirrors and zone plate has been presented in Fig. 2(b) and shows that the performance of zone plate is poorer than that of parabolic mirrors. Nevertheless these results verify the zone plate focusing principle and there is scope for optimizing the setup. For further study, the setup may be optimized to minimize losses and photo-induced zone plate will be employed.

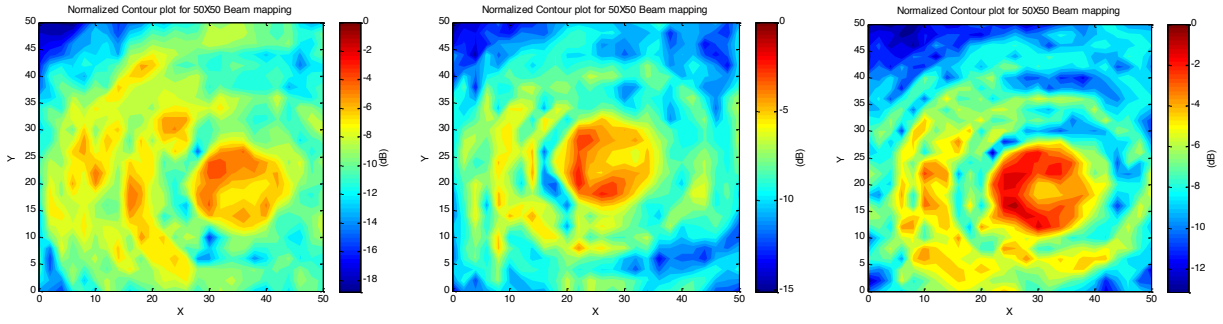

Fig. 2(a). Zone plate-focused Beam images at 13cm, 14cm and 15cm respectively from the zone plate, presenting a focusing trend as approaching the focus (15cm)

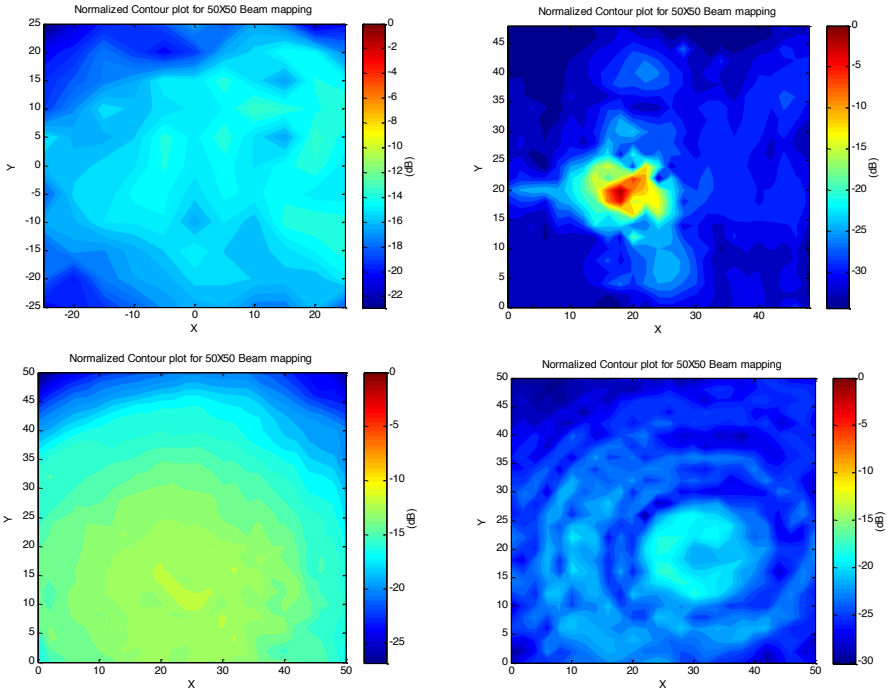

Fig 2(b). Comparison of Beam images: (i) Parallel beam (ii) Beam focused with parabolic mirror (iii) Parallel beam for FZP setup (iv) Beam focussed using physical FZP

Publications (papers/posters/presentations):

- M. I. B. Shams, Z. Jiang, J. Qayyum, S. Rahman, **S. Singh**, J. L. Hesler, P. Fay and L. Liu, "Characterizing a WR-1.5 Diagonal Horn Antenna Using Photo-Induced Coded-Aperture Imaging", IRMMW-THz 2014, Tucson, AZ.
- Presented a poster on "Photo-Induced Fresnel-Zone-Plates for Tunable Terahertz Beam Focusing" in the Summer Undergraduate Research Symposium (SURS) 2014