ND*nano* Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Nicole McMillan
2) Faculty mentor name: Tao Wang, Lei Liu, Li-Jing (Larry) Cheng
3) Project title: Lab-on-a-chip molecular binding detection with terahertz waves

4) Briefly describe any new skills you acquired during your summer research:
During my summer research I learned about the different uses for microfluidic devices. I also learned how to incorporate terahertz wave technology into chemical sensing techniques along with the data analysis that goes along with experimentation. I learned how to make a scientific poster and presented it at the Advanced Diagnostics and Therapeutics symposium.

5) Please briefly share a practical application/end use of your research:
Terahertz frequency domain spectroscopy can be used in many chemical sensing techniques. It can monitor chemical reactions on a small scale by running multiple chemicals through the microfluidic device at once. This technology can be used for chemical sensing in medicine and biology to improve the enzyme linked immunosorbent assay (ELISA) test which is used as a diagnostic tool in medicine. Designing a new microfluidic device could improve the ELISA test by using label-free chemical sensing and decreasing the amount of time required to complete the test.

Project summary:
Terahertz waves are located between microwaves and infrared light on the electromagnetic spectrum. It is believed that terahertz spectroscopy can determine the low-frequency vibrational modes of molecules which are related to intermolecular bonds, such as hydrogen bonds or Van der Waals interactions between molecules. It is possible to differentiate different concentrations of a particular chemical in an aqueous solution using terahertz frequency-domain spectroscopy (THz-FDS) since the chemical disrupts the hydrogen bonding and Van der Waals forces within the water molecules. Our goal is to see how individual chemicals behave at different frequencies and concentrations.

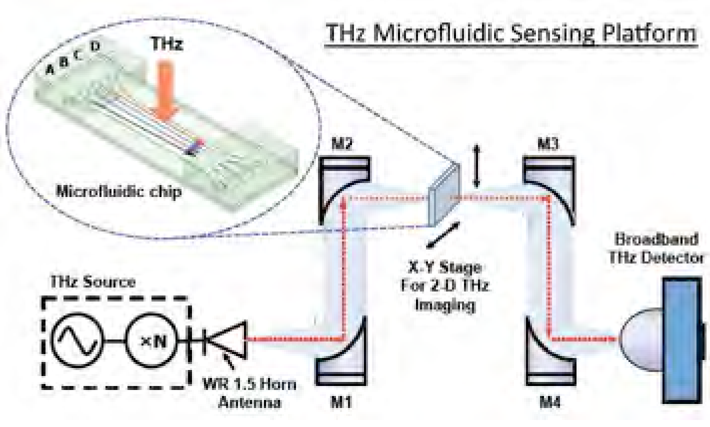

Fig. 1 The terahertz microfluidic sensing platform includes a terahertz source which is reflected through a series of curved mirrors to gather the waves and create a focal point on the microfluidic device and the detector for increased accuracy and sensitivity.

Using the terahertz system as outlined in figure 1, we tested several different chemicals (methanol, isopropyl alcohol, hydrochloric acid, sodium hydroxide and sodium chloride) at different concentrations (ranging from .01 M to 1 M) to find calibration curve for each particular chemical in the frequency range between 0.57 THz and 0.63 THz. Figure 2 shows an example of the output from aqueous sodium chloride solutions at concentrations of 0.01 M, 0.1 M and 1 M. Figure 3 shows the linear calibration curves generated by HCl, NaOH and NaCl.

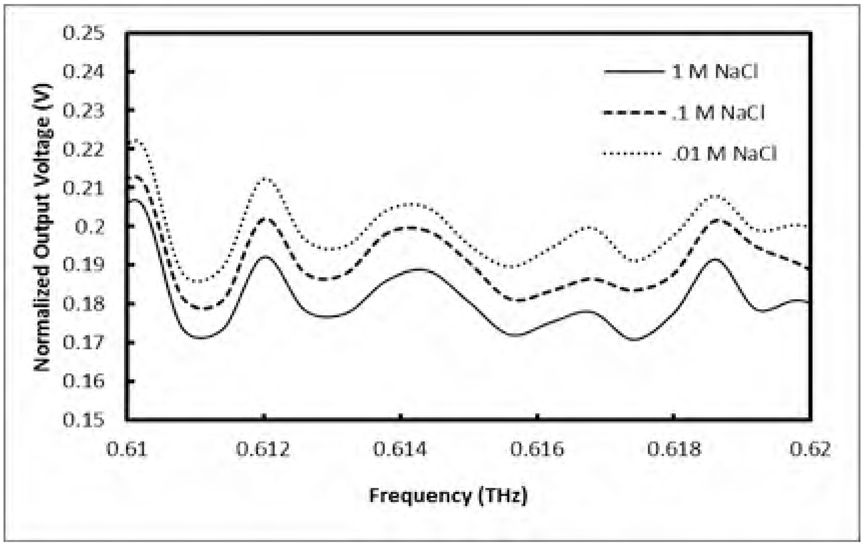

Fig. 2 The zoomed in normalized output data for different concentrations of aqueous NaCl measured using THz-FDS. The more concentrated solutions absorb more terahertz waves because they form intermolecular interactions with the water molecules that are stronger than hydrogen bonds.

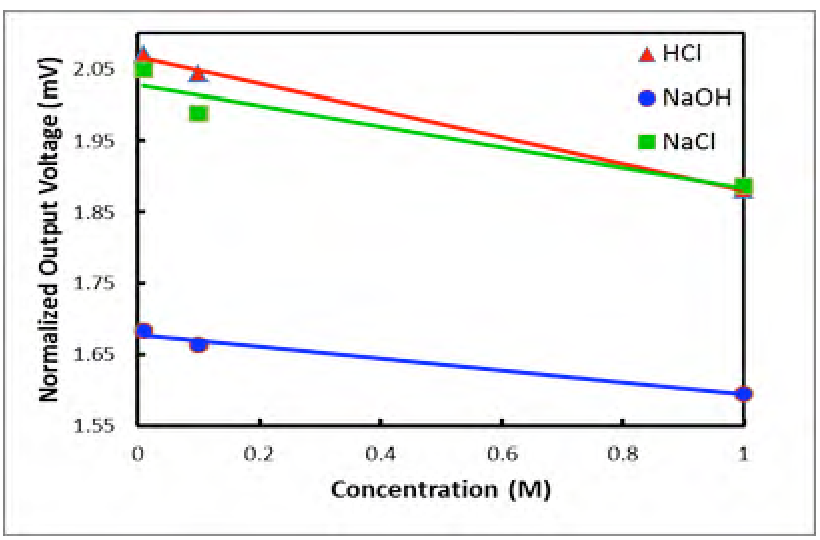

Fig. 2 Linear fit to show how the output voltage varies linearly with the concentration of the chemical. Further experiments are necessary to prove the linear trend line. All data points are for .1644 THz where there was adequate separation between the different concentration transmission signals.

Once we established that it was possible to differentiate concentrations of an individual chemical, we moved on to working on improving the ELISA test by seeing if we could use THz-FDS to sense different concentrations of antigen-antibody binding complexes. Using a Tumor Necrosis Factor Alpha (TNF-α) protein ELISA kit we were able to detect the difference in THz-FDS signal for the ELISA microplate before and after binding of the TNF-α protein. We successfully determined that there was a difference in THz signal before and after binding however further experimentation is necessary to prove this result.

Publications (papers/posters/presentations):
Poster at the Advanced Diagnostics and Therapeutics symposium
"Terahertz microfluidic chemical sensing with high spectral resolution frequency-domain spectroscopy"