THz-Jets High Resolution Transmission Imaging

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Introduction

- Terahertz(THz) radiation is nonionizing is therefore harmless to live organisms, as opposed to higher energy radiation, such as x-rays and UV rays. THz low scattering characteristic, as compared to optical rays, and strong absorption by water makes THz useful for imaging organic tissue.
- In a Lumpectomy procedure, a tumor is removed from a predetermined area. In most cases, a surgeon will often remove a larger amount of tissue to ensure that all of the cancer is removed however this can extend the patient's recovery period and it does not guarantee that all the cancerous tissue was removed..
- Using the THz Jets Transmission (Tx) Imaging method the goal will be to allow a surgeon to better assess the margins of the excised tissue using higher THz resolution images.
- This method is done by transmitting a THz signal through a Teflon sphere, then through the sample, and finally to the receiver on the other side.
- Teflon spheres have the ability to filter out the lower terahertz frequencies which then have the potential to produce high-resolution images.

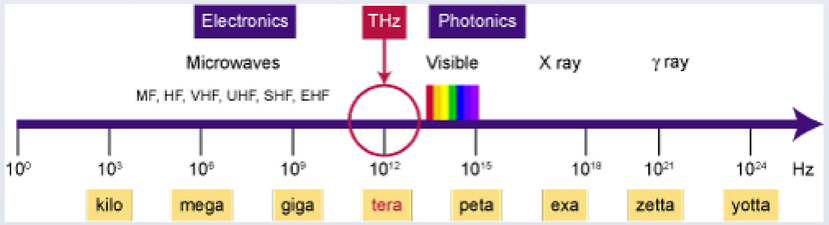

Figure 1. Terahertz on the electromagnetic spectrum: It lies between the Microwave and Infrared spectrums.

Approaches / Experimental Methods

Three Teflon Spheres of sizes 3mm, 4mm, and 5mm were used in this experiment. Various sphere holders were created as shown in Figures 2a, b, c, and d. Only the holders in Figure 2a and 2d were able to acquire a stable signal but only the results from Figure 2d were usable.

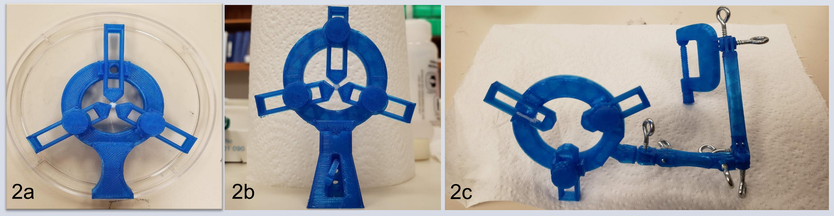

Figure 2. Teflon Sphere Holders: a) Prototype 1, b): Protype 2, Figure 2c: Prototype3, and Figure 2d: Prototype 4.

The pinhole in Figure 3 (right) has a hole 1mm in diameter and was used to find the signal and then used to help align the Teflon sphere in position to then scan the sample.

Figure 3. 1mm Pinhole

The sample used to test the resolution of the THz Jets images is the Thorlabs Resolution kit (Figure 4). The Imaging and Pulse analysis of the experiment was done using the core chamber in the TPS Spectra 3000 system. The Tera Align system was also used to try and replicate the THz Tx signal.

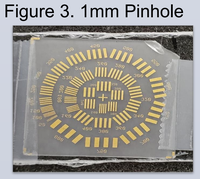

Figure 4. Resolution Kit Sample

Results and Discussion

After the Teflon sphere was aligned and the pinhole was replaced with the sample, transmission imaging mode was used to gather the Time Domain Images in Figures 5.

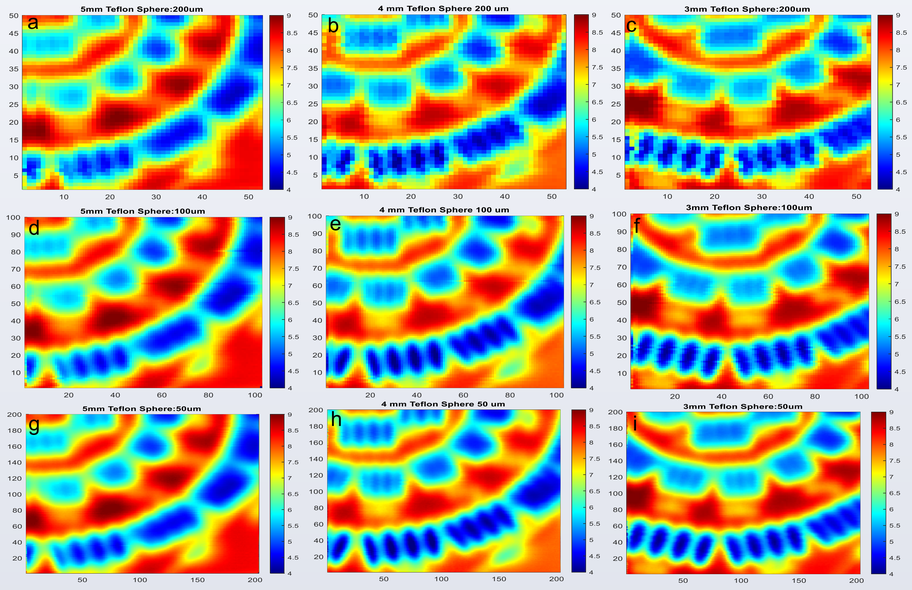

Figure 5. Tx Images: a,b, and C used motor step size of 200um, d,e, and f used motor step size of 100um and g, h, and i, used motor step size of 50 um.

The Time Domain Signal and Frequency Spectrum for the three different sized spheres from the TPS 3000 system and the Tera Align system were compared in Figure 6 and 7.

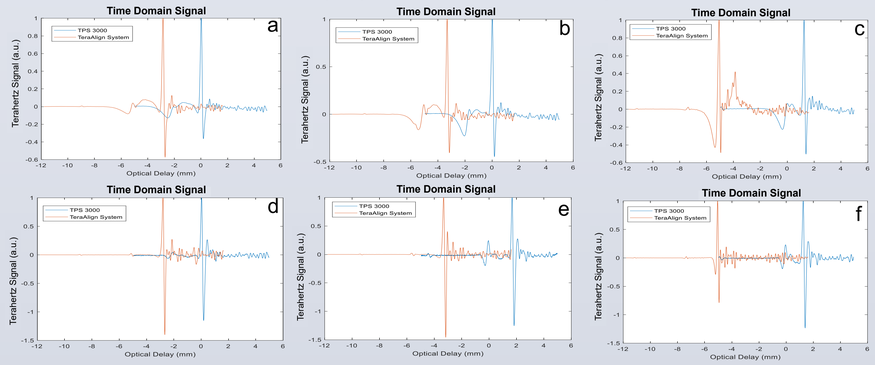

Figure 6. TPS 3000 (Blue) and Tera Align (Orange) system normalized Time Domain Pulse. Signals a, b and c contain only the sphere. Signals d, e, and f contain both sphere and 1mm Pin Hole

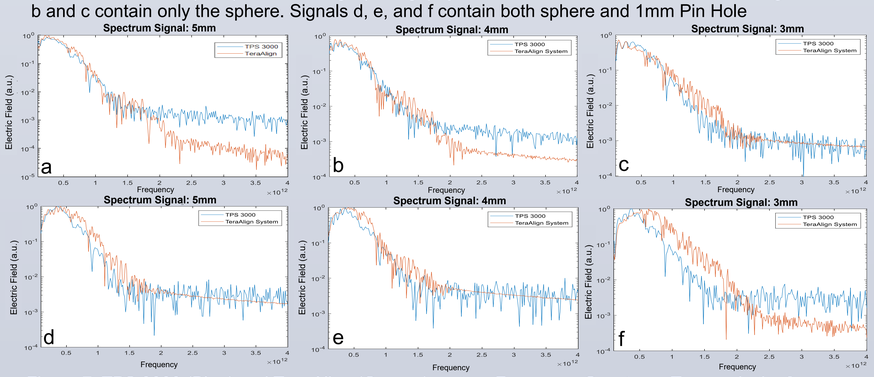

Figure 7. TPS 3000 (Blue) and Tera Align (Orange) system Frequency Spectrum. Top row is the frequency spectrum of the sphere alone and bottom row is the frequency spectrum of the sphere and pinhole.

Conclusion

Based on the results in Figure 5, the smaller Teflon sphere provided the best resolution, with the 50μm Image (Figure 5i) having the best resolution. Figures 6 and 7 showcases that the images from Figure 5 were done correctly as both the Time Domain signal and the Frequency spectrum were relatively similar to each other. The difference in position and magnitude between the TPS 3000 system and Tera Align system signals were most likely due to a wide variety of factors such as the method used to suspend the spheres (TPS 3000 used a clamp/glue and Tera Align used Tape) or the lack of nitrogen in the Tera Align system. Figures 6 and 7 also confirm that this experiment is capable of being reproduced in a different environment while still retaining a relatively similar signal shape. The signal shape is important as the first hump before the spike indicated that the signal is passing through the sphere. This small hump could be caused by internal reflections inside the sphere.

Future work

For future work, there is still a lot that must be done before this method can be used by surgeons in the medical field.

Further work in this area would involve further testing of Teflon spheres of varying sizes and distances from the sample. Further testing using similar materials with nonpolar and low electronegative properties could be done in order to identify other potential Teflon sphere substitutes.

A better sphere holder that eliminates the need to be adjusted manually could also be tested to see how much human error could have affected the results.

Acknowledgments

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