THz Medical Research

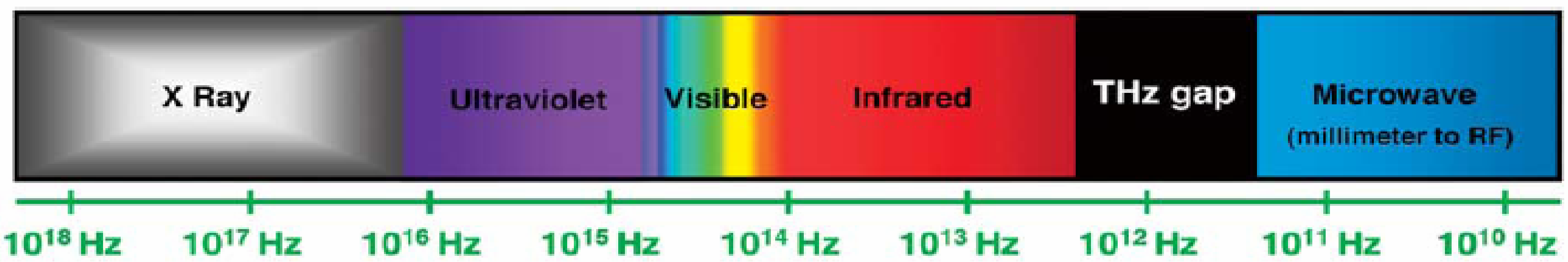


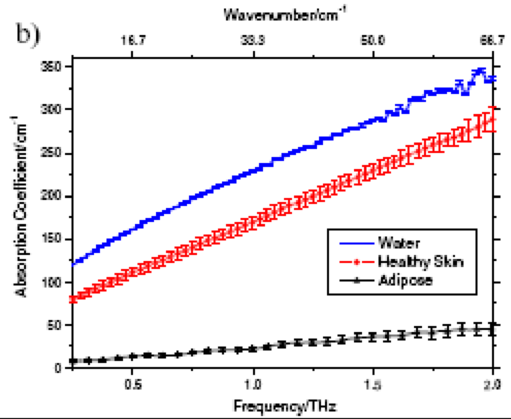
Fig. 1. Representation of the electromagnetic spectrum illustrating the "THz gap" relative to the microwave and IR. [1]

- Recent advances in laser technology have made THz frequencies accessible for science and engineering.
- These frequencies are non-ionizing and safe for biomedical research and human tissue diagnostics.
- Due to quantum resonances that exist at 0.5 – 3.0 THz, these frequencies can also provide valuable spectroscopic information
  - ultimately differentiating between healthy and cancerous tissue.
- The NEAR Lab is developing signal processing methods to characterize surface and sub-surface scattering of THz waves in biological tissues.

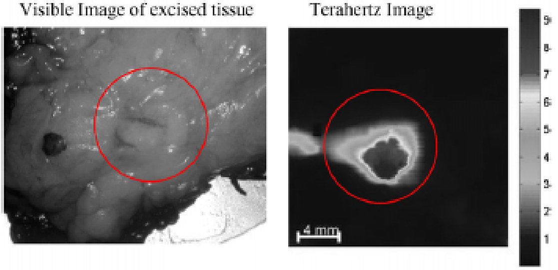
Portland State UNIVERSITY

Skin and Breast Cancer Detection

- THz can penetrate the outer surface of skin and adipose tissues which have a relatively low hydration level.
- Cancer cells contain more water than healthy skin tissue, providing a contrast mechanism for tumor detection.
- THz frequencies are particularly promising for detection of carcinomas and locating breast tumors during surgery.
- Boundaries between skin layers appear as rough surfaces in the Mie regime at THz wavelengths ~300μm.

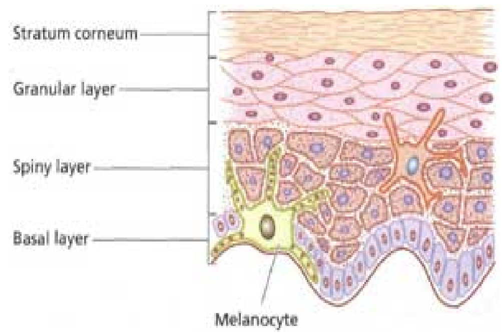


[2]



[2]

Figure 10. Mastectomy specimen from a patient of 52 years with an invasive lobular carcinoma (circled).



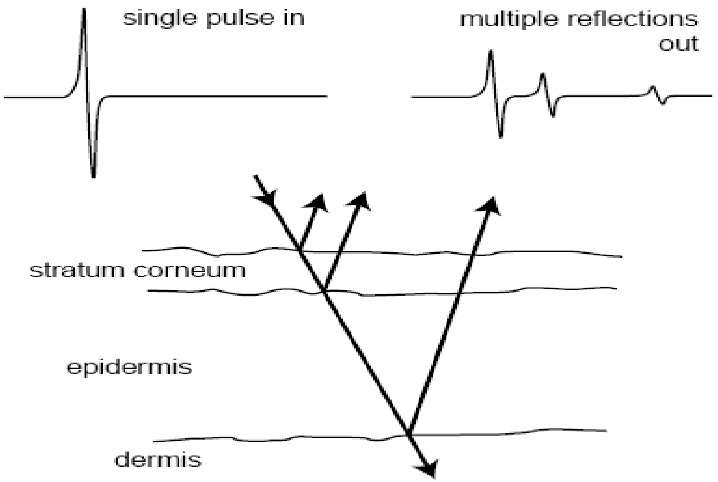
[3]

Portland State University

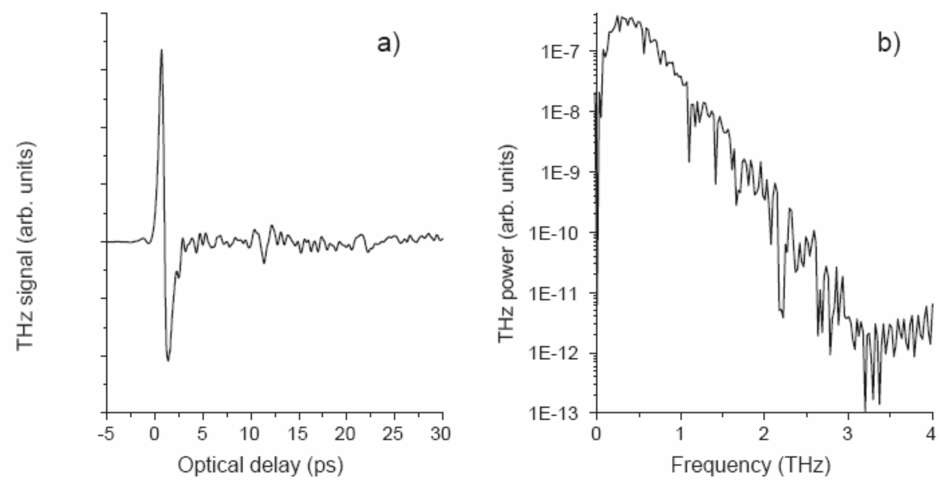
Absorption or Scattering?

- Medical scanning systems measure THz waves reflected from the skin's surface.
- Quantum energy absorption is frequency dependent and provides a spectroscopic signature between 0.5 – 3.0 THz.
- Rough surface scattering is also frequency dependent in this regime and causes distortion of the spectroscopic signature

- Modeling THz wave interaction with tissue layers can provide a mechanism to recover the quantum signature and improve tissue diagnostics…



[4]



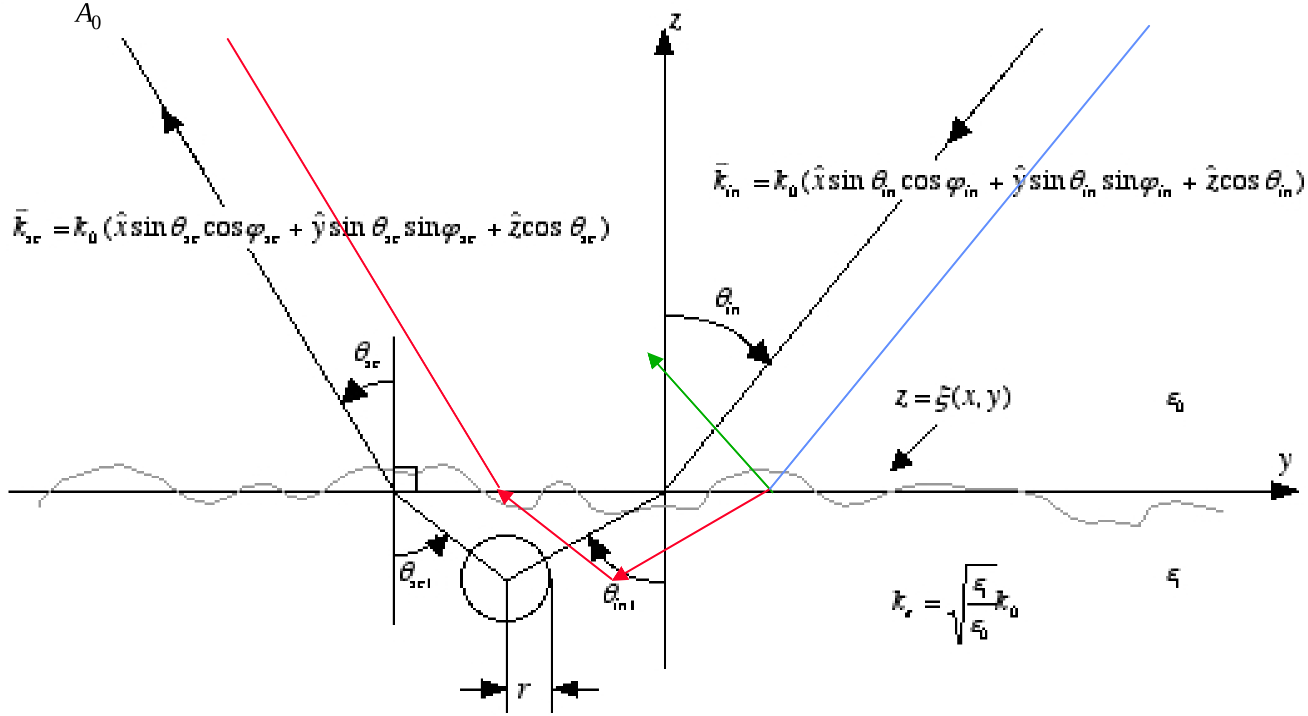
Portland State University

THz Scattering Models

Kirchhoff Approximation code models surface scattering from slowly undulating surfaces

$$\overline{E}_s = \frac{ike^{ikr}}{4\pi r} E_0 \left(\overline{\overline{I}} - \hat{k}_s\hat{k}_s\right)\cdot \int_{A_0} d\overline{r}_\perp' \, \overline{F}\left(\alpha,\beta,\hat{k}_i,\hat{k}_s,\hat{e}_i,\hat{n}\right) e^{i\left(\overline{k}_i-\overline{k}_s\right)\cdot\overline{r}'}$$

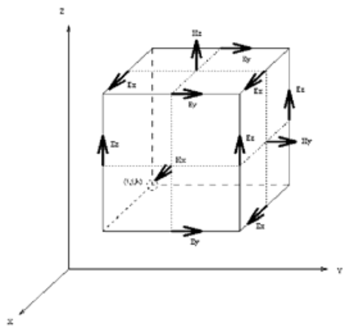
$$\overline{E}_i = \hat{e}_i E_0 e^{i\overline{k}_i\cdot\overline{r}}$$



Portland State University

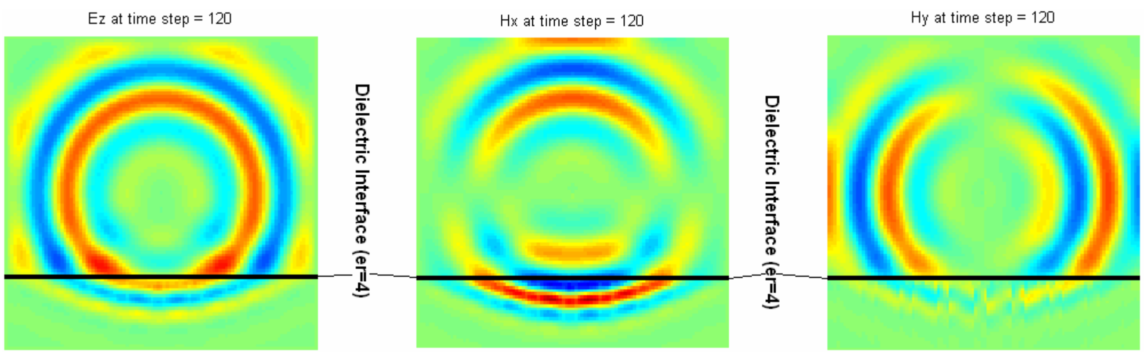
THz Scattering Models

Finite Difference Time Domain (FDTD) modeling provides an analytical method for evaluating surface and subsurface scattering.



Yee, K. S., "Numerical Solution of initial boundary value problems involving Maxwell's equations in isotropic media", IEEE Transcations on Antennas Propagation, Vol. AP-14, pp. 302-307, 1966.

Gaussian Pulse incident on a dielectric interface

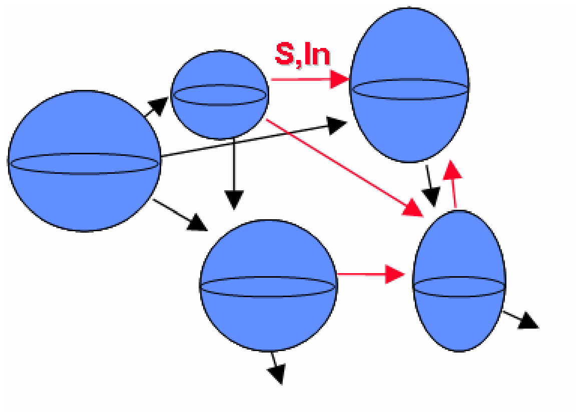


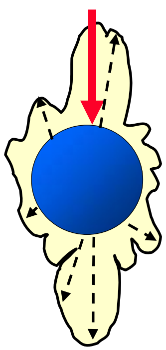
Portland State University

THz Scattering Models

•Quasi-Crystalline Approximation (QCA) models scattering from particles embedded in a background material (skin or breast tissue).

•T-Matrix describes scattering interactions between all of the internal scatterers.





$$\begin{bmatrix} p \\ q \end{bmatrix} = T \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} T^{11} & T^{12} \\ T^{21} & T^{22} \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix}$$

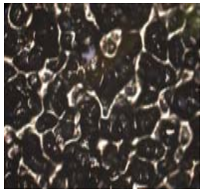
Portland State UNIVERSITY

THz Sandpaper Experiments

NEAR-Lab
Northwest Electromagnetics & Acoustics Research

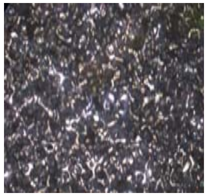
- The NEAR lab has partnered with Dr. Chen and Dr. Zhou at the Applied Physics Lab, UW Seattle to experiment with THz scattering from various materials.
- Silicon Carbide sandpaper is a fine grain (waterproof) sandpaper used for polishing metal.
- Experiments with 3 different grain sizes show how the spectroscopic signature is effected by rough surface scattering.

20x magnification

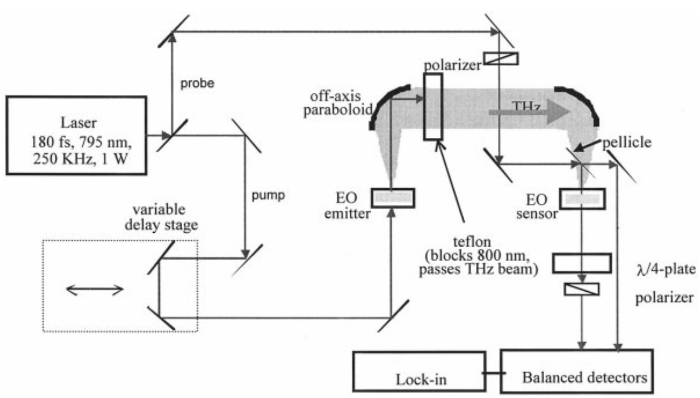


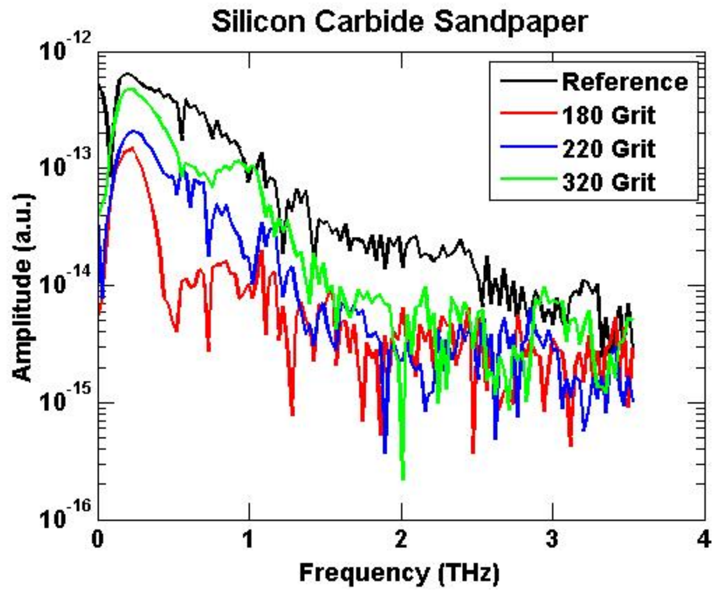
180 Grit
78 µm

220 Grit
62 µm



320 Grit
33 µm





Portland State University

References

[1] Woolard, Dwight L.; Brown, Elliot R.; Pepper, Michael; Kemp, Michael **Terahertz frequency sensing and imaging: A time of reckoning future applications?** P*roceedings of the IEEE*, v 93, n 10, October, 2005, *Blue Sky Electronic Technologies*, p 1722-1743

[2] Pickwell E.; Wallace V.P. **Biomedical Applications of Terahertz Technology** 2006 Journal of Applied Physics, 39 R301-R310

[3] Dr. John Gray, **The World of Skin Care** P&G Skin Care Research Center. http://www.pg.com/science/skincare

[4] Cole, B.E.; Woodward, R.; Crawley, D.; Wallace, V.P.; Arnone, D.D.; Pepper, M. **Terahertz imaging and spectroscopy of human skin, in-vivo** *Proceedings of SPIE - The International Society for Optical Engineering*, v 4276, 2001, p 1-10

Funding for this research is provided by the National Science Foundation.

Portland State UNIVERSITY