POLARIZATION DEPENDENT TERAHERTZ TIME-DOMAIN SPECTROSCOPY MEASUREMENTS ON ALIGNED CARBON NANOTUBE FILMS AND FIBERS

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Carbon nanotubes (CNTs) are novel one-dimensional materials with superior mechanical, thermal, and electrical properties. Electrons in CNTs are one-dimensional and behave unlike normal three-dimensional electrons. Here, in our experiments, two types of CNT samples were used: freestanding aligned multi-walled CNT films and aligned CNT fibers. Each fiber consists of many well aligned CNTs. We used terahertz (THz) time-domain spectroscopy to measure each samples THz transmissions. The THz radiation was highly linearly polarized, and the samples showed highly anisotropic properties. There was strong absorbance when the THz polarization was parallel with the CNT axes and weak absorbance when it was perpendicular. The results are discussed as they relate to the interactions between the THz radiation and the one-dimensional electrons in a CNT. Since the properties of a CNT fiber depend strongly on the alignment of the CNTs in it, THz beams can be used to characterize the degree of overall alignment. CNT films and fibers have the potential to replace wire-grid polarizers in the THz range.

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OBJECTIVE

To characterize anisotropic terahertz (THz) absorption of multi-walled carbon nanotubes (MWNTs) thin films and fibers.

MOTIVATION

- The electron behavior inside a CNT is one-dimensional and unique
- Highly aligned single-walled carbon nanotubes (SWNTs) films have shown strong anisotropic polarization of THz waves [1]
  - High transmission at 90°, low transmission at 0°
  - Potential to replace wire-grid THz polarizers
- Anisotropic absorptions of MWNTs are not well defined
- Carbon nanotube (CNT) fiber properties strongly determined by overall alignment of its component nanotubes, and is expected to show strong anisotropy

THZ PUMP-PROBE SPECTROSCOPY

- Time-domain spectroscopy → transmission spectrum
- ZnTe THz emitter and low-temperature grown GaAs detector
- THz beam polarized by free-standing wire-grid polarizer

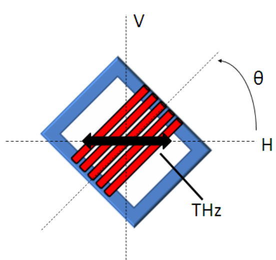

Figure 1: Sample orientation definition

ABSORPTION AND TIME-DOMAIN MEASUREMENTS

Thin MWNT Sample

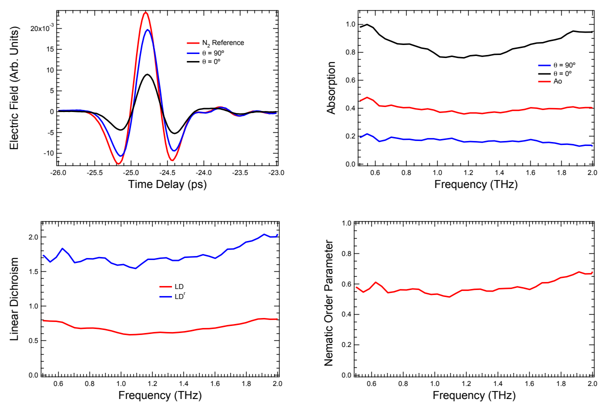

Figure 2: Layer of MWNT film pulled from bulk sample using tape.

MWNT Fiber Sample

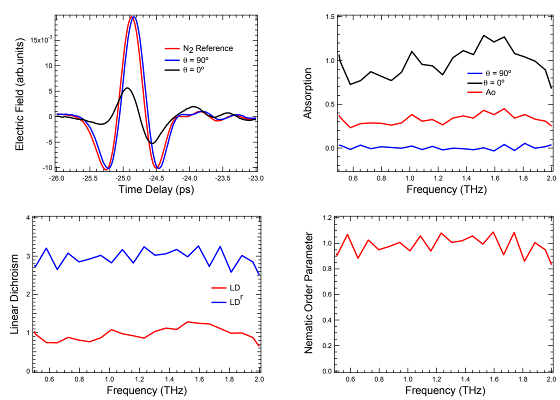

Figure 3: Several adjacent MWNT fibers for higher signal to noise ratio.

CONCLUSIONS

- Anisotropic absorption seen in thin MWNT sample
  - Frequency-dependence might be due to inter-wall interaction
  - The assumption that the order parameter, α, is 0° may be incorrect
- CNT fiber sample showed strong alignment

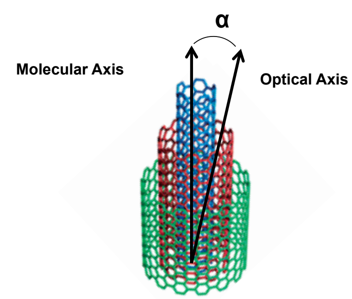

Figure 4: Nematic order parameter diagram

FUTURE WORK

- Test MWNT on a substrate for a thinner, more uniform sample
- Test more CNT fibers to see absorbance variation based on fiber alignment quality

References

[1] L. Ren, C. L. Pint, A. K. Wójcik, T. Arikawa, Y. Takemoto, K. Takeya, I. Kawayama, A. A. Belyanin, M. Tonouchi, R. H. Hauge, and J. Kono, "Anisotropic Terahertz Dynamics of Highly-Aligned Single-Walled Carbon Nanotubes," *Journal of Terahertz Science and Technology* **3**, 26 (2010).

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