Terahertz Emission from Aligned Carbon Nanotubes

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There are a variety of potential applications for terahertz (THz) radiation, including security, imaging for pharmaceuticals, and various uses in medicine.[1] However, THz technology is poorly developed compared to microwave, infrared, and visible technology, leaving the THz frequency range as the last frontier of the electromagnetic spectrum. Some semiconductors, such as low temperature-grown gallium arsenide (LT-GaAs), have proven to be effective emitters and detectors of THz radiation, but recent theoretical studies have shown that aligned carbon nanotubes (CNTs) could provide a higher efficiency.[2,3] In this study, we fabricated photoconductive antenna (PCA) switches with CNT films as base material. The CNT film we used for our emitter consisted of aligned (6,5) single-wall CNTs made using a controlled vacuum filtration method.[4] Our PCA switches were fabricated on top of the CNT films using standard sputtering and lift-off processes. The devices were photoexcited with laser pulses of tunable wavelength from an optical parametric oscillator system, and the THz signal was directed via parabolic mirrors to our LT-GaAs detector, which was excited by laser pulses of a different frequency. Using this setup, we measured both the THz emission and induced photocurrent through the CNT sample simultaneously. By varying the experimental conditions such as laser power, wavelength, polarization, and applied bias, we were able to investigate the THz emission properties of our devices and study the dynamics that are unique to one-dimensional systems such as CNTs.

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2. B. Heshmat, H. Pahlevaninezhad, and T. E. Darcie, *IEEE Photonics J*, 2012, **4**, 970-985
3. B. Heshmat, H. Pahlevaninezhad, M. C. Beard, C. Papadopoulos, and T. E. Darcie, *Opt. Express*, 2011, **19**, 15077-15089
4. X. He, W. Gao, L. Xie, B. Li et al., *Nature Nanotechnology*, 2016, **11**, 633-638

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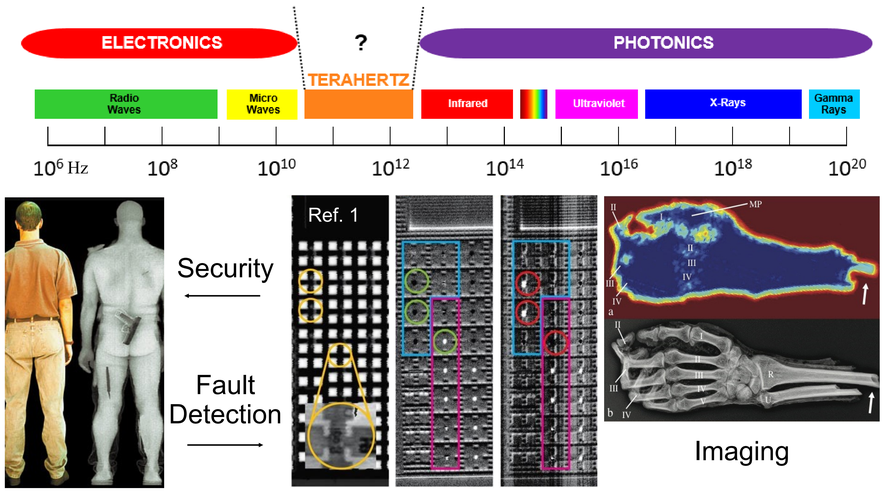
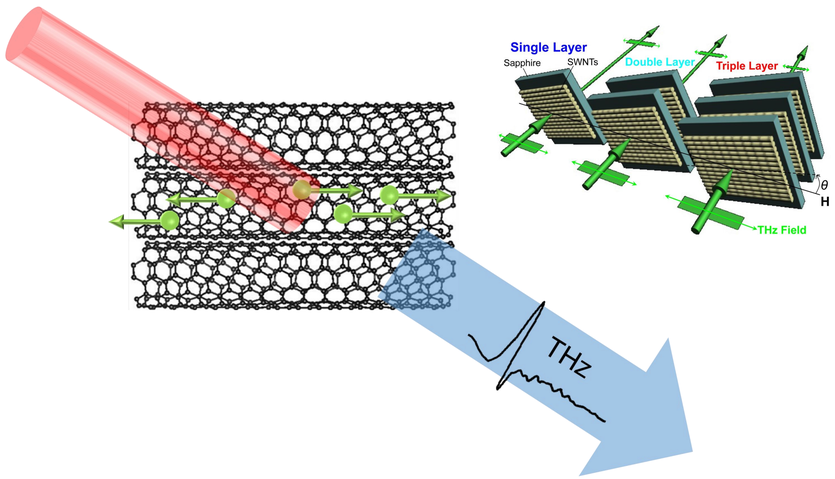
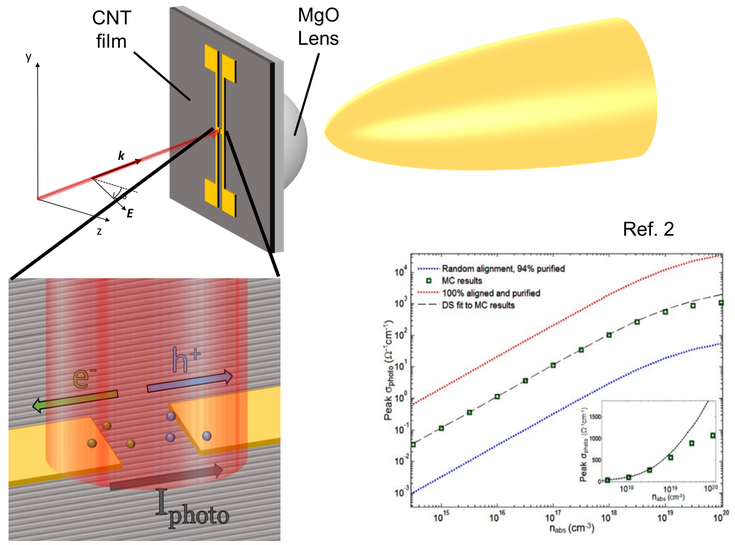
Why Terahertz?



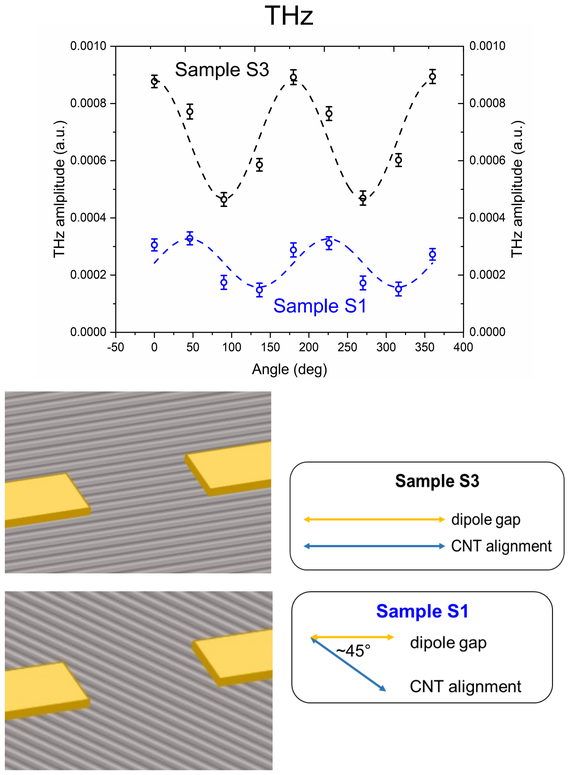
Why Carbon Nanotubes?



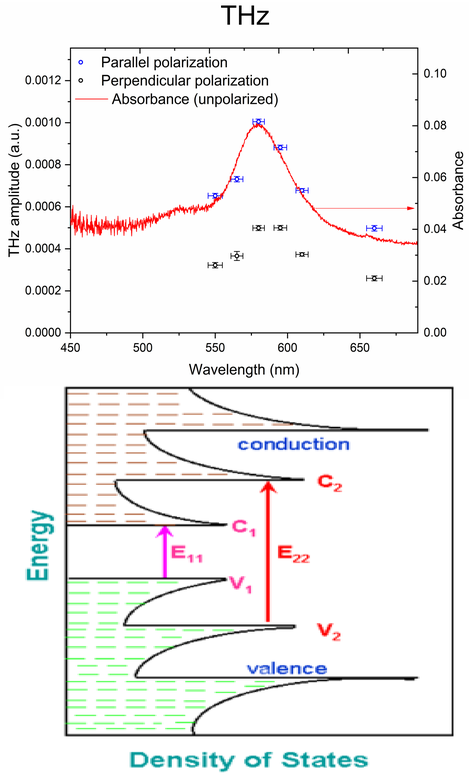


Terahertz Amplitude and Photocurrent Data

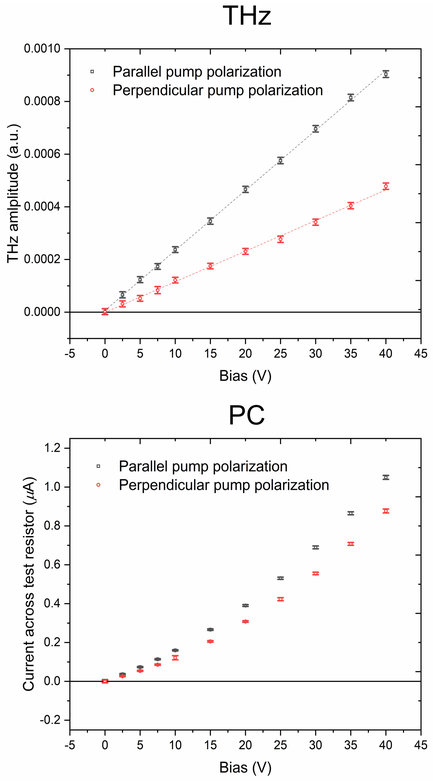
Polarization Dependence



Wavelength Dependence



Bias Dependence



Conclusions

- First observation of THz emission from aligned and chirality-enriched single-wall CNTs
- Confirmed strong polarization dependence and relation between THz emission and absorbance spectrum
- CNT alignment is the primary factor in polarization dependence for THz amplitude and PC, not bias direction
- Opened a path towards understanding 1D exciton dissociation and multiplication
- The nonlinearity of PC with increasing bias is under further investigation

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1. M. Tonouchi, *Nature Photonics*, 2007, **1**, 97-105
2. B. Heshmat, H. Pahlevaninezhad, M. C. Beard, C. Papadopoulos, and T. E. Darcie, *Opt. Express*, 2011, **19**,15077-15089