“Hearing” Terahertz Electromagnetic Waves

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Abstract

We develop a unique method to coherently interrogate terahertz (THz) pulses using the acoustic emission from a bichromatic laser-induced air plasma that interacts with THz electromagnetic transients as depicted in FIG. 1 (a). The near instantaneous expansion of the gas during ionization releases an acoustic pulse that is broad in frequency and can travel great distances in the atmosphere as seen in FIG. 1 (b). The electric field of the THz wave influences the plasma dynamics by accelerating or decelerating free electrons and inducing electron-molecule energy transfer. FIG 2 shows the consequent plasma temperature increase results in uniform enhancement of acoustic emission, and that the pressure enhancement is a linear function of the THz intensity incident the plasma. This makes TEA useful as a THz detector. Furthermore, the coherent time-resolved THz transient can be recovered by subtracting the TEA curves for the two electron drift asymmetries produced by changing the phase between the optical pulses as seen in FIG 3.

Relevance

By using bichromatic laser fields to manipulate the free electron drift velocity inside a plasma, and measuring the acoustic signals under opposite electron drift symmetry, we demonstrate that information concerning polarity and magnitude of the THz wave can be obtained in all directions without a need for direct line of sight to the detector. Coherent detection of ultrashort THz pulses through photoacoustic encoding has been realized and will minimize strong ambient water vapor absorption of THz wave propagating through the atmosphere when extended to larger distances. These achievements open new ways to uncover the potential of THz wave technology in homeland security for use in remote explosives detection and environmental monitoring.

Technical Approach

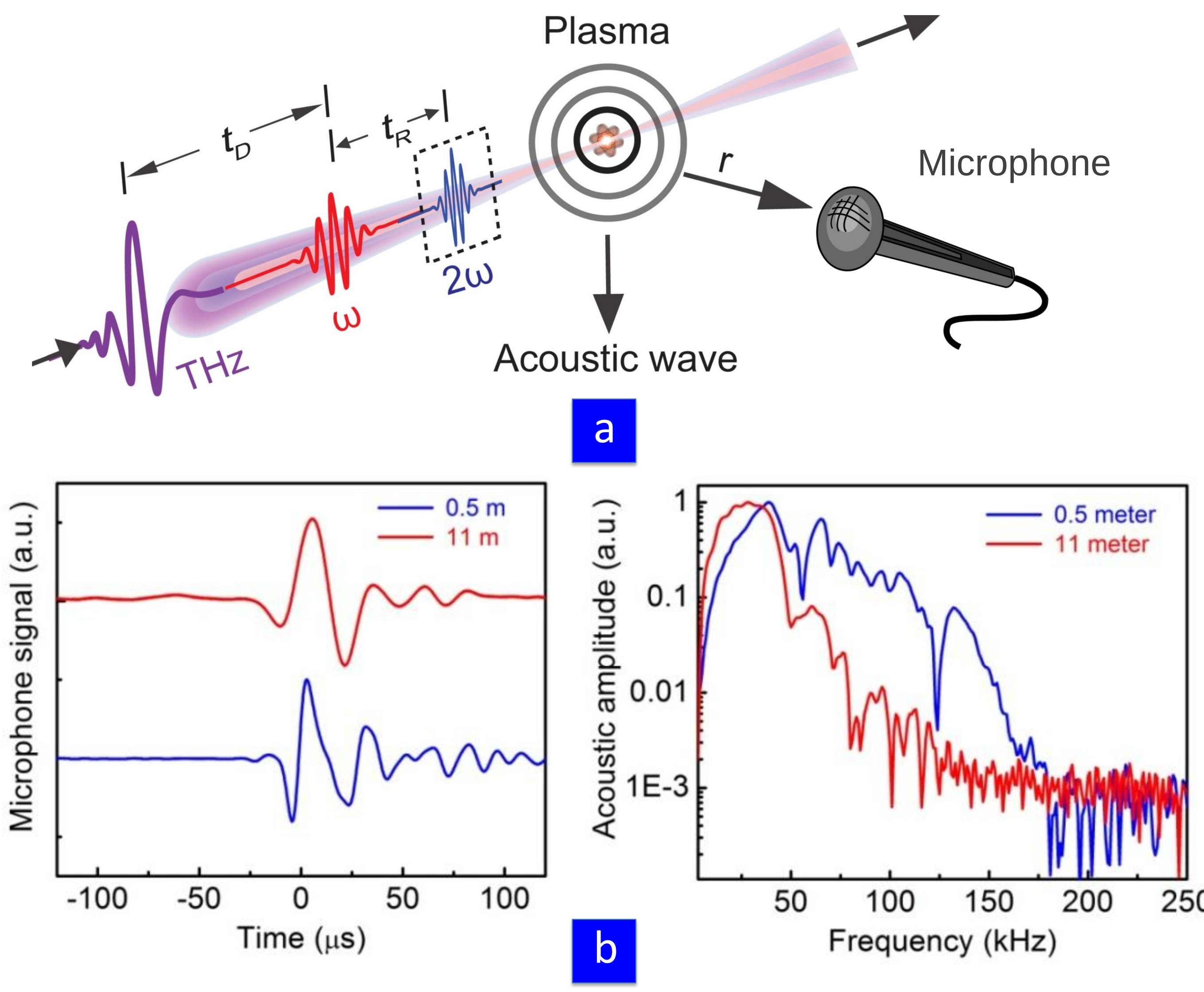

FIG. 1 (a) Experimental schematic for the THz-enhanced acoustics using bichromatic (ω+2ω) femtosecond laser excitation. (b) Normalized acoustic pulses and corresponding spectra at 0.5 and 11 meters from the plasma acoustic source.

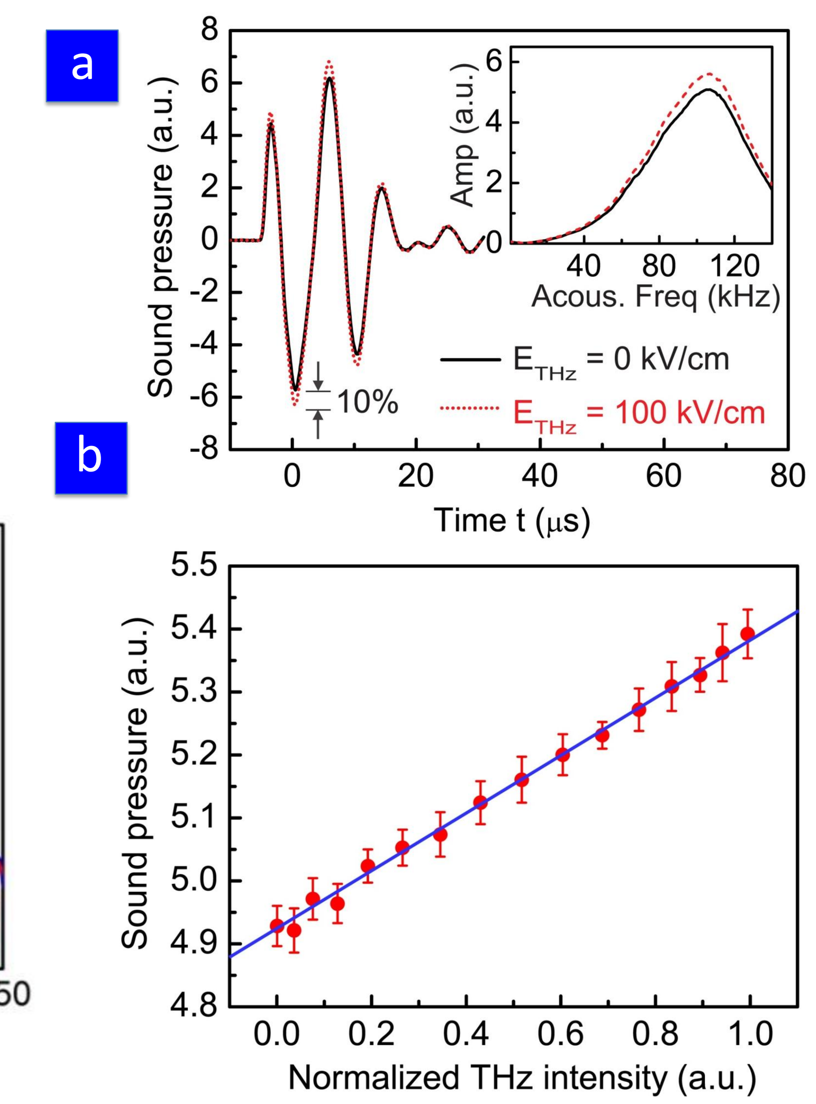

FIG. 2 (a) Single photoacoustic waveforms and spectra with and without THz interaction. (b) Acoustic emission vs THz intensity incident on the plasma.

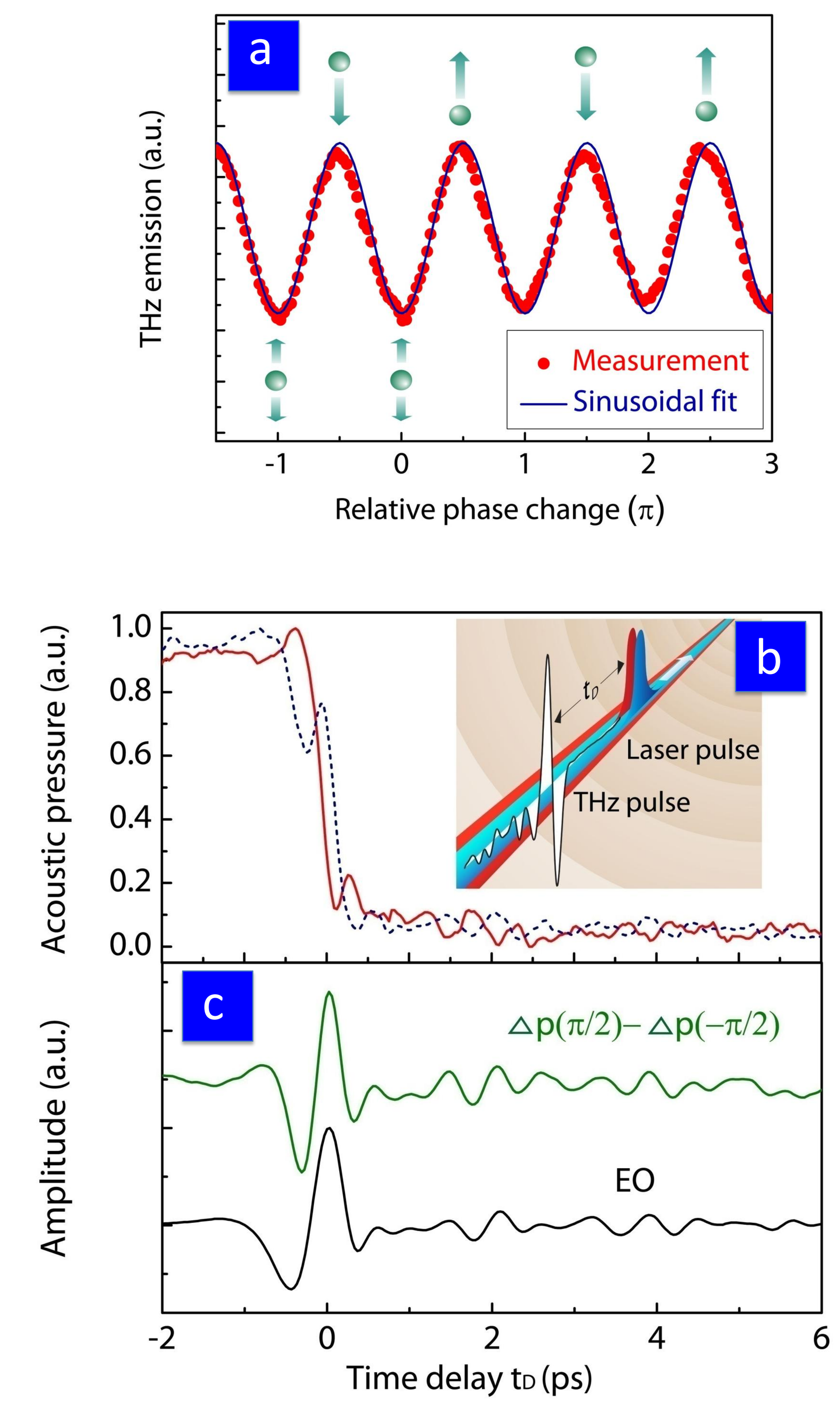

FIG. 3 (a) THz emission as ‘t_R’ delay between ω and 2ω is scanned. The THz emission reveals the electron drift asymmetry and is indicated by the green electrons and arrows. (b) Time resolved THz-enhanced-acoustics (TEA) for various electron drifting conditions. Red curve: ‘T_R’ is set to π/2 and the delay between THz and optical pulses ‘T_D’ is scanned. Blue dashed curve: ‘T_R’ is set to -π/2 and the delay between THz and optical pulses ‘T_D’ is scanned. (c) Coherent THz waveform obtained through acoustics compared with a THz waveform acquired through conventional methods.

Accomplishments Through Current Year

The photoacoustic THz-encoding technique for sensing electromagnetic transients, with femtosecond time resolution and unlimited signal collection directionality, has provided a method to circumvent 100 dB/km attenuation of THz in the atmosphere. This has opened new avenues to apply the powerful characteristics of THz waves, while overcoming fundamental limitations.

Future Work

Currently, detection and generation of THz waves from a remote distance have been performed separately. We aim to close this loop by demonstrating a fully remote system that incorporates the techniques discussed here in combination with existing remote generation techniques utilizing air photonics (laser-plasma formed through ionization of the air).

Opportunities for Transition to Customer

Terahertz remote sensing was once thought impossible due to several fundamental limitations such as high atmospheric absorption, a need for forward signal collection, and a need for direct line of sight to the detector. This photoacoustic THz detection method shows promise for extending THz capabilities for non-invasive material spectral “fingerprinting,” from a safe distance.

Patent Submissions

Clough, B. , Liu, J. & Zhang, X. C. “Method for terahertz wave detection utilizing terahertz-enhanced acoustics.” (Submitted April 2010, Invention disclosure No. 1357)

Publications Acknowledging DHS Support

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2. B. Clough, J. Liu, and X.-C. Zhang, **Opt. Lett.** *35, 2544* (2010).
3. J. Liu, B. Clough, and X.-C. Zhang, **Phys. Rev. E** *82, 066602* (2010)

Lemelson-MIT Rensselaer Student Prize

Benjamin Clough, a student in the Department of Electrical, Computer, and Systems Engineering at Rensselaer, is one of three finalists for the 2011 $30,000 Lemelson-MIT Rensselaer Student Prize. His project is titled “Terahertz Enhanced Acoustics.” For more information on the ceremony visit: http://www.eng.rpi.edu/lemelson

This material is based upon work supported by the U.S. Department of Homeland Security under Award Number 2008-ST-061-ED0001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Department of Homeland Security.