Development of THz Photomixing Spectrometer for Gas Phase Spectroscopy

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Motivation—In the rapidly developing Terahertz (THz) region of the electromagnetic spectrum, from 100 GHz to 10 THz, there is need for tunable, compact and spectrally narrow sources that operate at room temperature. Conventional THz sources produce discrete frequencies of radiation and often require cryogenic temperatures and/or a large physical footprint to operate. Conversely, a photomixer THz source can be constructed of compact, inexpensive diode lasers that provide a narrow source of tunable THz radiation and operate at room temperature.

An important application of THz is the spectroscopic identification of molecules. A photomixing based spectrometer can achieve frequency resolution of ~ 1 MHz, making it approximately 1000 times more sensitive than time domain spectrometers which are the workhorses of THz spectroscopy. With this increased resolution, compact design, and frequency flexibility, a spectrometer based on THz photomixing is an important tool for identification of explosives, biological pathogens, and other signature applications that are of national interest.

Accomplishment—We have developed a compact THz spectrometer to perform gas phase spectroscopy that is completely contained on a 2' x 4' portable optical breadboard. This THz source is based on the principal of optical heterodyning in which two lasers with different frequencies are spatially overlapped on a beam splitter, generating a beatnote at the difference frequency. Stabilizing the frequency of one laser to an atomic reference, the output beatnote can be tuned by changing the frequency of the second laser with respect to the first. In this configuration, THz radiation can be generated between 0 – 2THz, limited only by the bandwidth of the THz emitter.

The experimental setup can be seen in Fig. 1, where the heart of the spectrometer is two external cavity diode lasers which are coupled to the same single mode optical fiber to ensure spatial overlap. At the output of the fiber the lasers are tightly focused onto a THz emitter structure using a 20x microscope objective. The beatnote modulates the conductance of the emitter, producing continuous wave THz radiation which is coupled to free space via a Si lens. After a sample region, the THz beam is focused onto a Golay cell which detects the THz radiation.

Figure 2 depicts the output spectrum of the THz photomixer. The black curve is the output of the emitter in a nitrogen purged environment with relative humidity of 0.2%. The blue curve depicts the emitted radiation in ambient conditions with 45.0% relative humidity. The absorptions are due to well documented water lines. This initial measurement of the water vapor spectrum has been used to calibrate the system, and future work will focus on measuring spectrum of other molecules in the gas phase.

Significance—The THz photomixing spectrometer provides a system to measure high resolution spectra of molecules. This system adds a flexible, tunable source of THz that can be used throughout Sandia's developing THz research program.

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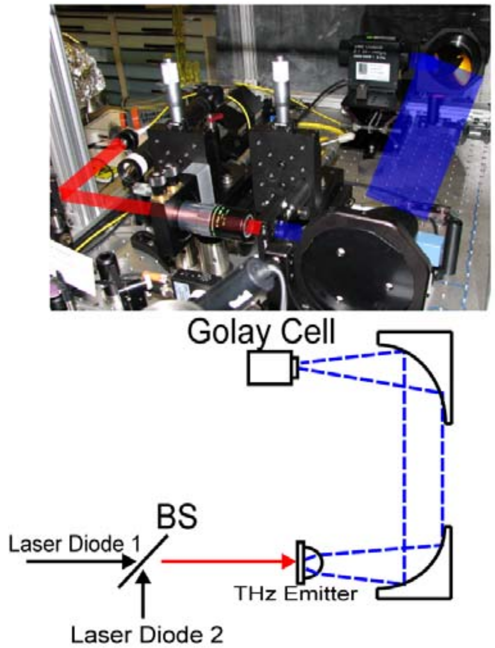

Figure 1. A schematic for generating THz radiation via photomixing. Two laser diodes are combined on a beam splitter and then focused onto a THz emitter. The emitted beam is collimated for 20 inches before it is refocused onto a Golay cell detector. A photograph of the experiment where the paths of the lasers that generate the THz beatnote are highlighted in red and the emitted THz beam is highlighted in blue.

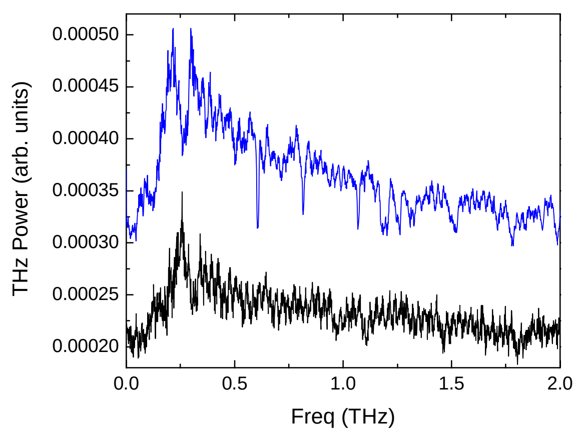

Figure 2. Water vapor spectrum measured by the THz photomixing spectrometer. The black curve shows the output of the THz emitter which can generate radiation from 0 to 2 THz. This spectrum was measured in a nitrogen purged environment that removes water vapor. The blue curve shows the spectrum measured in ambient conditions of 45 % RH where water vapor absorbs the THz. For clarity the spectra are offset.