

Electro Optic Sampling of Ultrashort Mid-IR/THz Pulses

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Introduction

Electro optic sampling (EOS) is a technique in which the electric field of a light pulse is measured. By measuring the electric field in the time domain, one can extract the full waveform of the pulse, including spectral and temporal data. This information can be used to characterize light pulses and determine their potential use for experiments. The EOS system can also be used to perform reflection pump-probe experiments in the Mid-infrared/high-frequency Terahertz range (10-20 THz). These experiments have a number of interesting applications, like the exploration of superconductivity in cuprates or selective pumping/probing of lattice modes in solids.

Keywords: Electro optic sampling, Terahertz, spectroscopy, pulse characterization, Mid-IR

Methods/Research

This EOS system relies on nonlinear optical properties of GaSe crystals. GaSe is used for both the generation and measurement of Mid-IR/THz pulses. It produces a THz pulse when struck by a high intensity 800 nm pulse. Additionally, when light passes through GaSe in the presence of an electric field, its polarization changes at an amount proportional to the strength of the electric field.

In order to produce and measure THz pulses, an 800 nm laser beam consisting of 50 femtosecond pulses is split into a generation beam and reader beam, the former carrying most of the energy. After the generation beam is converted into THz radiation, both beams are focused onto a GaSe crystal. The reader beam is then split into its vertical and horizontal polarization components by a Wollaston prism, and the difference in intensity of the polarizations (which is proportional to the electric field strength of the THz pulse) is measured by a detector.

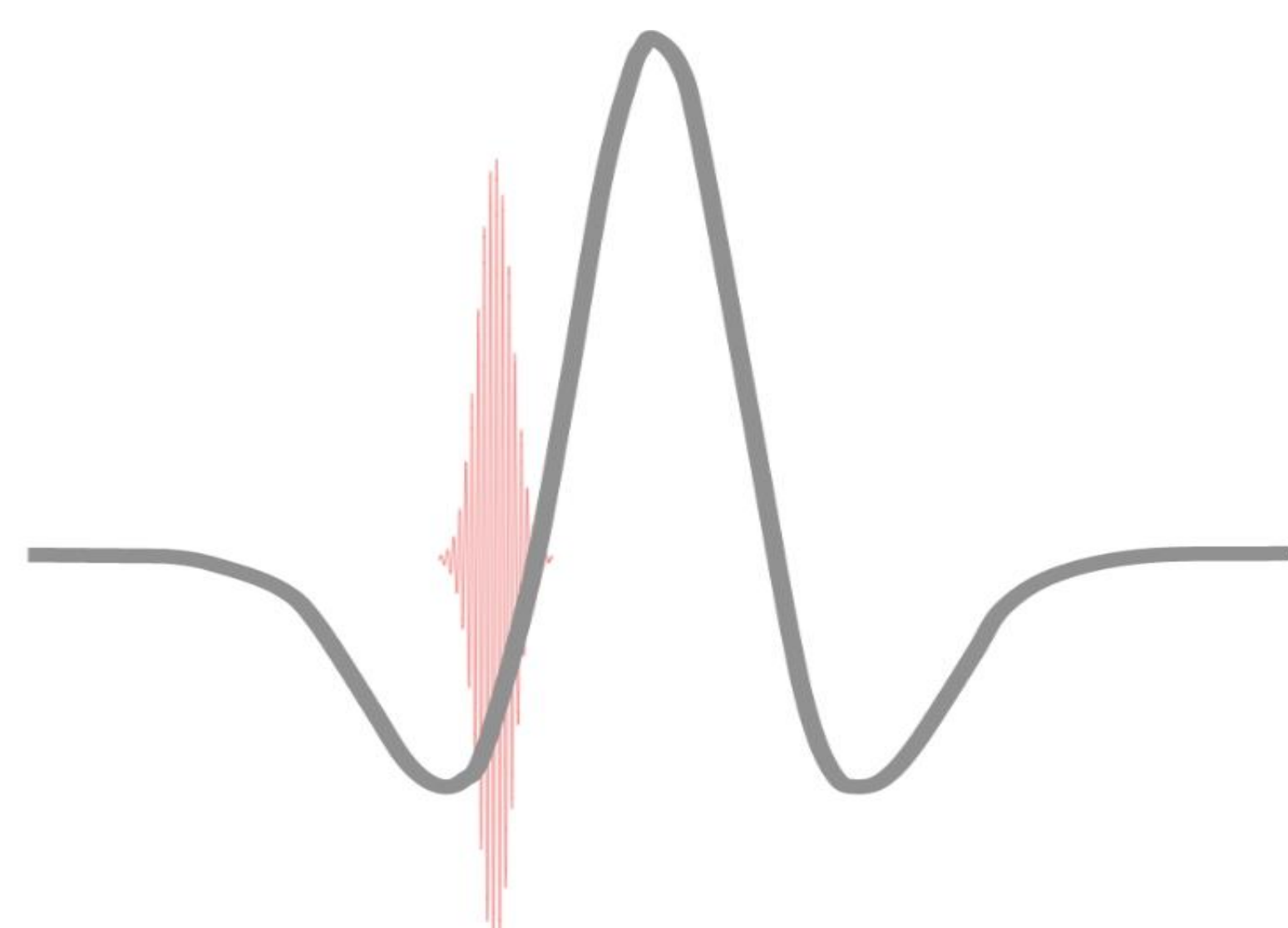


Figure 1. Terahertz pulse (gray) being sampled by a reader pulse (red). As the temporal overlap of the two pulses changes, the reader pulse measures the electric field of the THz pulse at different positions. Relative magnitude and duration of the pulses are not to scale.

The temporal overlap of the THz and reader pulses is controlled by a retroreflector on a motorized stage. This changes the path length of the the generation/THz pulse, thus the relative time at which the THz and reader pulses reach the crystal. Since THz pulses are on the order of a hundreds of femtoseconds in time, the reader beam can sample the electric field of the THz beam at different relative times with very good resolution (≈ 50 fs).

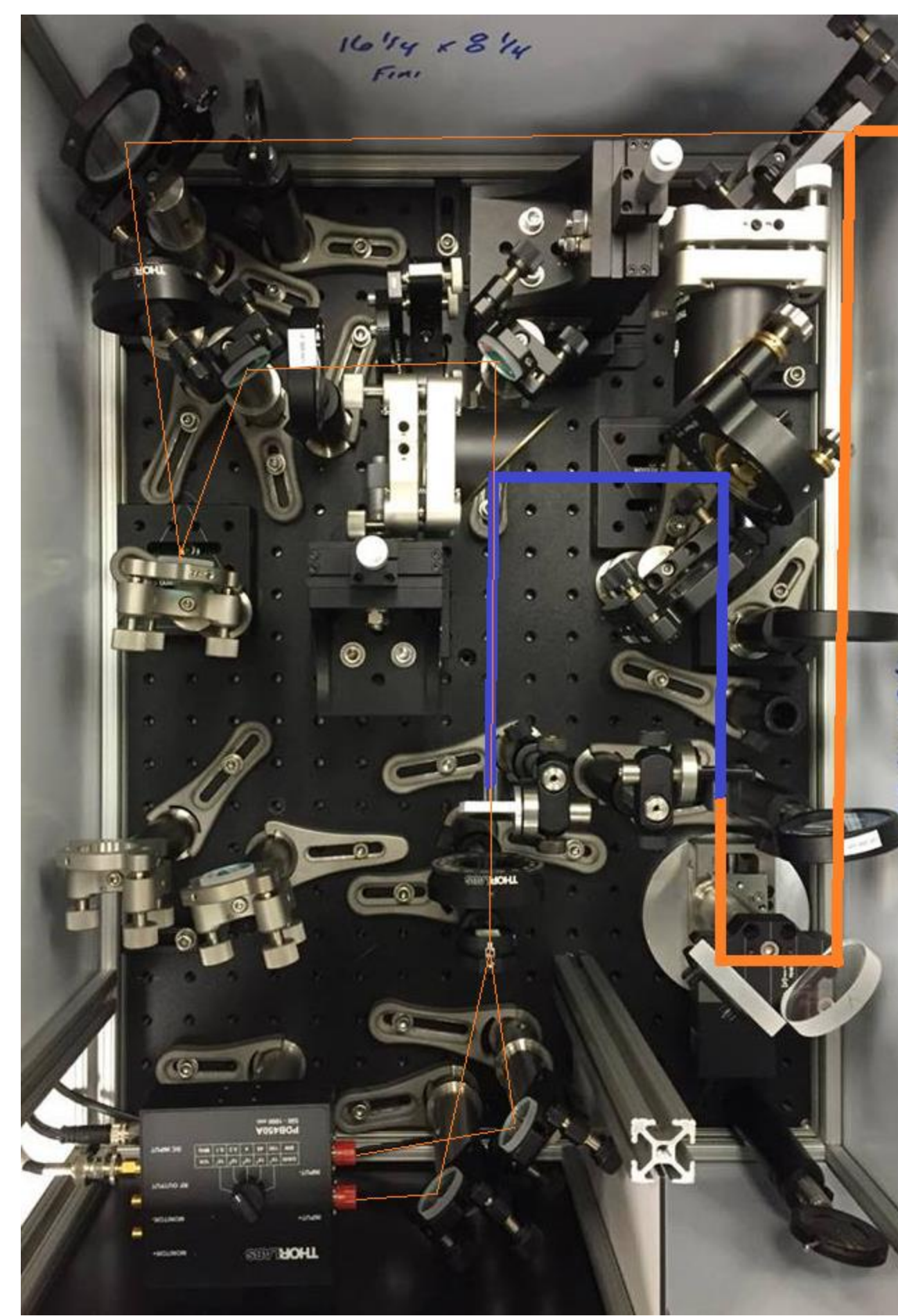


Figure 2. EOS system with beam paths drawn in. The thick orange lines represent the generation beam, the thin orange lines represent the reader beam, and the blue lines represent the THz beam.

The EOS system can easily be modified to perform reflection pump-probe experiments. By exchanging optics on magnetic mounts to minimize realignment procedures, one can direct the THz beam to be focused on a sample which reflects it back to be measured. The reader beam's path is also modified to account for the difference in path length.

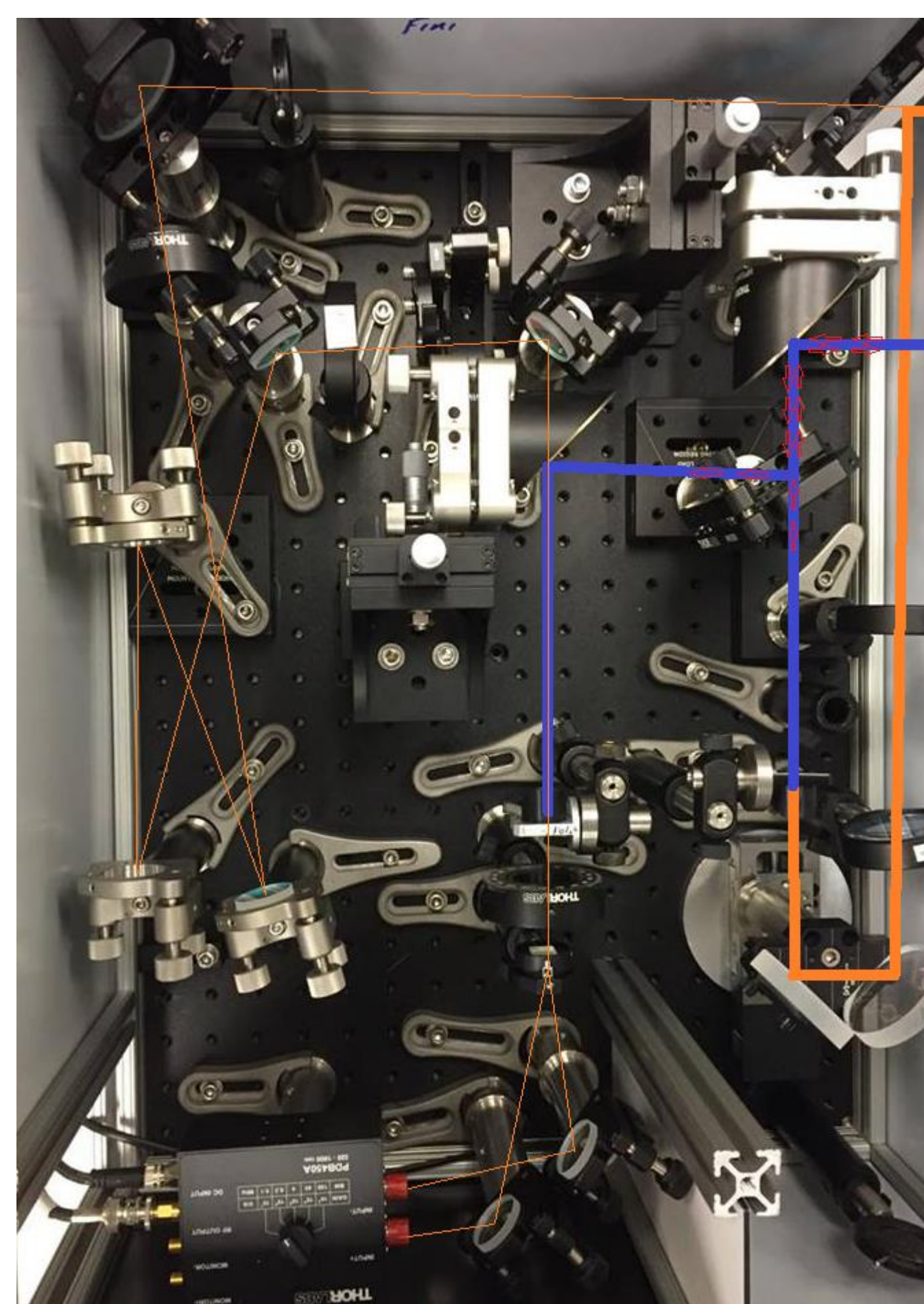


Figure 3. EOS system modified for pump-probe experiments. The THz beam is now reflected off of a sample (out of picture) before measurement. The path of the reader beam is modified to match path lengths.

The differential signal of the reader beam is recorded and plotted as a function of the position of the retroreflector, which is analogous to the electric field of the THz pulse as a function of time. The frequency spectrum is extracted by Fourier analysis. Reflective properties of materials can be observed by comparison of measurements made with and without a sample, or measurements made at various temperatures, probe beam delay times, etc.

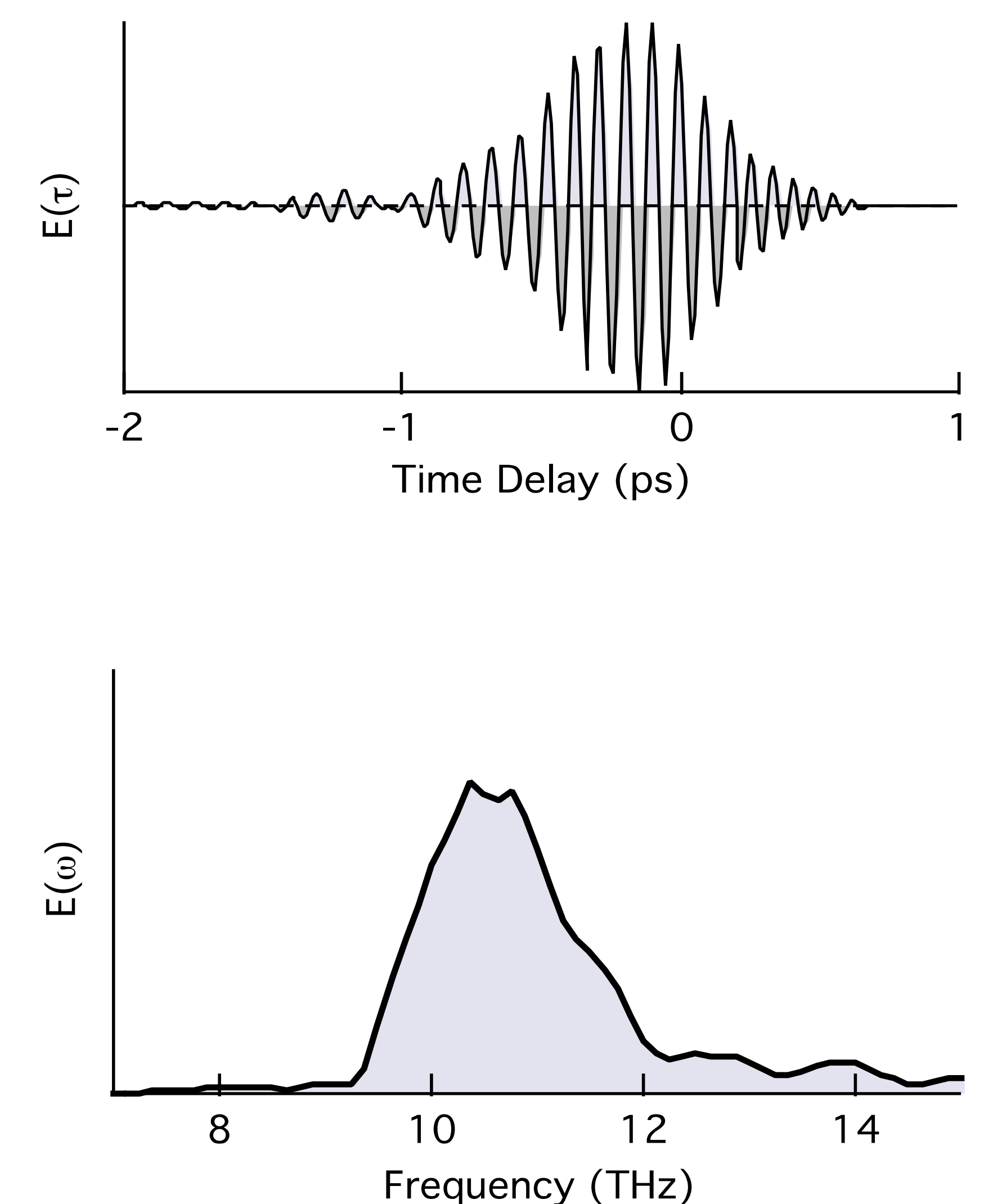


Figure 4. Waveform and frequency data of a Mid-IR pulse (data from G. Coslovich *et al.* arxiv/1603.07819). Experimental conclusions can be made by observing how this data changes under varying conditions.

Conclusions

Electro optic sampling is an effective technique in characterizing light pulses. This EOS system can measure useful properties of Mid-IR/THz pulses and can be used to perform pump-probe reflection experiments. Spectroscopy in the Mid-IR range is of great interest and use to many scientists, therefore this system has the potential to perform a variety of intriguing experiments.

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