TERAHERTZ PULSE SHAPING

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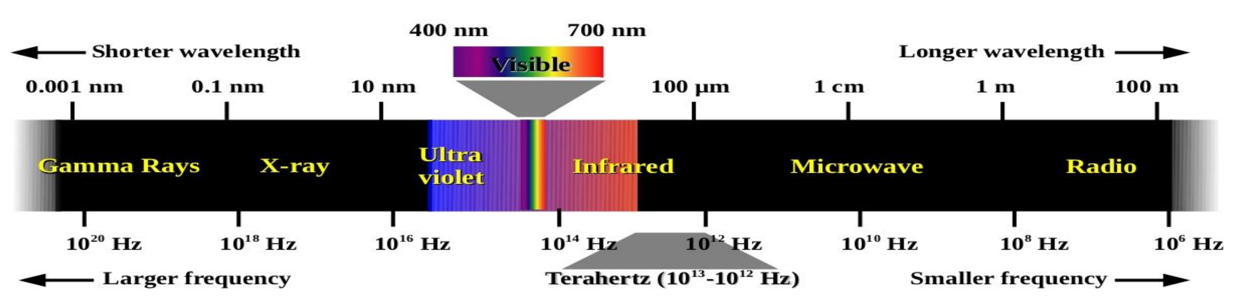
Journal Article

This research aims at gaining better control of the terahertz (THz) generation mechanism.

What is THz?

Terahertz (THz) radiation is located between the microwave and infrared regions of the electromagnetic spectrum.



THz interacts with materials in different ways. It is highly reflected by metals, highly absorbed by water, and passes through some materials unimpeded. This leads to interesting applications such as security measures in airports.

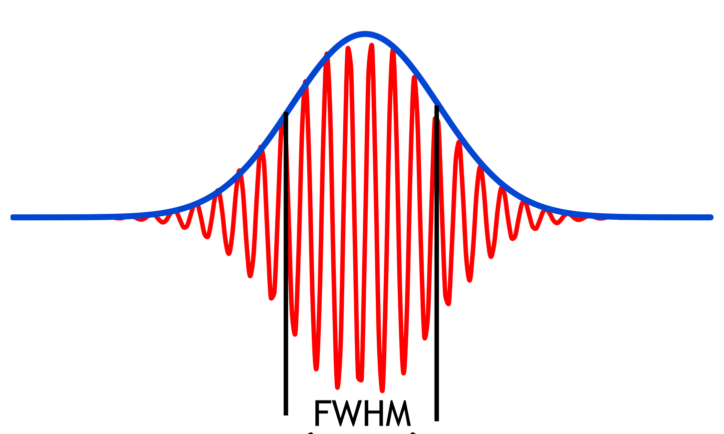
Scientific Problem

The range of available photonic components is very limited. This in turn inhibits new applications.

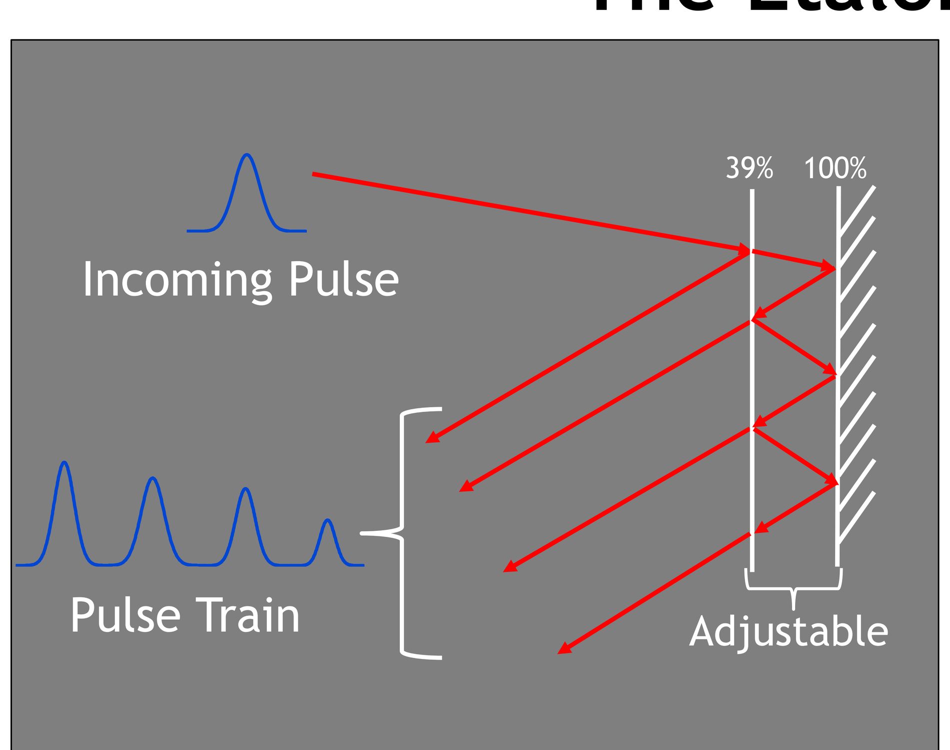
We will compare a traditional Michelson interferometer setup with that of an etalon. Each of these systems modifies the temporal and spectral characteristics of the THz.

What is an Ultrafast Laser?

Ultrafast lasers have pulses whose duration is on the scale of nanoseconds (10^{-9}s) down to even femtoseconds (10^{-15}s). By shining them on an InAs semiconductor, terahertz radiation can be produced. Manipulating the intensity and frequency of these pulses shapes the final terahertz radiation.



The Etalon



It comprises two reflective surfaces placed microns apart. The laser pulse reflects multiple times between the surfaces and emits a pulse train. Adjusting the distance between the two surfaces changes the distance between the pulses in the pulse train.

How Did We Make THz?

Step 1 – Ultrafast laser excites the surface of an InAs semiconductor producing pairs of charge carriers (electrons and holes).

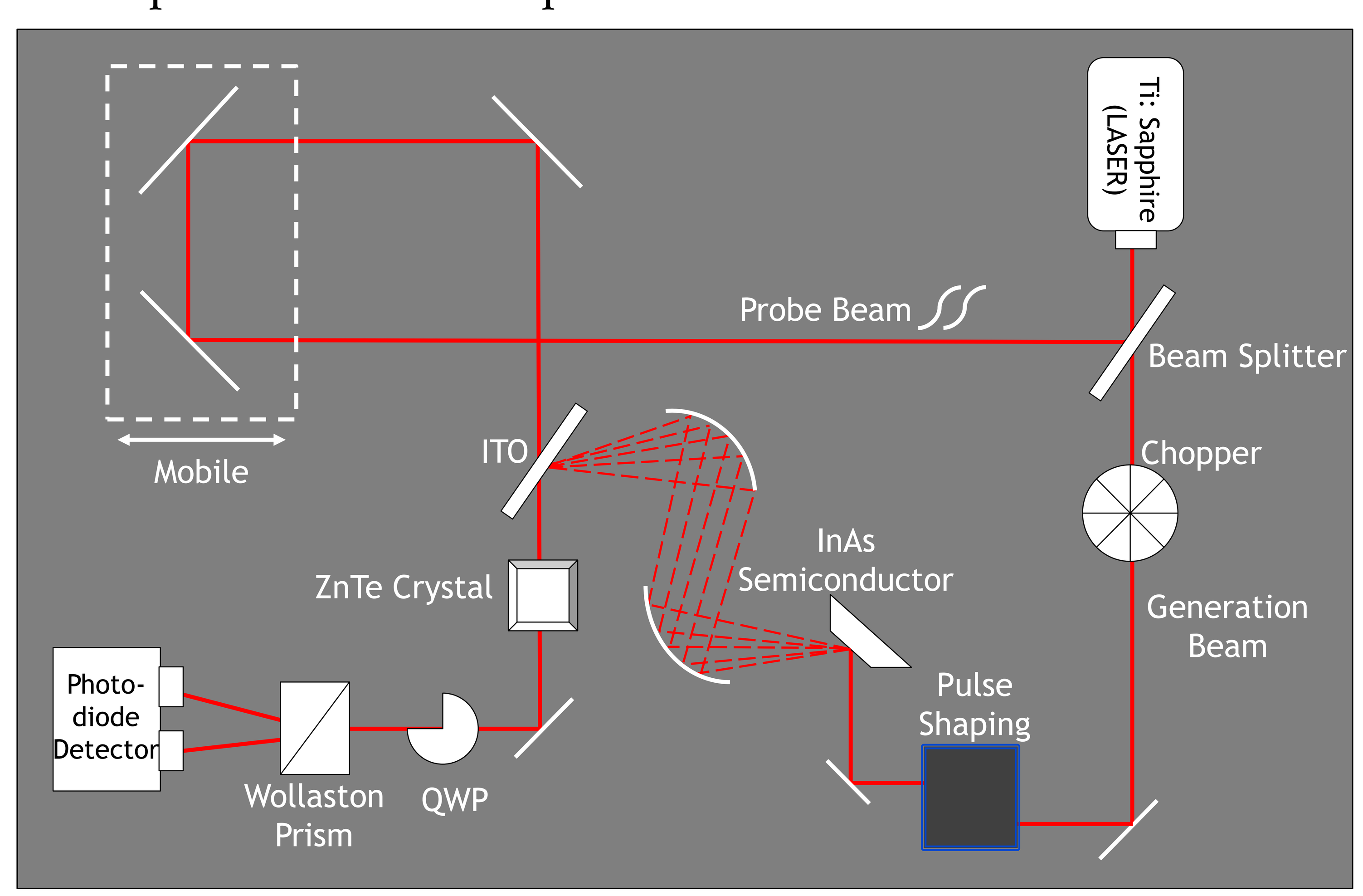
Step 2 – The difference in mobility of the carriers means that one travels faster than the other and this what generates the THz.[1]

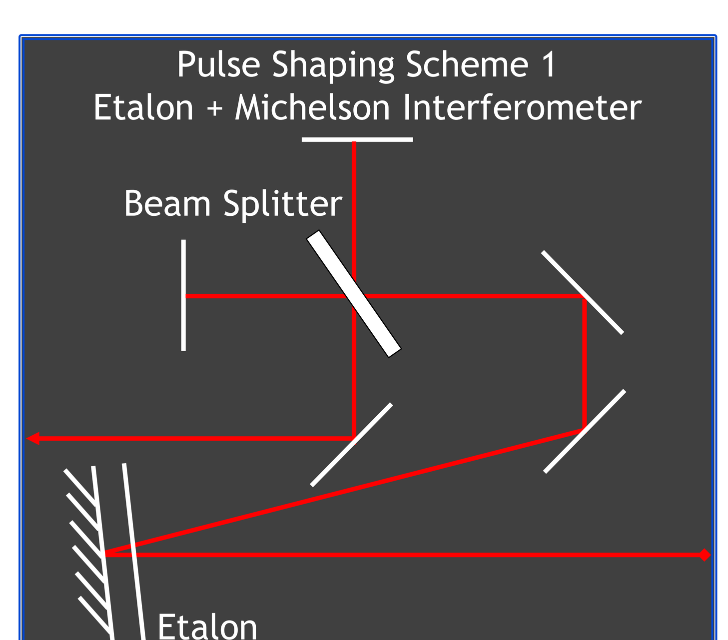
Generation

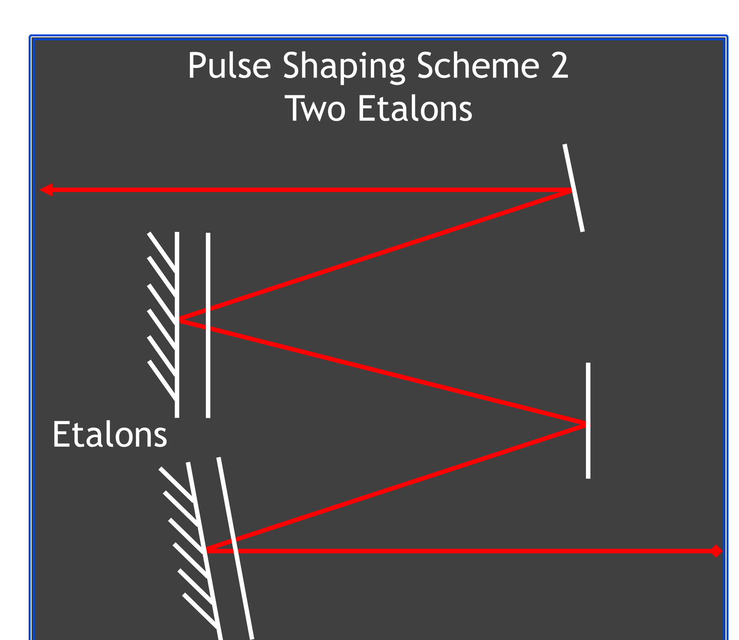
Ti: sapphire Oscillator – 650 mW. 30 fs – 50 fs
Beam Splitter - Splits the laser pulse into two. 96% goes into the generation beam, 4% goes into in the probe beam.
Chopper - It modulates the laser to a set frequency which is picked up by a lock-in amplifier.
Indium arsenide (InAs) - Produces terahertz radiation when the ultra-fast laser hits it.

Detection

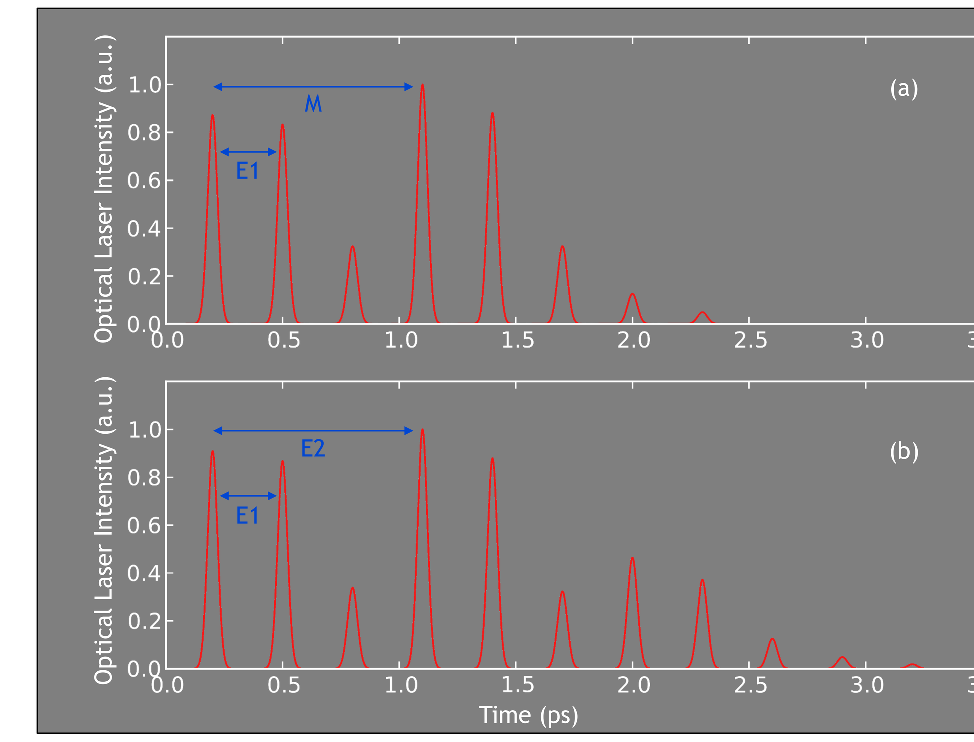
Zinc telluride (ZnTe) crystal - The probe beam and THz are overlapped and synchronized in this crystal.
Quarter-Wave Plate (QWP), Wollaston Prism & Photo-diode detector – Components for electro-optic detection.



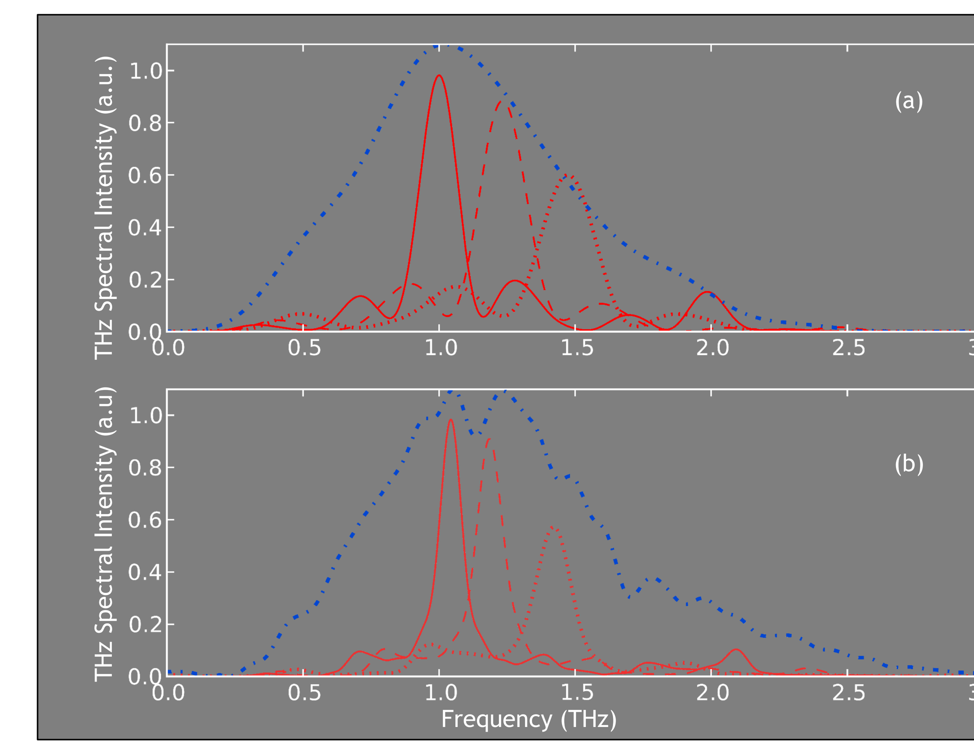




Results



Model of the train of 50 fs pulses after the different pulse shaping configurations. (a) One etalon and a Michelson interferometer. The spacing E1 is controlled by the etalon and the spacing M is controlled by the Michelson interferometer. (b) Two etalons. The spacing E1 is controlled by the first etalon and E2 by the second. The pulse train in (b) is much longer, and has more total energy than in (a).



Measured THz spectra showing frequency selectivity for pulse shaping using (a) one etalon and a Michelson interferometer and (b) two etalons. The peaks displayed in (a) are centered at 0.99 THz, 1.22 THz, and 1.47 THz. The peaks in (b) are centered at 1.03 THz, 1.18 THz, and 1.41 THz. For both figures, the broad spectrum of the THz pulse arising from a single 800 nm laser pulse is also shown in blue.

Conclusion

The first scheme has an efficiency of 36%, but the two etalon setup increased that to 87 or 98% depending on the type of mirrors used. With the this second scheme, we demonstrated bandwidth selectivity $\Delta f/f = 0.10$ at 1.18 THz, and that can be increased by adding more etalons, which is possible due to their high efficiency.

Furthermore, the optical alignment involved in setting up our pulse shaping method is very simple and stable due to the absence of gratings. Using staggered etalons for pulse shaping as was done here requires mechanical stability on the order of only 50 fs.

The two etalon setup was found to be favorable compared to other pulse shaping schemes. This method is especially well suited for low-power systems that cannot afford the power loss associated with many other pulse shaping techniques and for researcher needing a modular approach.

(1) Animation

Bibliography