Asynchronous Time Resolved Terahertz Spectroscopy

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Motivation

We use terahertz spectroscopy to study charge carrier lifetime in solar cell materials. Adding a diode laser to the time resolved terahertz spectroscopy (TRTS) setup lets us use electronic timing, permitting measurement of longer lifetime solar cell materials.

Introduction

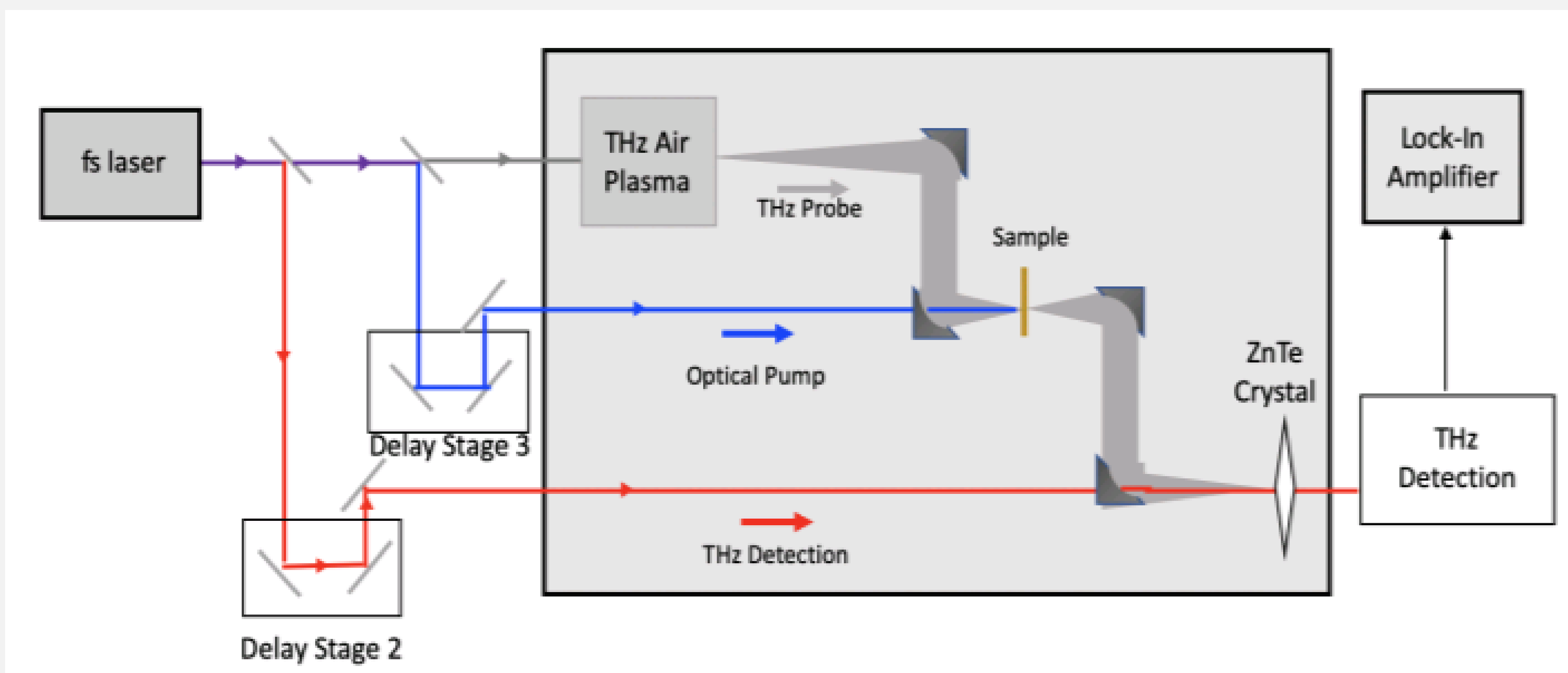


Figure 1 – Current TRTS setup [1]

To perform terahertz spectroscopy on PV material, first we excite the sample with an optical beam pulse, then a THz pulse must pass through the sample. Excited electrons in the conduction band absorb THz, but those in the valence band do not. Measuring the difference in THz conductivity over time reveals the charge-carrier lifetime of the sample. The TRTS method takes a single laser pulse and splits it into two pulses. One of these pulses is used as the exciting pulse and one is converted into terahertz via air-plasma. To produce the variable delay, the optical path length varies. To study long-lifetime samples the time between the exciting pulse and the probing pulse must be long as well. Alignment issues make using path delays prohibitively difficult.

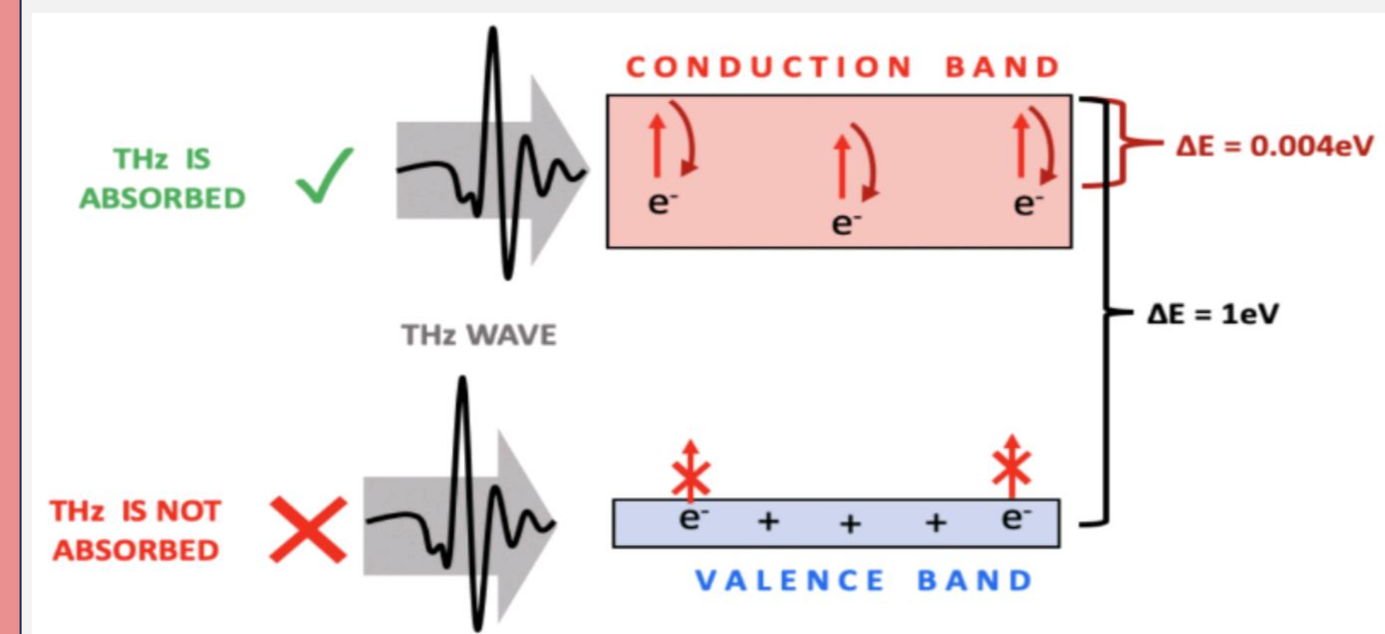


Figure 2 – THz interaction with electrons [2]

Method

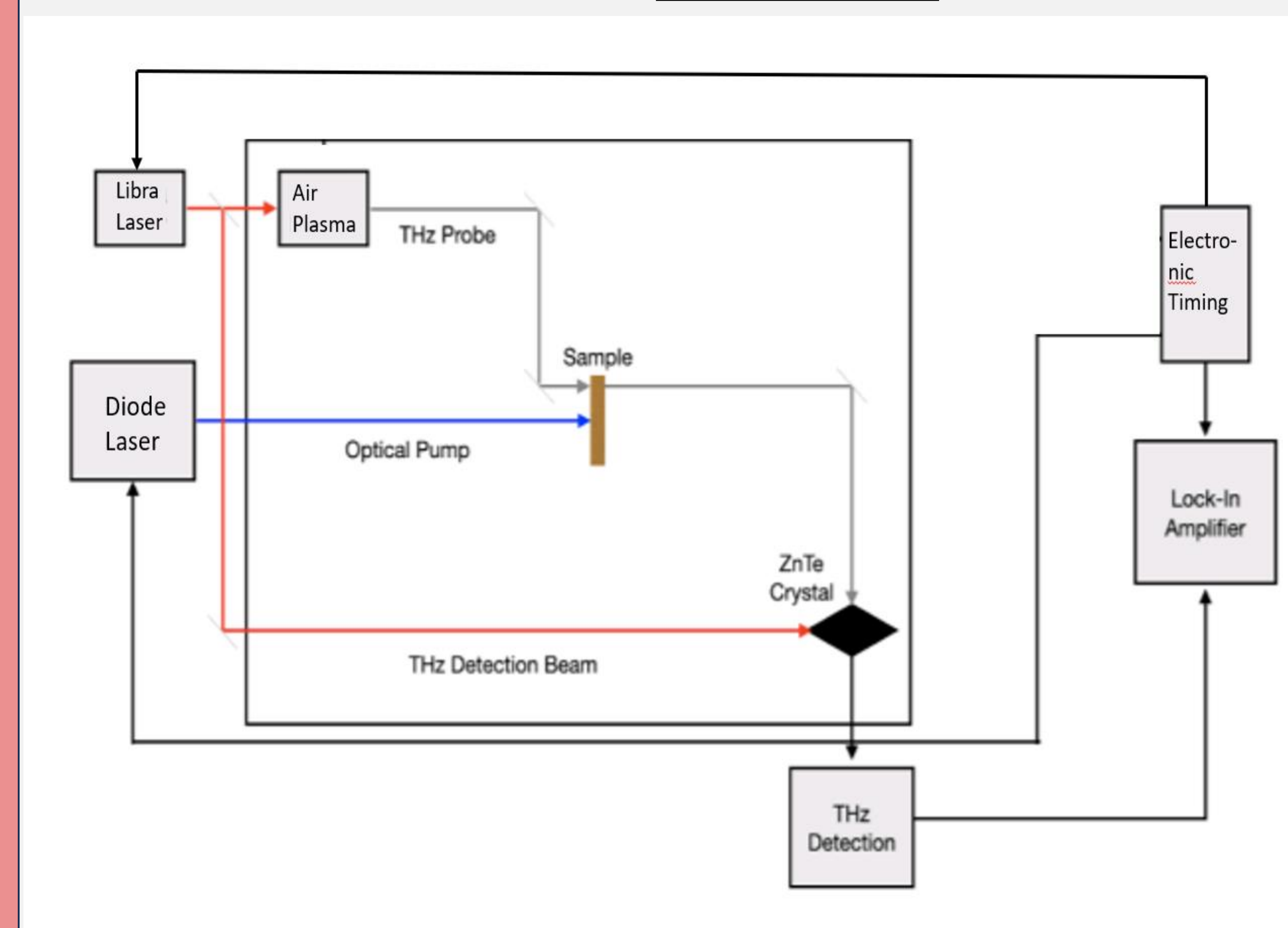
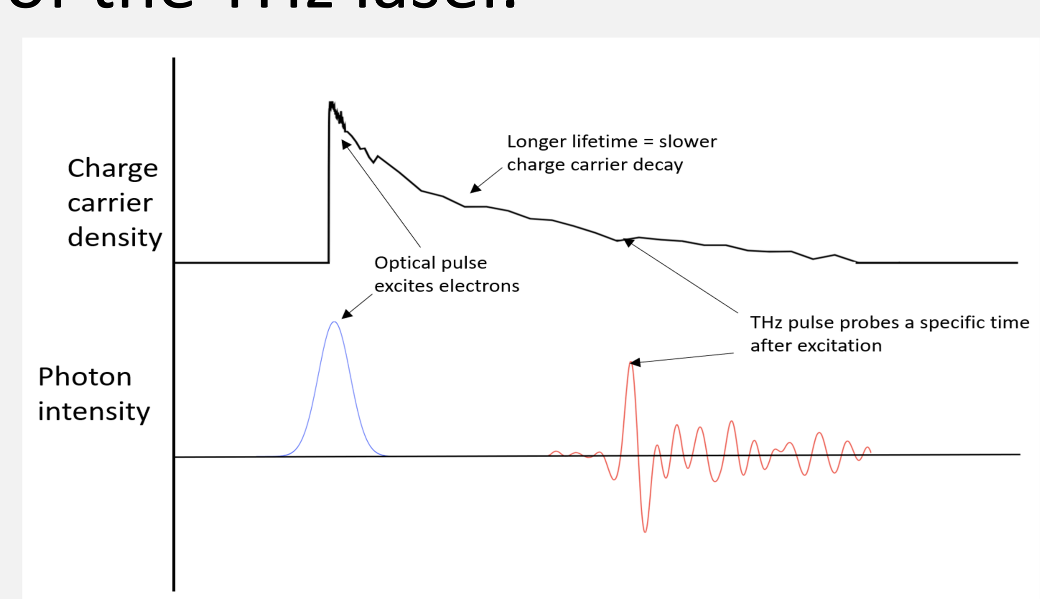


Figure 3 – ATRTS setup

To address these challenges, we are developing an Asynchronous Time-Resolved Terahertz Spectroscopy (ATRTS) setup by incorporating an additional diode laser and an electronic timing system. By using two separate pulses instead of one split pulse, we are no longer constrained by the speed of light, nor are we constrained to use the wavelength of light of the THz laser.

Figure 4 – Timeline of pulses and charge carriers at sample



Results

We successfully proved that using air-plasma THz we could attain sufficiently high signal to noise, proving that using the cleaner THz from an emitter is unnecessary. We did this initially without incorporating electronic timing. The data in table 1 was produced without electronic timing.

Attempts to increase pump power and to use potentially faster switching devices were unsuccessful. We have also not yet finalized the electronic timing system to study lifetimes.

Data	Diode Pump Off	Diode Pump On
THz signal (mV)	1.17 ± 0.00333	1.14 ± 0.00478

Figure 5 –Results

Conclusion

We successfully demonstrated two-laser spectroscopy, and in doing so opened up a great deal of functionality in both studying long-lifetime samples and studying Perovskite halide segregation.

We are currently developing the electronic timing system required for ATRTS. Finishing this, as well as potentially applying more power to the laser diode are clear paths for future work.

References

[1] Root, Jack. *Measuring Lifetimes of Solar Cell Materials Using Terahertz Absorption and Continuous Wave Laser Excitation.* Wesleyan university, 2022.

[2] Yun, Bin. *Enhanced pump-probe terahertz spectroscopy setup and the analysis of the charge carrier lifetime in solar cells.* Wesleyan University, 2023.