New Lifetime Instrumentation for Solar Cell Materials

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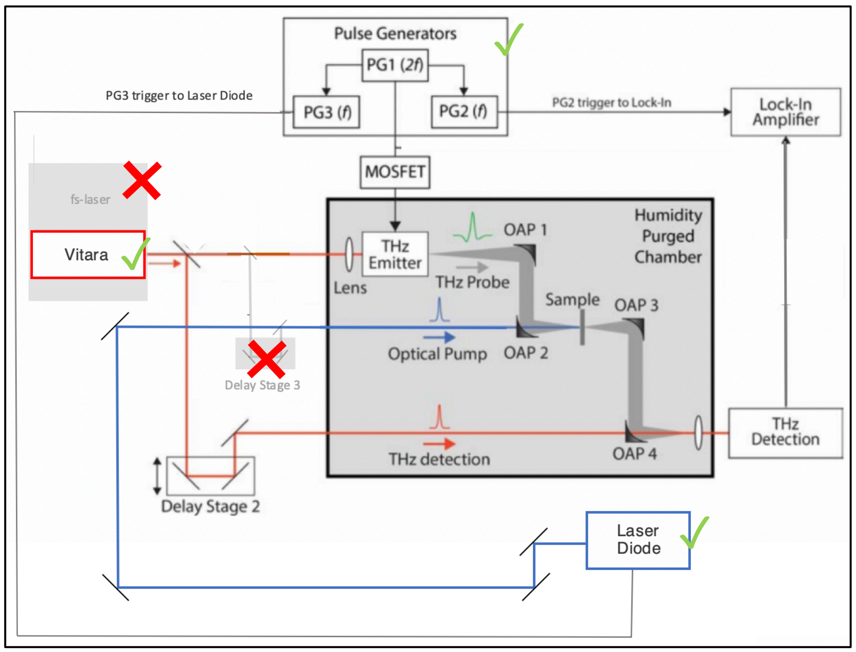
Introduction

In order to better understand (and ultimately improve) solar panel efficiency, it is important to improve our methods of studying the behavior of charge carriers (i.e. electrons) in solar cell materials. One such method, known as terahertz spectroscopy, uses an optical laser to 1.) excite (or "pump") the electrons within the solar cell material, and 2.) produce terahertz waves to detect, or "probe" the excited electrons. While this is an effective method of analyzing the material without the need of metal electrodes, this THz set-up suffers from **two** issues:

1.) The "delay" between the "pump" and "probe" laser pulses relies on Delay Stage 3, which changes the physical distance of the pump beam path. Due to physical limitations of Delay Stage 3, we cannot accurately model longer lifetimes.

2.) The current "pump" laser is a poor imitation of sunlight, both in wavelength and intensity.

Modifications to Current Set-Up



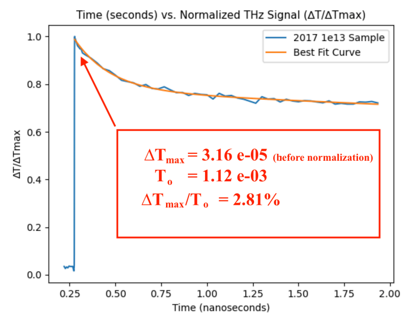
1.) Decoupling the "Pump" and "Probe" Laser

By replacing the **Libra fs-laser (in grey)** with **Vitara (in red)** as the "probe", and our **Laser Diode (in blue)** as our "pump," and coordinating the delay electronically through Pulse Generators, we are no longer limited by **Delay Stage 3 (in grey)**, and we may model longer lifetimes.

2.) Installing Laser Diode as "Pump" Source

By replacing the Libra fs-laser (400 nm) with interchangeable photodiode lasers that operate at ~450 nm and have a lower peak intensity, our optical pump may better mimic sunlight.

How Do We Increase Our Signal?



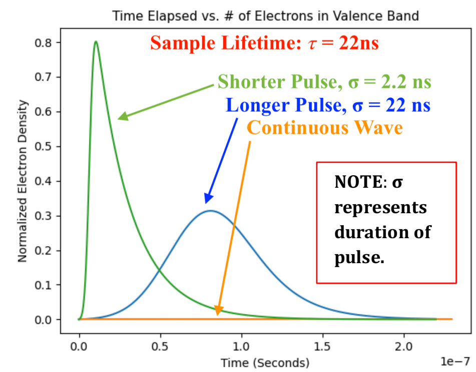
By plotting the normalized change in the THz transmission (ΔT) as a function of time, and fitted to a bi-exponential decay function $\frac{\Delta T}{T_{max}} = a_1 * e^{-t/\tau_1} + a_2 * e^{-t/\tau_2}$, we are able to extract the lifetime values. τ_1 = 22ns and τ_2 = 0.20 ns for the hyperdoped silicon sample on the left.

Side note: This data is obtained using the Libra fs-laser and the current lifetime setup. One of the goals with our modification is to enable accurate evaluation of the long decay dynamics like the τ_2 component here.

However, the sample above was analyzed using the Libra fs-laser. Currently, the photodiode laser is unable to produce a $\Delta T/T_o$ large enough to accurately model the lifetime of the sample. Since ΔT is proportional to the conductivity of the material, which in turn is proportional to the number of excited electrons in the material, the question becomes: **How do we increase the number of excited molecules in the material?**

Answer: We can Pulse the Laser

Currently, the diode laser is a continuous wave laser, which allows the electrons to reach a steady state, where the # of electrons being excited = the # of electrons recombining (i.e. becoming "de-excited). Using a short laser pulse, more electrons can be excited than are able to recombine, increasing the peak number of excited electrons (see figure to right)



Future Work

The next step is to increase our THz signal, so that we may produce significant data. This will involve pulsing our laser externally through Pulse Generators. We may also try to make our laser more intense, by either shrinking the spot size of our laser or reducing our mirror lens.

Alternatively, we may increase the THz Signal read by the Lock-in Amplifier (see diagram of THz Set-Up to left). Using a chopper, we can make the change in THz signal more easily apparent in the Fourier Transform produced by the Lock-in Amplifier, allowing us to better detect it.

Finally, we need to electronically coordinate the Pulse Generators, so that we can produce the delay between the "Pump" and "Probe" laser, without relying on Delay Stage 3. This will allow us to analyze longer lifetime materials more thoroughly.