Waveform-Agile Frequency Doubled Laser System for Optical Switching and Characterization of Phase Change Materials at Near-IR Wavelengths

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Abstract: We created a system for the characterization of Ge2Sb2Te5 starting with a 1550 nm CW laser and utilizing second harmonic generation through a PPLN crystal in order to achieve full pulse control at 775 nm.

Phase change materials - first used as electronic memories - have been making a resurgence in the last several years especially in the optical domain. One material, Germanium Antimony Telluride (GST), has been of interest recently for its possible use in optical multi-level memory and computing [1] applications. GST possesses the ability to switch between an amorphous disordered phase and a face-centered cubic (fcc) crystalline phase [2] via an optical excitation. In order to truly understand and be able to implement this material into future devices and systems, the phase change characteristics need to be fully understood at multiple wavelengths, depending on the region of interest. Understanding the dynamics of phase change requires controlling the beam size of the excitation pulse, its power/energy, pulse width and temporal profile (from the picosecond to the microsecond range). While such control is readily availabe at the telecom band [3], it is a trickier prospect in the NIR/visible. Earlier studies of phase change dynamics in the NIR/visible regime either relied on high energy fixed-pulse (doubled) YAG lasers, or on CW lasers that are modulated via electro/acousto optic modulators. Both approaches suffer from shortcomings: doubled YAGs have too low repetition rates to allow for multi-pulse investigation and offer fixed pulse width/profile, while externally modulated CW lasers require generally expensive (and slow) external modulators for pulse shaping, and their limited peak power prohibits larger beam sizes and requires tight focusing to induce the phase change. Moreover, in either of these systems, it is hard for investigations to show the dynamics in the sub-nanosecond regime. Here, we propose, implement, and test a system that retains all the flexibility of telecom-band operation while providing a 775 nm excitation for future investigations of GST dynamics in the near-IR regime.

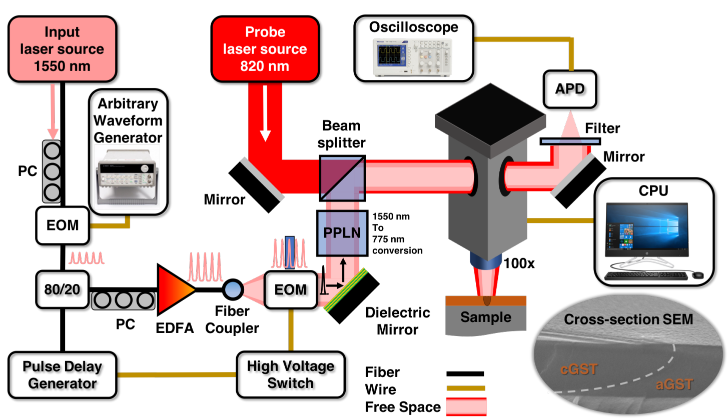
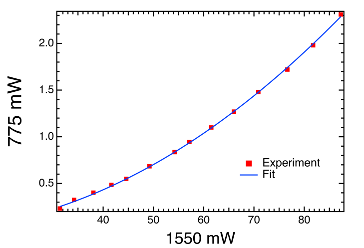
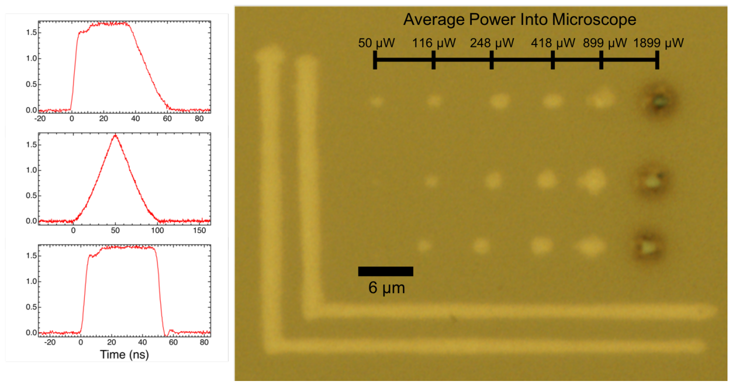


Fig. 1: 1550 nm to 775 nm setup.

Our system, seen in Fig. 1, begins with a 1550 nm constant wave (CW) laser. We pass through a fiber coupled electro-optic modulator (EOM) connected to an arbitrary waveform generator in order to create our pulses. From there we pass through an 80/20 splitter where 80% of our signal goes into an Erbium doped fiber amplifier (EDFA) where the pulses are amplified to the needed powers to pump a periodically poled Lithium Niobate (PPLN) crystal for the second harmonic generation (SHG) used to achieve the 775 nm laser pulses. After the EDFA the now amplified pulses exit the fiber through a coupler and pass through our free-space EOM. This is where we pick off our individual pulses. The other 20% of light from the 80/20 splitter is sent to a pulse delay generator which is triggered by the pulse and sends a signal to our high voltage switch. The switch then passes the voltage needed to open our free-space EOM and allow a specified number of pulses through. The allowed pulses from the EOM are then sent into the PPLN crystal where, through SHG (efficiency shown in Fig. 2a), they are converted into 775 nm light. After the conversion of the pulses the now 775 nm light is co-aligned with a CW 820 nm laser that is used for reflectivity monitoring of the GST during the change. The co-aligned beams are then passed into a 20x or 60x microscope objective and focused down to a 1-2 μm spot onto the surface of the sample. The reflected light exits the microscope and passes through an 820 nm bandpass filter to get rid of the pump wavelength and is then detected using a silicon avalanche photo-diode (APD) detector allowing us to monitor the reflectivity and phase-change dynamics in-situ.



(a) Conversion efficiency of 1550 nm light to 775 nm light through PPLN crystal.



(b) Crystalline spots from differing pulse shapes and powers.

Fig. 2

The major benefit of our system is that we have the ability to switch between 1550 nm light and 775 nm light with full control of the shape and number of pulses incident on our sample for a wide range of characterization tests for GST in particular, but other materials as well. The benefits of switching to the 775 nm light are three-fold. First, we can probe the GST at a new wavelength in the visible spectrum - a region of interest for spatial light modulators - while still maintaining the full control of pulse shape and power as demonstrated earlier via 1550 nm encoding [3]. This gives us the ability to probe how GST reacts to the different pulse shapes which from Fig. 2b can be seen to affect the crystallization dynamics. Secondly, we can focus the 775 nm light into a smaller spot which boosts the power going into the GST and lowers the powers needed to impart the change. And Finally, GST has a higher absorption at visible wavelengths so the phase change can be accomplished at even lower switching powers and with thinner samples. While our initial prototype system relied on bulk PPLN second harmonic generation, future systems will rely on PPLN waveguide geometries [4], where we can achieve even greater flexibility at lower powers and without requiring any amplification.

References

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