Shack-Hartmann Thermal Lensing Characterization of Mid-IR Materials

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We quantify the thermo-optic response of chalcogenide glasses to 2µm laser irradiation using Shack-Hartmann thermal lensing metrology. Induced dioptric powers as strong as $0.21m^{-1}$ are observed for CW pump irradiances as low as 38.2 W/cm^2.

1. Introduction.

High brightness mid-IR sources have matured and are becoming viable solutions to many medical, defense, and sensing demands. Recently, super-continuum from 3.6-4.8µm with an average power of 22W has been demonstrated using a ZGP optical parametric oscillator [1]. To fully utilize the power and bandwidth of sources like these, passive optical components possessing both high optical and high thermal power handling capabilities are necessary. Glasses based on the chalcogenide elements show promise for these applications as they offer a large wavelength transmission window that spans from ~1µm to ~10µm [2]. However, many of these glass compositions require thorough evaluation of their thermo-optic behavior relating to both intrinsic properties and purity concerns.

In order to evaluate the relative strengths of the thermo-optic responses of chalcogenide glasses, we utilize a CW pump-probe experiment in which the thermally induced parabolic phase is directly measured with a Shack-Hartmann array.

2. Experiment.

During evaluation, the chalcogenide sample is heated through the absorption of a 2µm pump laser. This laser possesses a Gaussian spatial profile with an M^2 of 1.4. The 2µm wavelength is chosen to target contaminant absorption that may be present in the glasses. The pump laser is collimated with a beam diameter of 1.6mm on the target sample. The probe beam is collimated to fill the clear aperture of the sample. The probe wavelength is 1.08µm. As both the pump and probe laser frequencies lie below the band-gap of the materials tested here, photochemical changes are avoided in the glass matrix. The probe counter-propagates through the sample and is collected by the Shack-Hartmann wavefront sensor in the far field. The experimental layout is shown in Figure 1. Through paraxial optics formulations, the sensor software returns the distance from the sensor to the beam waist. The separation between the beam waist and the target sample is defined as the thermally induced focal length *f*. From *f*, the optical power K is given by $K = f^{-1}$.

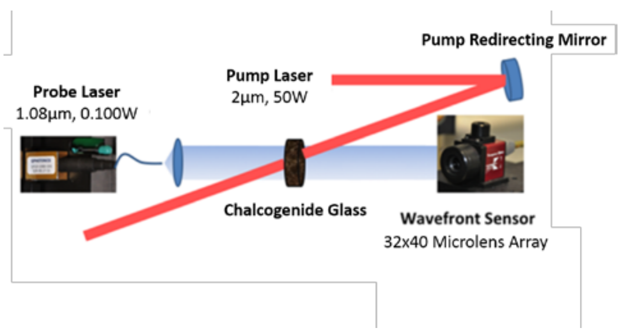

Figure 1: Experimental Schematic.

Three disk-shaped chalcogenide samples are tested in this work. Each has a diameter of 25.4mm. One disk is an $As_{40}Se_{60}$ sample of 8mm thickness and is suspected of having O-H contamination. The other two samples are commercially available Schott materials, consisting of $Ge_{33}As_{12}Se_{55}$ (IG2) and $As_{40}Se_{60}$ (IG6) compositions. Both Schott samples are 5mm thick. A CARY500 spectrophotometer provided extinction spectra of the samples. These spectra are shown in figure 2-a.

3. Results and Discussions.

All three samples tested demonstrate strong thermal lensing. The Schott materials show <0.25m^{-1} dioptric powers up to 1.25W incident 2µm pump signal. Moreover, the sample suspected of contamination yielded an induced dioptric power >7x stronger than the IG6 material that should be compositionally identical. In addition, this more responsive sample suffered a 0.21m^{-1} dioptric power at 1.24W. Response of these materials is significantly stronger than that of oxides per a given heating load. Previously, we have shown that BK7 responds to 25W of 2µm pump with a relatively weak 0.052m^{-1} dioptric power [4]. This dioptric power occurs in these chalcogenide glasses at nearly 100 times lower pump powers.

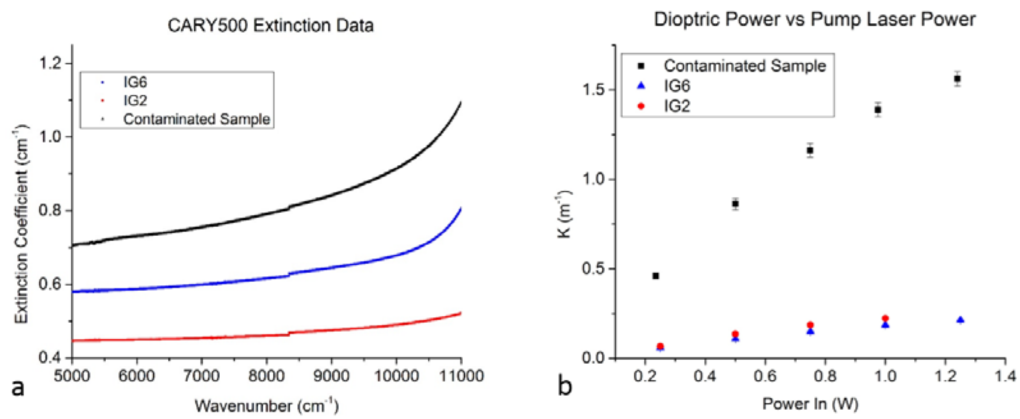

Figure :2a) Extinction spectra. 2 b) Dioptric power of induced thermal lens as a function of input 2µm pump power.

4. Conclusion.

We have implemented Shack-Hartmann wavefront sensing to analyze the response of different compositions of chalcogenide glass from different glass producers. We have shown that chalcogenide glasses respond to sub-band gap irradiation at a 2µm wavelength with strong thermal lensing. The ability of this technique to clearly discriminate the responses of all the samples tested demonstrates its sensitivity. This sensitivity in turn allows for qualification of real-world performance of the glass with no a-priori knowledge of material thermo-optical parameters.

5. References.

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