Phase-Change Materials for Photonic Limiters

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Introduction

Photonic Limiters: why they are important and what they are made of

Photonic limiters are devices whose optical property is highly dependent on the wavelength and intensity of the incident light. Because of such selectivity of incoming lights, photonic limiters can be used to protect sensitive optical sensors ranging from military radar to human eye. While photonic limiters can assume different structures, the one we are studying is a layered structure: a phase-changing material sandwiched in between Bragg mirrors. The key element in such structure is the phase-change material, whose refractive indices change dramatically as it switches between different phases.

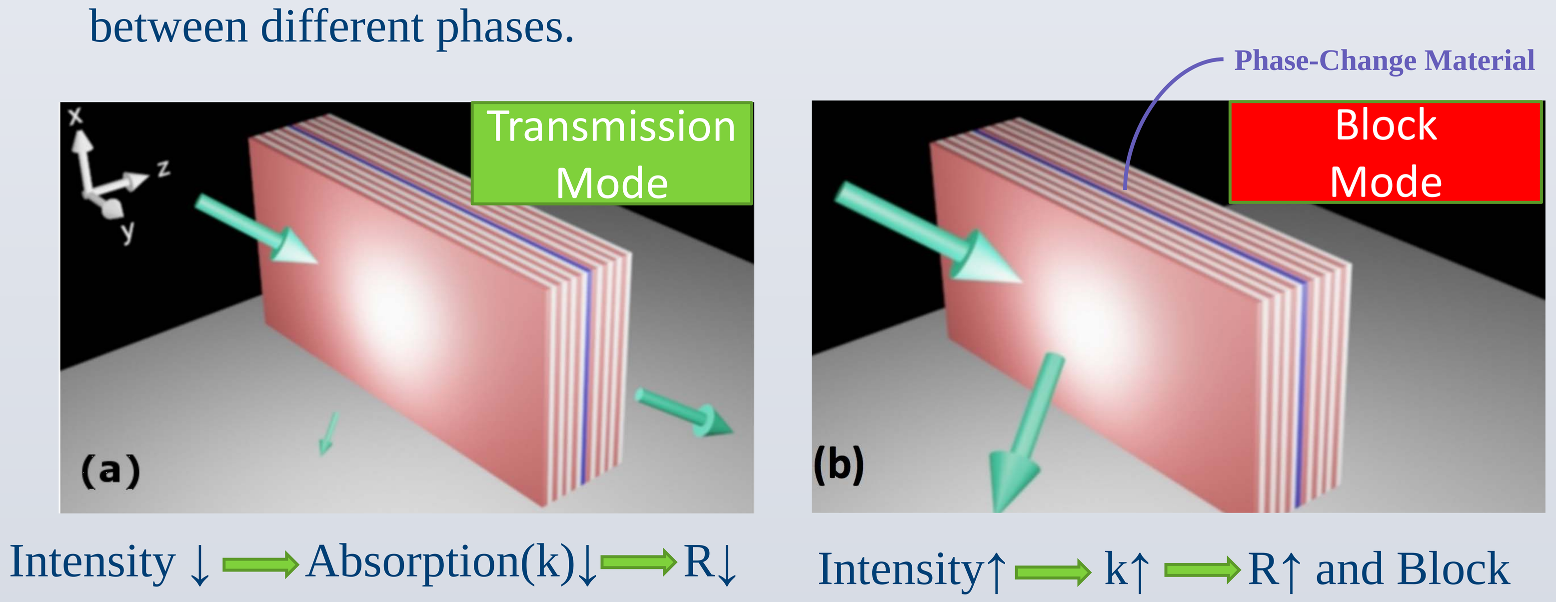

Figure 1. Two Modes of a Photonic Limiter[1]

GST: a Phase Change Material

- An alloy that consists of germanium, antimony and tellurium.
- Low absorption index in the amorphous phase
- Higher absorption index in the crystalline phase

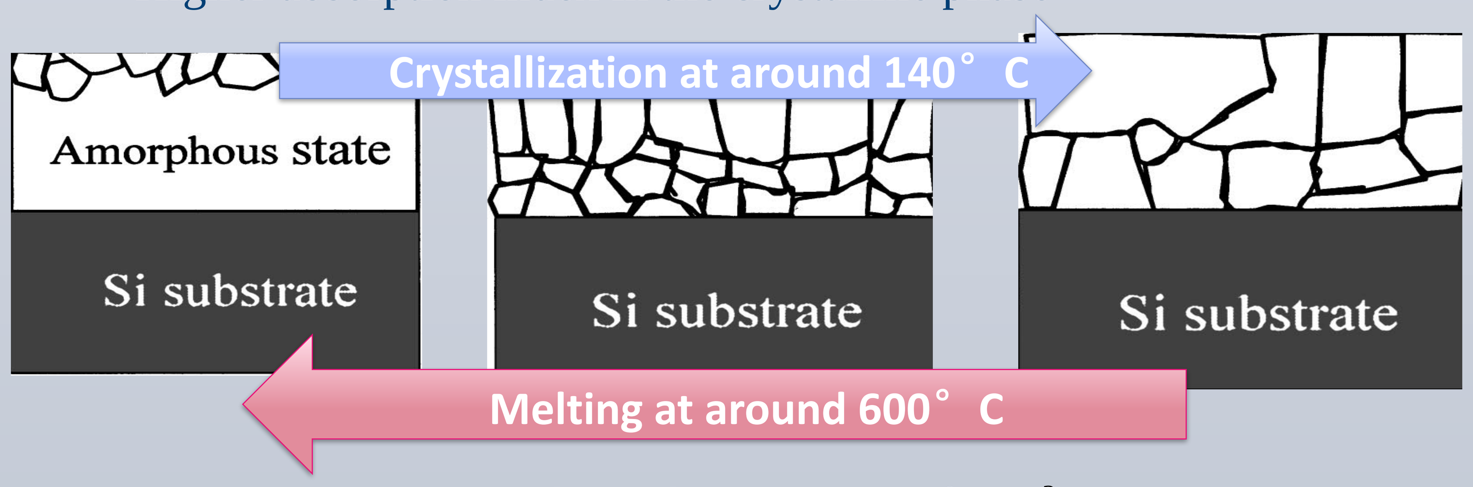

Figure 2. Phase-Change Process of GST[2]

Goal of The Research: What Do We Not Know about GST225?

This research aimed at characterizing the changes in GST225's optical properties as it undergoes phase change. We were particularly interested in its optical properties under the ***near-infrared wavelength range*** (~1600nm), a range that is not well-documented but is gaining increasing attention in both academia and the industry.

[1] Figure adapted from *J. H. Vella et al. Experimental Realization of a Reflective Optical Limiter, Phys. Rev. Applied 5, 064010 (2016)*

[2] Figure adapted from Jeong et al. *Crystallization behavior of sputter-deposited amorphous $Ge_2Sb_2Te_5$ thin films, Journal of Applied Physics 86, 774 (1999)*

Sample Preparation

Sputtering Deposition

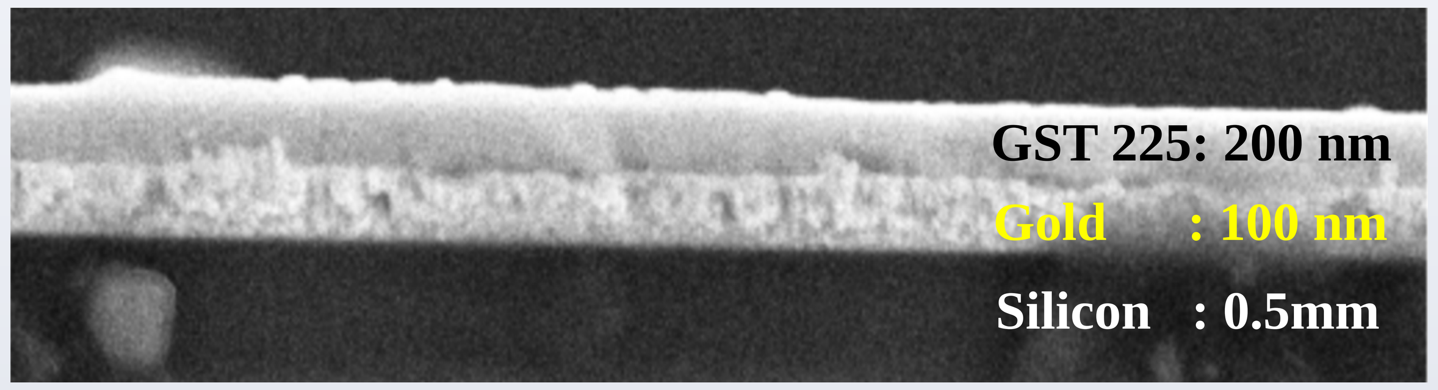

Figure 3. SEM Imaging of a GST Sample

Sample Number	Substrate	Gold	GST225
1	Si	100 nm	200 nm
2	Si	/	200 nm

Figure 4. Two Samples of Different Sputtering Structures

Experiment Set-Up

Ellipsometry: Measures Refractive Indices N and K

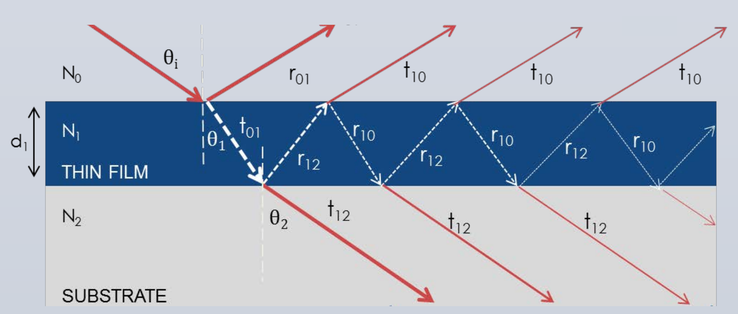

Figure 5. Mechanism of Ellipsometry[3]

- Irradiates the sample surface with polarized light
- Measures the reflected light and compares how intensity and polarization patterns are changed by interaction with the sample
- Infers optical properties of the sample

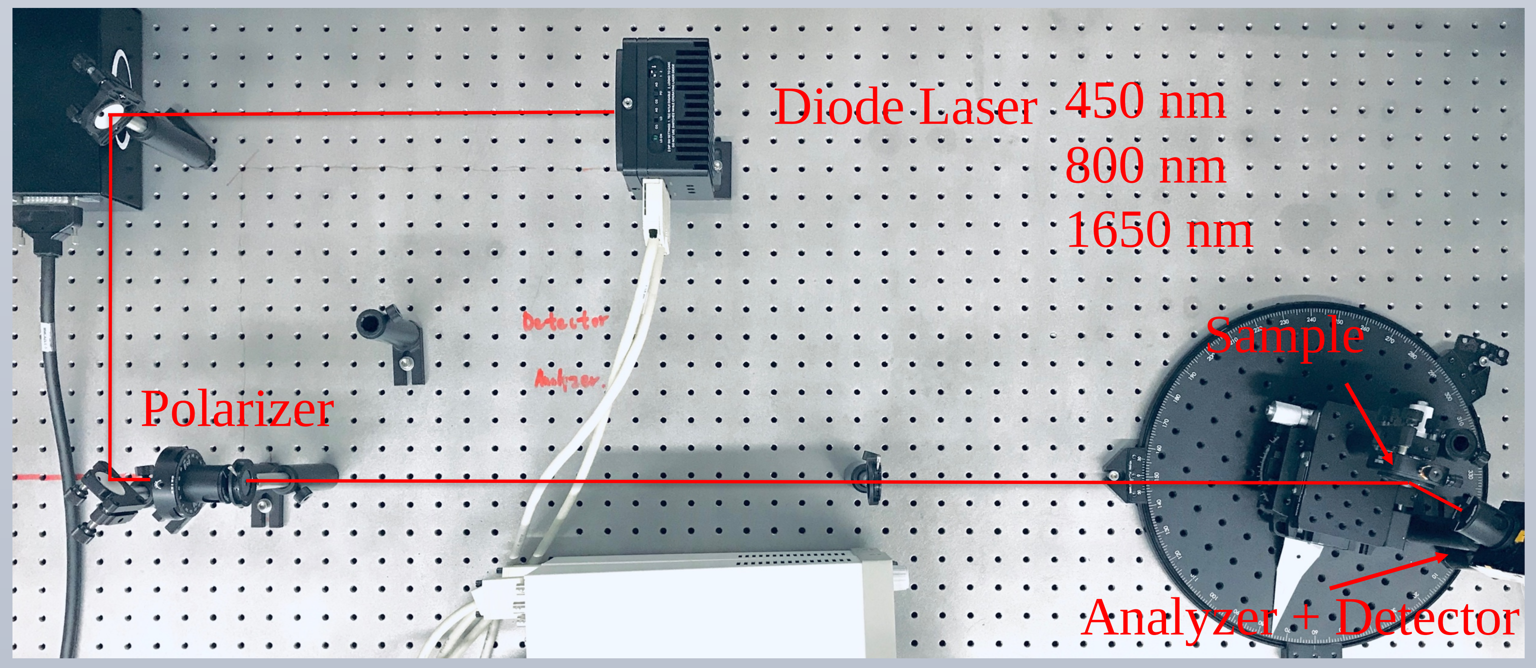

Figure 6. Sher Lab Ellipsometer

[3] Figure adapted from www.jawoollam.com

Results and Data Comparison

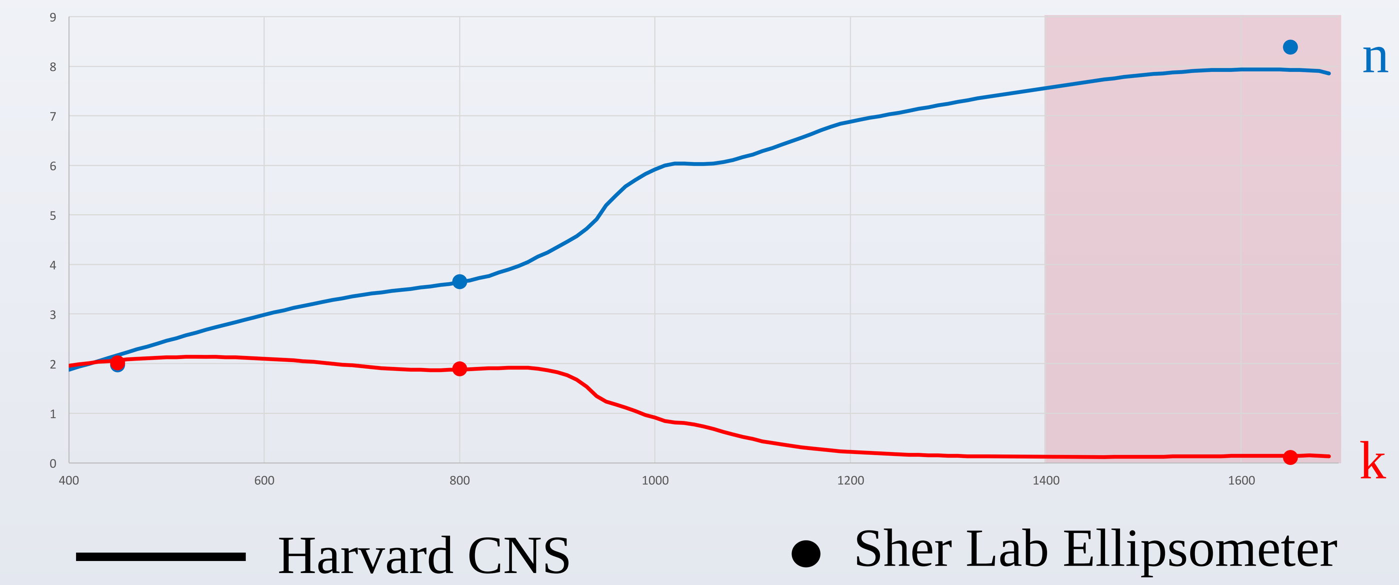

Figure 7. Amorphous GST's Refractive Indices Measured by Harvard CNS and Sher Lab

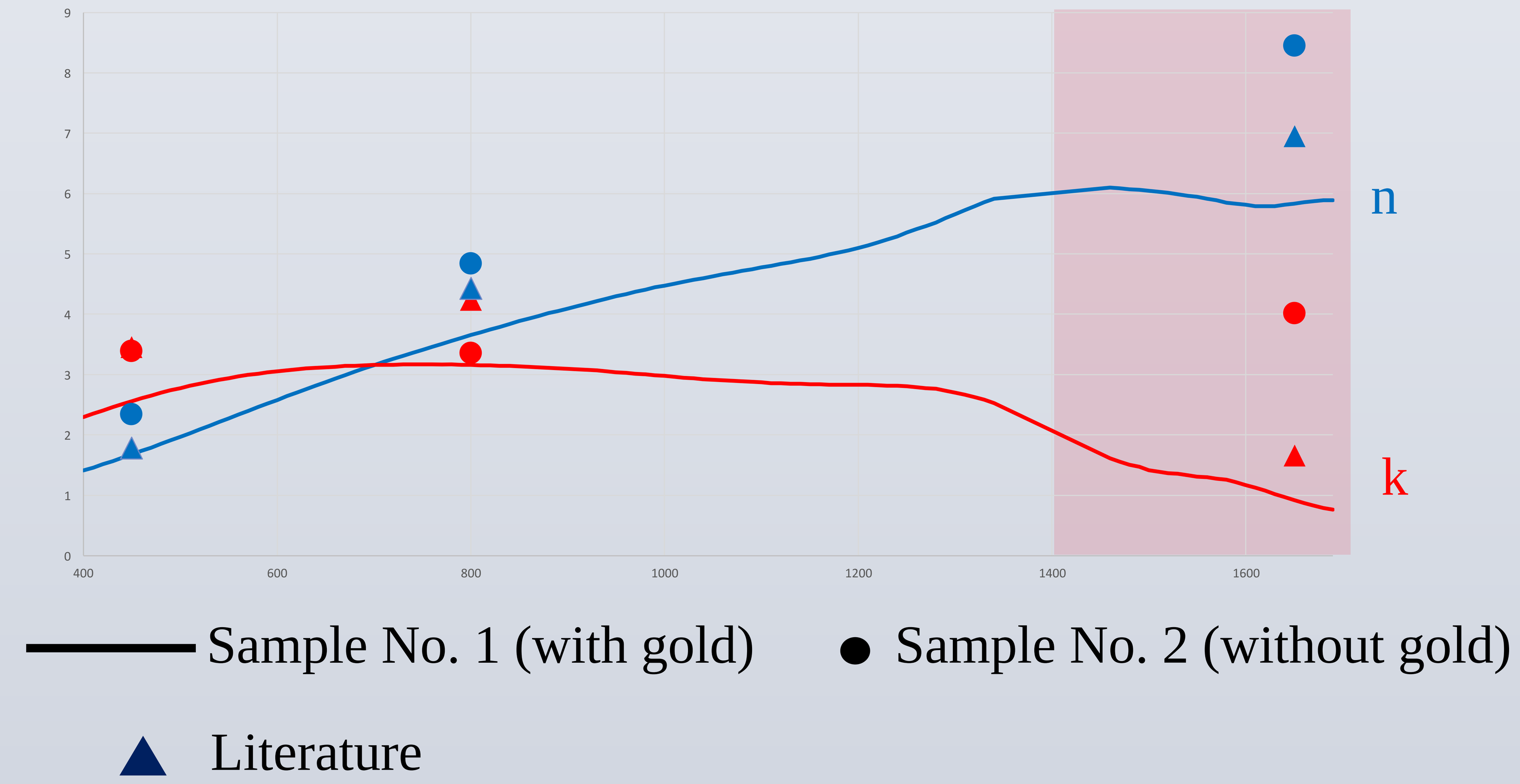

Figure 8. Crystalline GST's Refractive Indices Measured by Harvard CNS and from Literature[4]

Conclusions and Future Work

Figure 9. The Cryostat for Future In-Situ Measurements

- GST samples with thin layers of gold underneath always agree with the literature better than those without the gold. This is because gold and GST have very different refractive indices and therefore allow more reflection at their interface.
- In the near-infrared range, GST's absorption index (k) rises significantly when it is crystallized. This makes GST a potential phase-change material for photonic limiters.
- In order to fine-tune the photonic limiter designs, we want to characterize GST's refractive indices as a function of temperature and time. To achieve this, we need to perform in-situ measurements by putting the samples in a cryostat that can dynamically adjust temperature.

[4] Data obtained from *Kostiantyn Shportko et al. Resonant bonding in crystalline phase-change materials, Nature Materials, Vol 7, 653 (2008)*