Non-Linear Materials for Photonic Limiters

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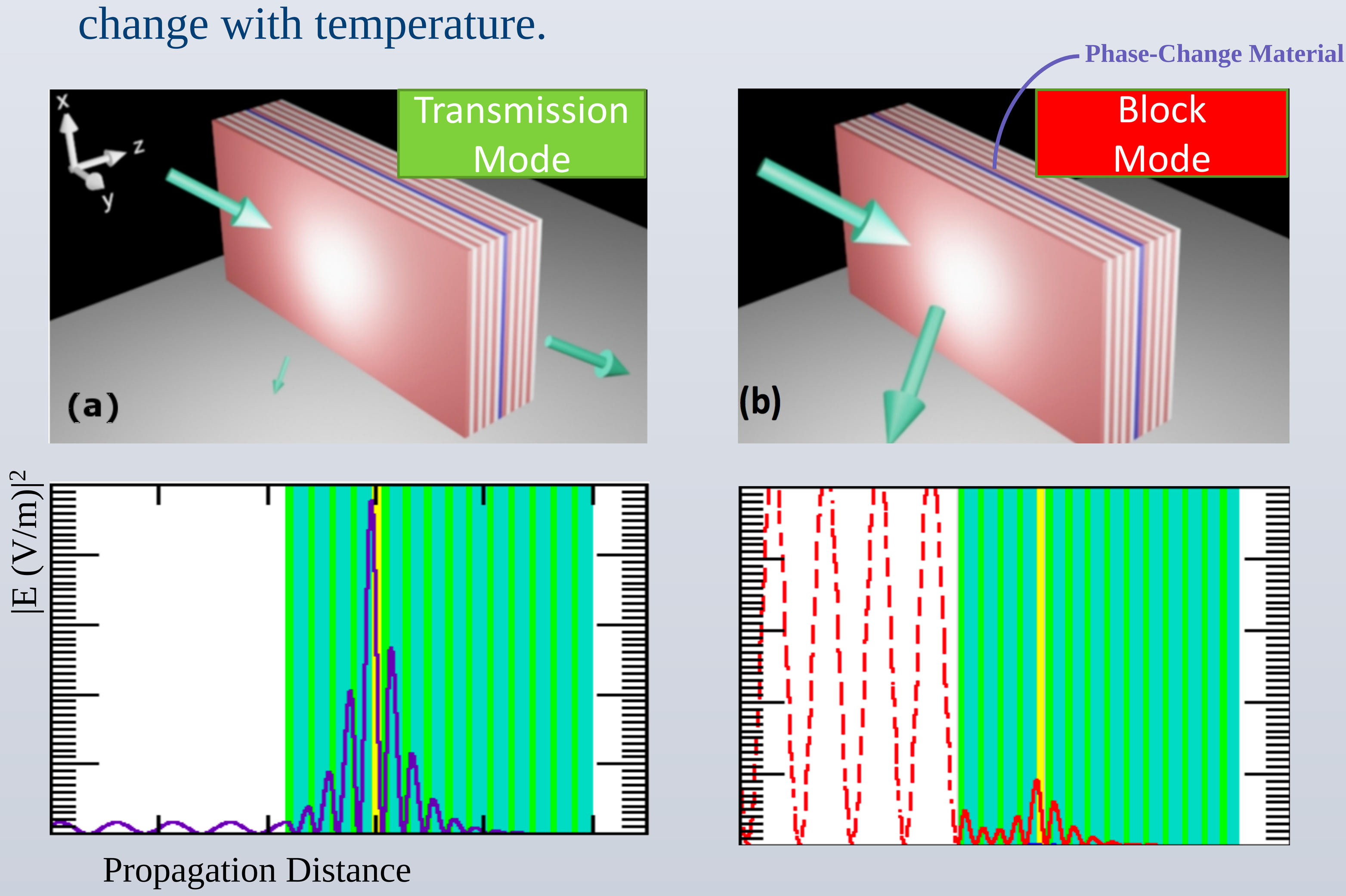
Introduction

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

Photonic limiters are devices whose optical properties are highly dependent on the wavelength and intensity of incident light. Because of such selectivity of incoming lights, photonic limiters can be used to protect sensitive optical sensors ranging from military radars to human eyes. 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 a phase-change material, whose optical properties, such as reflectivity and absorptivity, change with temperature.



At low-intensity irradiance, non-linear defect layer forms a resonant cavity that supports transmission of incident light.

High-intensity irradiance heats up the non-linear defect layer, which then changes optical properties. As a result, resonance transmission is destroyed, and reflection increases.

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

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

This research aims to dynamically characterize how GST225 changes optical properties as it undergoes phase change. We are 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) And N. J. Antonellis et al. Asymeetric Transimission in Photonic Structures with Non-Linear Components*

Experiment Set-Up

Sputtering Deposition

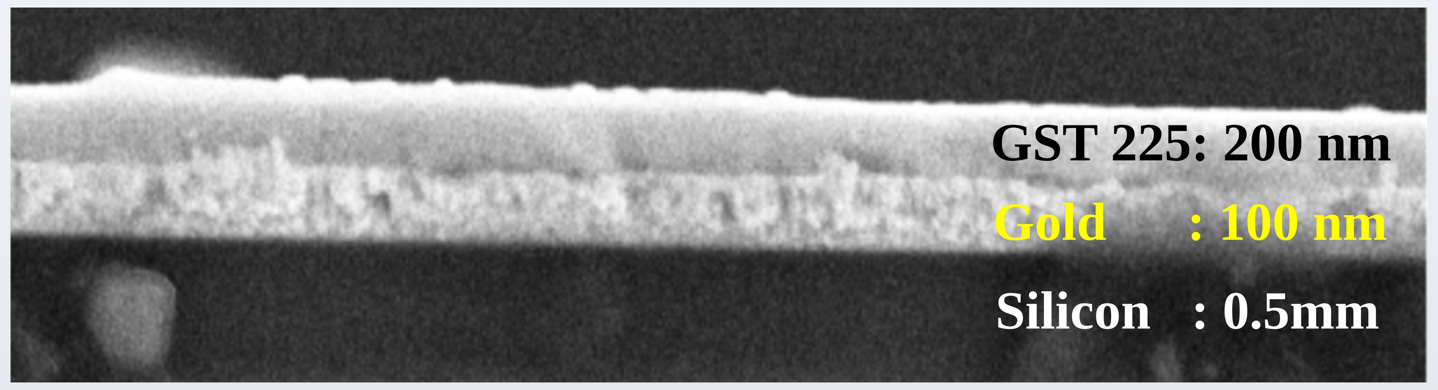


Figure 2. SEM Imaging of a GST Sample

Ellipsometry: Measures Refractive Indices N and K

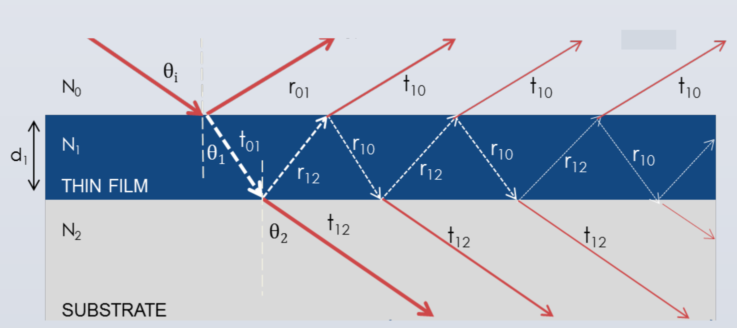


Figure 3. Mechanism of Ellipsometry[3]

- Irradiates the sample surface with polarized light
- Measures polarization patterns of reflected light
- Infers optical properties of the sample

In-Situ Ellipsometer Set-Up

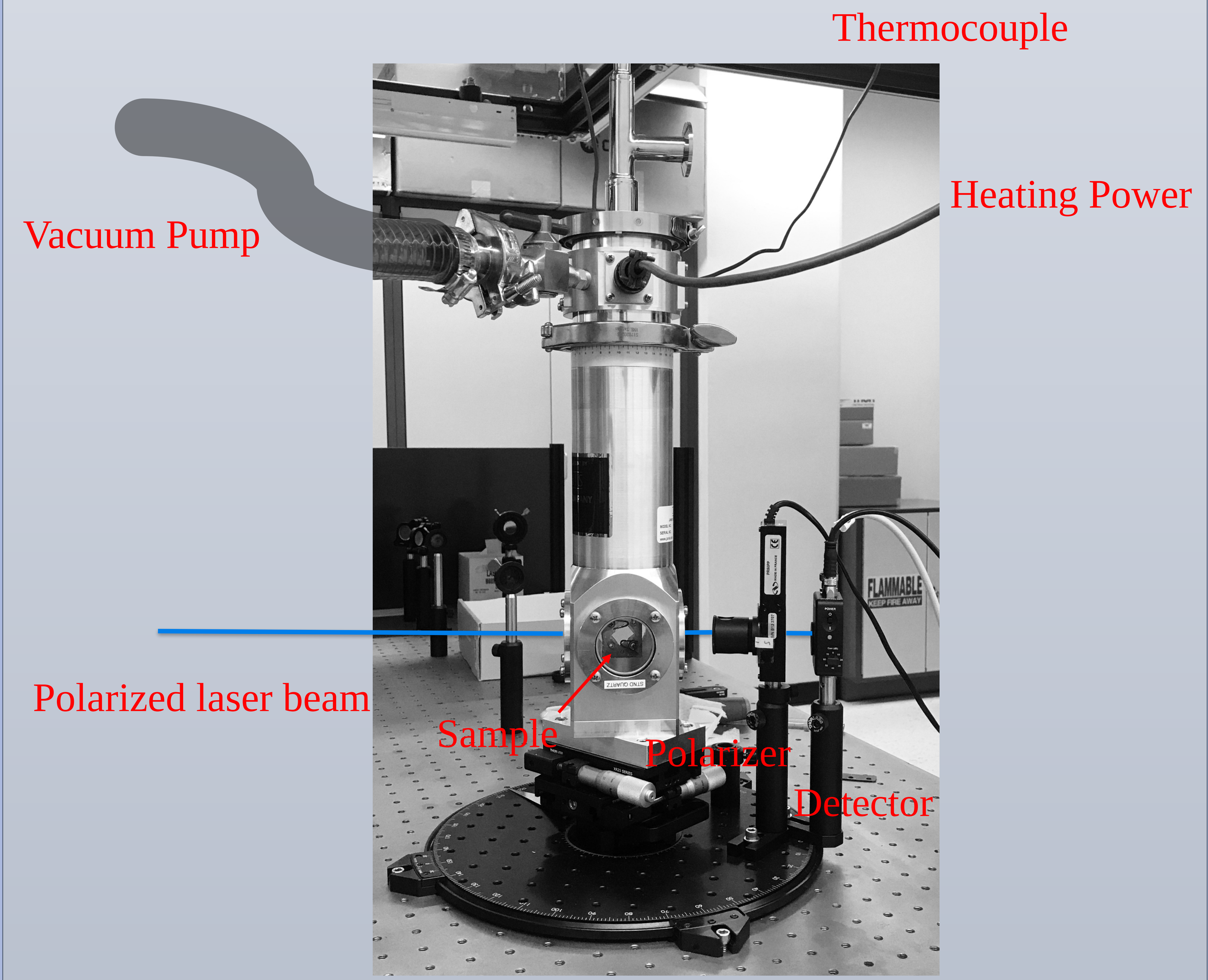


Figure 4. Sher Lab In-Situ Ellipsometer

[3]Figure adapted from www.jawoollam.com

Results and Data Comparison

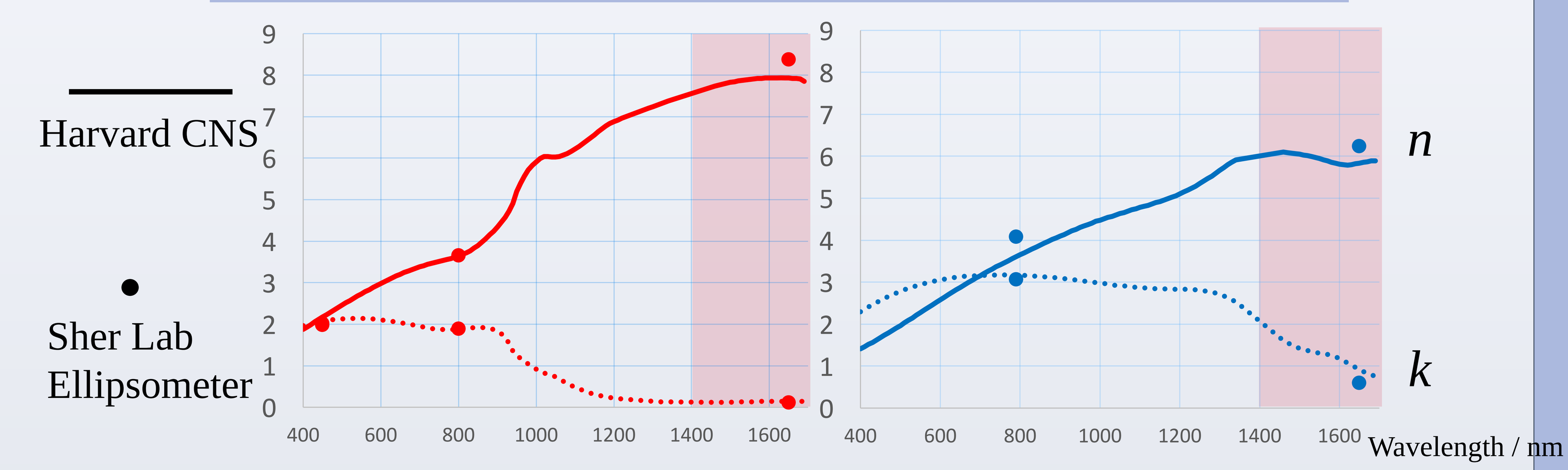


Figure 5. Amorphous GST's Refractive Indices Measured by Harvard CNS and Sher Lab

Figure 6. Crystalline GST's Refractive Indices Measured by Harvard CNS

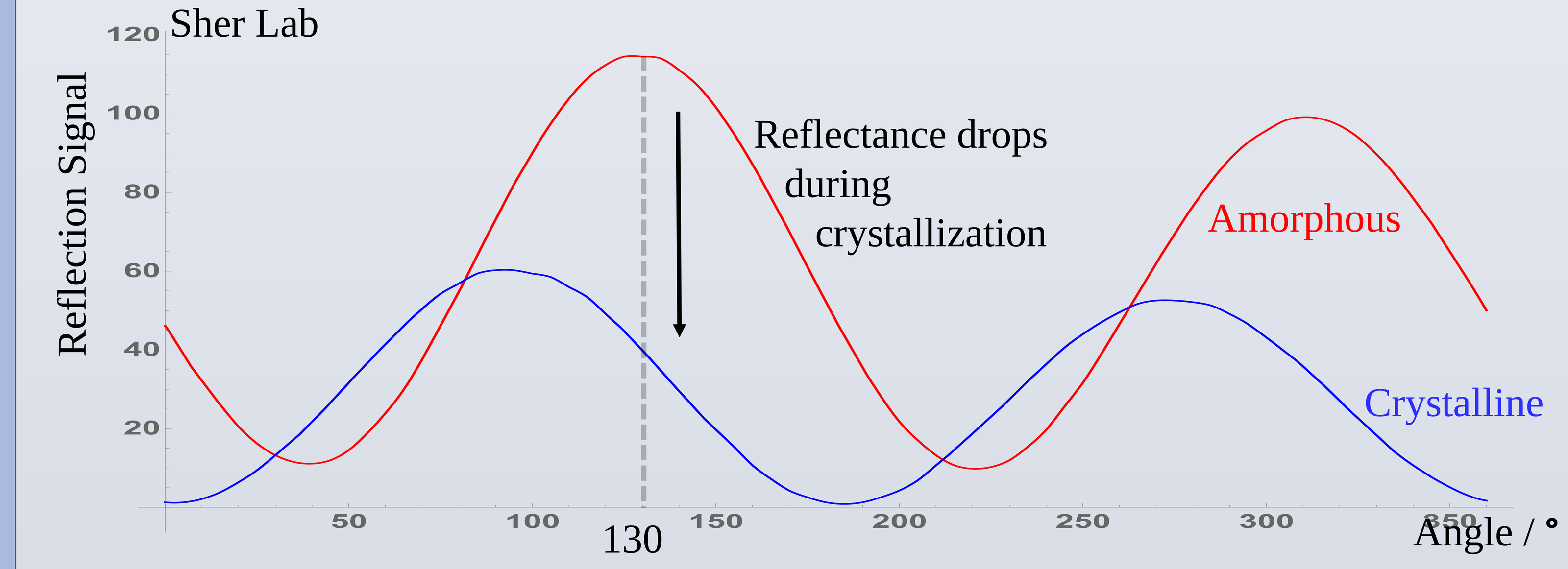


Figure 7. Polarization patterns of amorphous and crystalline GST materials at 1650 nm wavelength

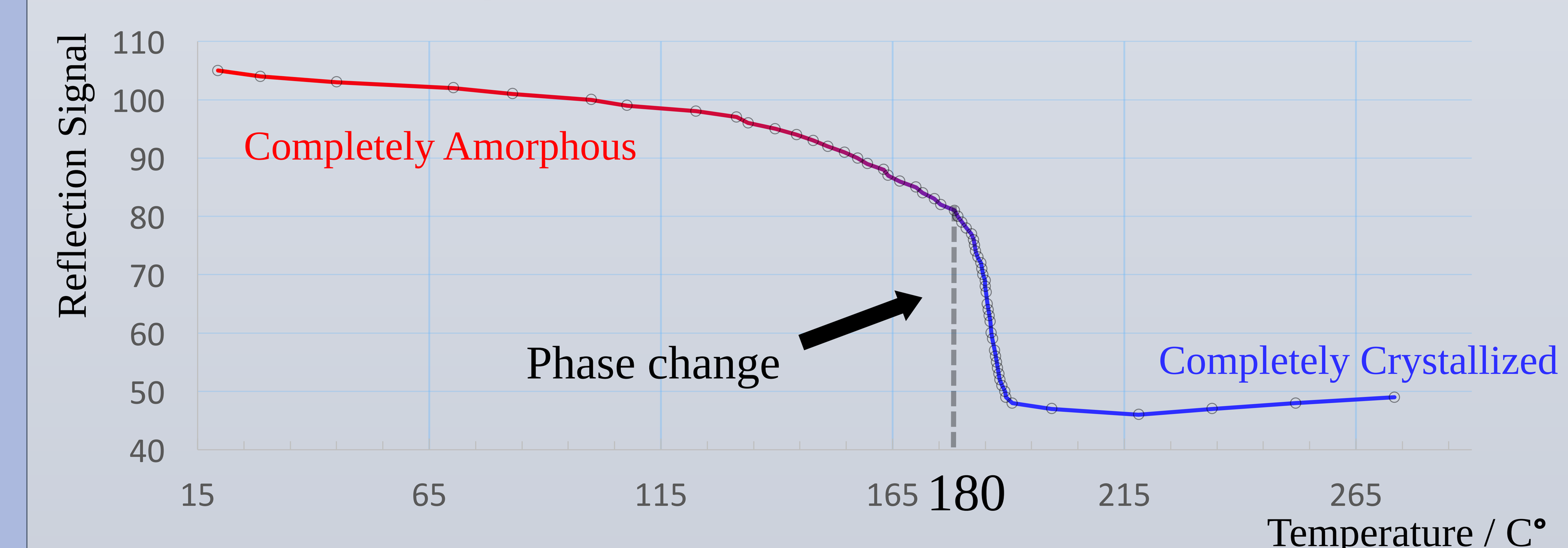


Figure 8. Reflection from GST sample (arbitrary unit) as a function of temperature, measured by Sher Lab Ellipsometer

Conclusions and Future Work

● 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.

● Crystallization of GST is irreversible, so any photonic limiters based on GST would be sacrificial, which are much less economical than reusable limiters.

● To develop reusable photonic limiters, we are studying reversible non-linear materials such as zinc oxide (ZnO). However, ZnO's refractive indices change very modestly (4%) when heated. We aim to improve resonant cavity designs in order to harness and amplify ZnO's non-linearity.