Cryogenic Refractive Index and Coefficient of Thermal Expansion for the S-TIH1 Glass

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Outline

➤ Background on S-TIH1 Glass and its use on WFIRST

➤ Experimental Details
  ➤ CTE
  ➤ Spectral
  ➤ CHARMS

➤ CTE and Spectral Results

➤ CHARMS Refractive Index Results
  ➤ Comparison CHARMS vs. Ohara
  ➤ Sellmeier Fits

➤ Conclusions
Background on WFIRST

SpC detail: 14 surfaces, 12 spheres, 2 conic

![Diagram of optical system]

- 3-element focal prism with thin wedged gaps
- 4-element Shapley Lens (f/15.9 to f/0.4)
- Name: P1 P2 P3 L1 L2 L3 L4 L4S2
- Material: CaF2 S-TiH1 CaF2 ZnSe CaF2 Infrasil CaF2
- 500mm

Detail of spectroscopy channel, showing the prism and Shapley lens groups.
S-TIH1 space qualification

S-TIH1 Ohara glass, high index, high dispersion Used in IDRM1 as dispersing material in BAO and SN prisms

Not space qualified

Outline of test plan:
- Verify high transmission in NIR
- Cryo CTE
- Test cryo index [CHARMS]
- Test transmission loss after radiation exposure [rad hard] ~6.7%
  loss at 0.6um, 2.2% at 1.0um, ~1% >= 1.1um
Lab setup used in 541 for cte measurements

Laser Interferometer

- Thermal expansion $\Delta L/L_0$ is measured and normalized at 293.15K (20°C)
- The $\Delta L/L_0$ data is best-fit with a polynomial equation
- The instantaneous CTE is calculated from the derivative of the polynomial equation of thermal expansion
Spectral Measurements

Instruments used: Perkin-Elmer (Lambda 950) with URA accessory

Provides absolute data over UV/VIS/NIR
Spectral range: 200-2500nm (2 nm resolution)
CHARMS: Cryogenic High Accuracy Refraction Measurement System
Spectral Results

Transmission & reflection tested using PE Lambda900 spectrophotometer
Cryo CTE

- Two Ohara S-TIH1 glass samples, 4"x2"x0.08"

- CTE between 313K (40°C) and 100K (-173°C) was measured using a Michelson laser interferometer measurement system (ASTM Standard E 289 - 95).

- Test conditions: 3 cycles, ramp rate 1°C/min, in vacuum
S-TIH1 Thermal Expansion

\[ y = 9.9192E-06x^4 - 9.7091E-05x^3 + 4.1992E-02x^2 \
- 1.4598E+00x + 1.4129E+03 \]

- Secant \( TE (25\,\text{K} - 300\,\text{K}) \):
  - \#1: 0.610 \( \pm \) 0.02 \( \text{ppm/K} \)
  - \#2: 0.580 \( \pm \) 0.02 \( \text{ppm/K} \)
  - Average: 0.60 \( \pm \) 0.02 \( \text{ppm/K} \)
S-TIH1 CTE

\[ y = 3.9671E-07x^3 - 2.9127E-09x^2 + 8.3883E-02x - 1.4095E+00 \]
S-TIH1 Absolute Refractive Index

![Graph showing the refractive index of S-TIH1 as a function of wavelength. The graph compares the refractive index data from Ohara and CHARMS. The x-axis represents the wavelength (μm) ranging from 0.25 to 2.50, and the y-axis represents the refractive index ranging from 1.65 to 1.75. The graph includes a scale for index difference from -1.50E-04 to 1.50E-04.]
Index Temperature Dependence

Temperature Dependence

- 0.445 μm
- 0.50909 μm
- 0.69292 μm
- 1.32504 μm
- 1.7818 μm
- 2.5312 μm

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Sellmeier Fits: Dispersion

Dispersion in S-TIH1 with temperature

![Graph showing dispersion in S-TIH1 with temperature across different wavelengths and temperatures.](Image)
Thermo-optic coefficient (dn/dT) of S-TIH1 with temperature

wavelength (μm)

Thermo-optic coefficient (dn/dT) of S-TIH1 with temperature

- 120 K
- 150 K
- 170 K
- 200 K
- 250 K
- 270 K
- 290 K
- 300 K
- 310 K
- 340 K
Using the CHARMS facility at NASA GSFC, we have measured the cryogenic refractive index of the Ohara S-TIH1 glass from 0.40 to 2.53 μm and from 120 to 300K. We have also examined the spectral dispersion and thermo-optic coefficients (dn/dT). We also derived temperature-dependent Sellmeier models from which refractive index may be calculated for any wavelength and temperature within the stated ranges of each model. The S-TIH1 glass we tested exhibited unusual behavior in the thermo-optic coefficient. We found that for λ < 0.5 μm, the index of refraction decrease with a decrease in temperature (positive dn/dT). However, the situation was reversed for λ larger than 0.63 μm, where the index will increase with a decrease in temperature (negative dn/dT). We also measured the coefficient of thermal expansion (CTE) for the similar batch of S-TIH1 glass in order to understand its thermal properties. The CTE showed a monotonic change with a decrease in temperature.