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

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 is Conic
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
Transmission & reflection tested using PE Lambda900 spectrophotometer
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

\[ \Delta L/L_0 = 9.9192E-08x^4 + 9.7091E-06x^3 + 4.1992E-02x^2 - 1.4889E+00x - 1.4520E+03 \]
S-TIH1 CTE

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SPIE Optics + Photonics
S-TIH1 Absolute Refractive Index
Index Temperature Dependence

Graphs showing the index temperature dependence for different wavelengths:

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

Each graph plots index against temperature in Kelvin (K) over the range of 100 to 350 K.
Dispersion in S-TIH1 with temperature
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

wavelength (µm)
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.