Cryogenic Refractive Indices of S-LAH55, S-LAH55V, S-LAH59, S-LAM3, S-NBM51, S-NPH2, S-PHM52, and S-TIH14 Glasses

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K.H.M. and D.B.L. with the Cryogenic High Accuracy Refraction Measuring System (CHARMS) at NASA GSFC
Outline of Slides

- Motivation for measurements (TESS mission)
- CHARMS: operation and capabilities
- CHARMS: cryogenic capabilities
- Ohara glass map and nomenclature
- First evidence of intra-melt variability in S-LAH55V
- Optical properties of “high” index prisms
- Optical properties of “middle” index prisms
- CHARMS measurements compared to literature values
Motivation: Transiting Exoplanet Survey Satellite (TESS)

- Planet finder
- 2017 Launch date (Cape Canaveral, FL)
- Highly Elliptical Earth Orbit
- 4 identical cameras 90° X 90° FOV
- 600 – 1000 nm bandpass

Hybrid Petzval design
CHARMS: Operation and Capabilities

• CHARMS is a minimum deviation refractometer
• Five simple steps:
  1. Measure the apex angle of the prism
  2. Establish the condition of min deviation
  3. Measure angle of undeviated beam
  4. Measure angle of deviated beam
  5. Compute deviation angle; compute index

\[ n = \frac{\sin(\frac{\alpha + \delta}{2})}{\sin(\frac{\alpha}{2})} \]
CHARMS: Cryogenic Capabilities

Courtesy of S. Scola
CHARMS: data reduction and presentation style

\[ n^2(\lambda, T) - 1 = \sum_{i=1}^{3} \frac{S_i(T) \cdot \lambda^2}{\lambda^2 - \lambda_i^2(T)} \]

\[ S_i(T) = \sum_{j=0}^{3} S_{ij} \cdot T^j \]

\[ \lambda_i(T) = \sum_{j=0}^{3} \lambda_{ij} \cdot T^j \]

\[ AAR = \frac{\sum_{k=1}^{n} |index_{measured} - index_{fit}|}{n} \]

<table>
<thead>
<tr>
<th>Prism ID</th>
<th>average absolute residual</th>
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</thead>
<tbody>
<tr>
<td>S-LAH55</td>
<td>4.4E-6</td>
</tr>
<tr>
<td>S-LAH55V-1</td>
<td>3.7E-6</td>
</tr>
<tr>
<td>S-LAH55V-2</td>
<td>3.6E-6</td>
</tr>
<tr>
<td>S-LAH59</td>
<td>3.6E-6</td>
</tr>
<tr>
<td>S-TIH14</td>
<td>5.2E-6</td>
</tr>
<tr>
<td>S-NPH2</td>
<td>7.1E-6</td>
</tr>
<tr>
<td>S-LAM3</td>
<td>3.7E-6</td>
</tr>
<tr>
<td>S-NBM51</td>
<td>2.6E-6</td>
</tr>
<tr>
<td>S-PHM52</td>
<td>3.5E-6</td>
</tr>
</tbody>
</table>
Ohara Glasses

Ohara nomenclature example:

- Environmentally “safe”
- “H” for high index
- Most important chemical elements contained
- Number of glass within given family

S-LAH59 vs. S-LAH55V
S-LAH55V: Intra-melt Variability

Estimated Uncertainty in S-LAH55V glass

Difference = 3.9E-5

Difference = 4.8E-5
S-LAH55, S-LAH55V, S-LAH59

Constituent % by weight

<table>
<thead>
<tr>
<th>Constituent</th>
<th>S-LAH55</th>
<th>S-LAH59</th>
</tr>
</thead>
<tbody>
<tr>
<td>La$_2$O$_3$</td>
<td>40-50 %</td>
<td>20-30 %</td>
</tr>
<tr>
<td>Gd$_2$O$_3$</td>
<td>2-20 %</td>
<td>30-40%</td>
</tr>
</tbody>
</table>
**S-TIH14 & S-NPH2**

- TiO$_2$: 20—40%
- SiO$_2$: 30—50%
- Nb$_2$O$_5$: 40—50%
- P$_2$O$_5$: 20—30%
S-LAM3, S-NBM51, S-PHM52

La$_2$O$_3$: 10—20 %
BaO: 40—50 %
Nb$_2$O$_5$: 10—20 %
SiO$_2$: 30—40 %
P$_2$O$_5$: 40—50 %
BaO: 30—40 %
Index Comparison: Ohara MINUS CHARMS

Index difference: Ohara catalog MINUS CHARMS at 298 K

- S-PHM52
- S-LAH59
- S-LAH55V-1
- S-LAM3
- S-LAH55V-2
- S-TIH14
- S-LAH55
- S-NBM51
- S-NPH2

Wavelength [μm]

Ohara Optical Glass Catalog, http://Oharacorp.com/
Cryogenic Index Comparison: Yamamuro MINUS CHARMS

Yamamuro, T. et al., Optical Engineering 45(8), 083401 (2006)
Conclusions