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

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>Prism ID</th>
<th>average absolute residual</th>
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<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

Number of glass within given family

Most important chemical elements contained

S-LAH59

S-LAH55 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

Index difference

Wavelength [µm]

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

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

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