High Temperature Superconductor Lead Assemblies for XRISM

Edgar R. Canavan and Brian Comber

1 NASA – Goddard Space Flight Center
Background: RESOLVE

RESOLVE: soft x-ray spectrometer on XRISM (X-Ray Imaging and Spectroscopy Mission)
Rebuild of SXS instrument on Astro-H — no changes except where necessary
Uses a microcalorimeter array operating at 50 mK

RESOLVE Thermal System:
- (2x) 2 stage Stirling coolers
- JT cooler (4.5 K)
- 40 l LHe tank (1.2 K)
- 3 stage ADR (50 mK)
Background: HTS Lead Assemblies

• High Temperature Superconductor Lead Assemblies necessary to carry high current to 3 ADR magnets

• Driving requirements:
  – 2 Amp maximum on each of 3 circuits @ up to 62 K warm end
  – < 12 µWatt total conducted heat leak to 1.3 K
  – < 10 µΩ per circuit total resistance at cold end (bolted and solder joints)
**HTS Lead Assemblies — Configuration**

- **Status**
  - Engineering Model complete
  - Flight Model 1 fabricated and fully verified
  - Flight Model 2 fabricated; pre-vibe testing complete

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**Connector** to current harness

**3rd Stage Assembly**
- Warm (< 62 K) transition board
- JT (4.5 K) transition board

**1st & 2nd Stage Assembly**
- JT heat strap
- Bolted joints — transition to ADR magnet leads
- Cold (1.2 K) transition board
- Warm (< 62 K) transition board
Solder Joints: Material Changes

- HTS tape
  - SXS: AuAg alloy coated tape; slit to 1 mm after production (open sides)
  - RESOLVE:
    - Slit to 1 mm, then sputter coated with AuAg (all sides)
    - Individual sections cut and plated over solder region with > 20 µm Cu
    - Section $I_c$’s measured to 20 Amperes:
      - 37 of 48 long (590 mm), 21 of 24 short (335 mm) sections ≥ 20 A;
      - All $I_c$’s ≥ 16 A

- Solder
  - In3%Ag (SXS) → In48%Sn (RESOLVE)
    - Lower $T_{melt}$ (144 C → 118 C)
Solder Joints: Process Changes

• Solder rig
  – Precise control over pressure, temperature, & time
  – Changes for flight boards:
    • Custom soldering tips match joint length
    • Wires & bobbins act as cooling fins ➔ added secondary heaters to cancel effect
Solder Joints: Results

- Improved Consistency:
  - Compared all pre-vibe qualification tests: I-V measurement to 5 Amps, cold end at 4.5 K
  - Cold end solder joint resistances much more uniform
  - No values > 1.1 μΩ
  - Similar results for warm end (62 K)
- Very low resistance at low T
  - Bridge (low current) measurements show transitions at ~5.0, ~3.7 K
  - Below 3.7 K, R < 0.4 μΩ
Bolted Joints: Changes and Results

<table>
<thead>
<tr>
<th>Bobbins:</th>
<th>In-house</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu material:</td>
<td>99.999%</td>
<td>CU101</td>
</tr>
<tr>
<td>Au Plating</td>
<td>Ni flash, Thick Au</td>
<td>No Ni flash, Standard thickness</td>
</tr>
<tr>
<td>Fabrication</td>
<td>EDM, polished</td>
<td>Lathe</td>
</tr>
<tr>
<td>Metrology:</td>
<td>rounded</td>
<td>Flat, + ridge</td>
</tr>
</tbody>
</table>

Metrology points [mm]

Result:
Bolted joint resistance now typically < 0.5 μΩ at low T
HTS tapes in 1st&2nd Stage unit must be well heat sunk to JT shield

Concern over stress concentration at JT thermal intercept

New strap design:
- Multilayer Pyralux strap
- Compliant bridge for each HTS tape
- Each HTS tape bonded to small flag on bridge
1st & 2nd Stage Thermal Intercept: Results

- **Measurement:**
  - Control $T_{IVCS}$, $T_{JT} = T_{CSI}$
  - Measure $\Delta Q_{CSI}$ vs $T_{IVCS}$
- **If strap conductance, $\kappa \to \infty$**
  - $T_s = T_{JT} = T_{CSI} \Rightarrow \Delta Q_{CSI} = Q_{s \to CSI} = 0$
- **With imperfect strap:**
  - 1-D Conduction-only model
  - For flight condition ($T_{IVCS} = 28$ K, $T_{JT} = 4.5$ K, $T_{CSI} = 1.3$ K), heat leak to CSI:

![Diagram showing heat transfer and measurements](image)

- **Graph:**
  - $\Delta Q_{CSI}$ vs $T_{IVCS}$
  - Measured and predicted values for different conductance ($\kappa = 20, 30, 40$ $\mu$W/K)

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Conclusions

• HTS Lead Assemblies for RESOLVE instrument — largely rebuild, except
  • Solder joints:
    – New tape and solder
    – Tighter solder process control
    – Result: much more consistent solder joint resistances
  • Bolted joints:
    – Initial testing lead to change to commercial bobbins
    – Pre-assembly screening
    – Result: much more consistent and lower bolted joint resistances
  • JT heat intercept:
    – New design eliminates concern over stress concentration
    – Improved thermal test apparatus allows determination of 1st & 2nd Stage parasitic conductance
• Overall, RESOLVE HTS lead assemblies meet their requirements with significantly better margin than the Hitomi/SXS units