Optical metrology systems for space applications

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Assembly Integration Technologies
Assembly Integration Technologies

Optical setups can be built up with:

- opto-mechanical components
  - Very flexible
  - Easy handling
  - Mechanically and thermally often not suitable for Space applications

- Hydroxide-catalysis / silicate Bonding and optical contacting
  - Extremely stable (thermally and mechanically)
  - suitable for Space applications
  - Complex and time-consuming integration process
  - Cleanroom environment needed
## Assembly Integration Technologies
### Overview

<table>
<thead>
<tr>
<th>Mechanical setups</th>
<th>HC bonding/ optical contacting</th>
</tr>
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<tr>
<td><strong>Flexibility</strong></td>
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# Assembly Integration Technologies

## Overview

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<td>Lab</td>
<td>Clean lab</td>
<td>Cleanroom</td>
</tr>
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<td><strong>Curing time</strong></td>
<td>None</td>
<td>Hours - day</td>
<td>Days – weeks / none</td>
</tr>
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Assembly Integration Technologies
Adhesive Bonding / Hysol 9313

- Space qualified Epoxy

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Layer thickness</td>
<td>A few µm</td>
</tr>
<tr>
<td>Time to adjust</td>
<td>60 min</td>
</tr>
<tr>
<td>Curing time</td>
<td>1 day</td>
</tr>
<tr>
<td>Shear strength</td>
<td>28.9 MPa (25°C)</td>
</tr>
<tr>
<td>Temp. range</td>
<td>-55 to 50 °C</td>
</tr>
</tbody>
</table>

- Optical Components requirements
  - 2 arcsec right angle
  - $\lambda/10$ surface at the bottom
Interferometer
Assembly Integration Technologies
Interferometer

• Starting with a compact laboratory setup of a heterodyne interferometer (ORO)
• Testboard: Adhesive vs. HC Bonding
  • Shaker test (shock/sine/random)
  • Thermal test (-20°C to 50 °C)
  • Long time stability

→ Adhesive Bonding good enough for our application
Assembly Integration Technologies
Testboard shaker test

- Sine stimulation
- 5 Hz – 2 kHz
- 25.6 g_{rms}
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Interferometer

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  • Long time stability
  → Adhesive Bonding good enough for our application

• Built up a Zerodur based interferometer using adhesive bonding
  • 17 components
  • Noise performance in the pm range, close to the LISA requirement
Iodine Standard
Iodine Standard
Planned mSTAR mission

• mSTAR - mini SpaceTime Asymmetry Research
• international collaboration
• technology demonstrator mission in a low-Earth orbit
• dedicated to perform a Kennedy-Thorndike experiment (testing special relativity)
• comparing an iodine standard to a cavity-based frequency reference
• integration over 2 year mission lifetime
• Kennedy-Thorndike coefficient will be determined with up to two orders of magnitude higher accuracy than the current best ground experiment
Iodine Standard Basics

- NPRO-type Nd:YAG laser @ 1064 nm
  - intrinsically high intensity and frequency stability
  - frequency-doubled to 532 nm

- hyperfine transition in molecular iodine taken as reference (a10 component of R(56)32-0 near 532 nm)
  - strong absorption
  - small natural linewidth (380 kHz)

- Better long time stability w.r.t. cavities (maybe useful in later laser link acquisition)

- State-of-the-art technology realized in various laboratories worldwide
Iodine Standard

Laboratory setup @ HU Berlin

- Fiber-coupled setup
- Modulation transfer spectroscopy
- 80 cm long iodine cell in single-pass configuration
- Fibre EOM
  - low driving voltage
  - low RAM due to low temperature drift
- Intensity stabilization of pump and probe beams via AOMs
- Noise-cancelling detection (balanced detector)
- dimensions: ~ (90 x 60 x 20) cm³
Iodine Standard
Elegant Breadboard level

• Realization of an iodine frequency reference on EBB level
• compact and robust spectroscopy setup
  • dimensions: (60 x 30 x 10) cm³
• 30 cm long iodine cell in triple-pass configuration (interaction length 3 x 30 cm)
• use of a baseplate made of ultra-low expansion glass ceramics
  • Clearceram-HS by OHARA with a CTE of 2*10⁻⁸ K⁻¹
• Frequency stability: 4x10⁻¹⁵ at 1000s integration time
Iodine Standard
Engineering Model

• Based on EBB design
• Iodine cell in nine pass configuration (interaction length 9 x 10 cm)
• More compact setup: 38 x 18 x 10 cm³
• Modulation either using fiber-EOM or AOM
• Balanced detection
• Commercial fiber collimators (Schäfter & Kirchhoff)
• Baseplate, iodine cell, optics made of fused silica
• Mounts for collimators, waveplates, polarizers made of Invar
Iodine Standard

Performance measurements

![Graph showing Allan Deviation against Averaging time](image)

- EM-EBB
- EM-ULE
- EBB-ULE

Linear drift of ULE cavity ~50 mHz/s
Isothermal creep of ULE material
Iodine Standard
Performance measurements

Linear drift of ULE cavity ~50 mHz/s
Isothermal creep of ULE material
Conclusion

• Adhesive bonding
  • an alternative assembly integration technology for optical setups
  • Easy-to-handle (more easy than hc-bonding)
  • Shock, vibration and thermal tests were performed and passed

• realization of an ultra-stable interferometer with pm noise level for translation measurements

• Two Iodine standards were shown on EBB and EM level
  • Frequency stability: $4 \times 10^{-15}$ at 1000 s integration time
  • Compact setup: 38 x 18 x 10 cm³ (opt. part)
Thanks for your attention

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