

## **Optical metrology systems for space applications**

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LISA symposium X Gainesville, FL, May 22, 2014





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- Interferometer
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  - Iodine standard
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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





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## Assembly Integration Technologies Overview

	Mechanical	HC bonding/ optical
	setups	contacting
Flexibility	Good	Fixed
Time to adjust	Endless	Minutes / none
Mechanical stability (w.r.t. shaker tests)	Low	High
Thermal stability	Low	High
Handling	Easy	Complex
Components req.	negligible	High
Environment	Lab	Cleanroom
Curing time	None	Days – weeks / none



# Assembly Integration Technologies Overview

	Mechanical setups	Adhesive bonding	HC bonding/ optical contacting
Flexibility	Good	Fixed	Fixed
Time to adjust	Endless	Hours	Minutes / none
Mechanical stability (w.r.t. shaker tests)	Low	High	High
Thermal stability	Low	Mid	High
Handling	Easy	Mid	Complex
Components req.	negligible	Mid	High
Environment	Lab	Clean lab	Cleanroom
Curing time	None	Hours - day	Days – weeks / none



# Assembly Integration Technologies Adhesive Bonding / Hysol 9313

• Space qualified Epoxy

Layer thickness	A few μm
Time to adjust	60 min
Curing time	1 day
shear strength	28.9 MPa (25°C)
Temp. range	-55 to 50 °C

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

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#### Handling

 $Mixing \sim$  This product requires mixing two components together just prior to application to the parts to be bonded. Complete mixing is necessary. The temperature of the separate components prior to mixing is not critical, but should be close to runon temperature ( $77P/2S^{-}C_{2}$ ).



#### 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<sub>rms</sub>



# 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
- 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) cm<sup>3</sup>







# 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) cm<sup>3</sup>
- 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<sup>-8</sup> K<sup>-1</sup>
- Frequency stability: 4x10<sup>-15</sup> at 1000s integration time







# Iodine Standard Engineering Model

- Based on EBB design
- iodine cell in <u>nine</u> pass configuration (interaction length 9 x 10 cm)
- More compact setup: 38 x 18 x 10 cm<sup>3</sup>
- 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



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 lodine standards were shown on EBB and EM level
  - Frequency stability: 4x10<sup>-15</sup> at 1000 s integration time
  - Compact setup: 38 x 18 x 10 cm<sup>3</sup> (opt. part)



#### Thanks for your attention

Financial support by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers 50 QT 1102 and 50 QT 1201 is highly appreciated.

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