Optical metrology systems for space applications

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- Interferometer
    - Testboard
    - Optical read out
- Iodine Standard
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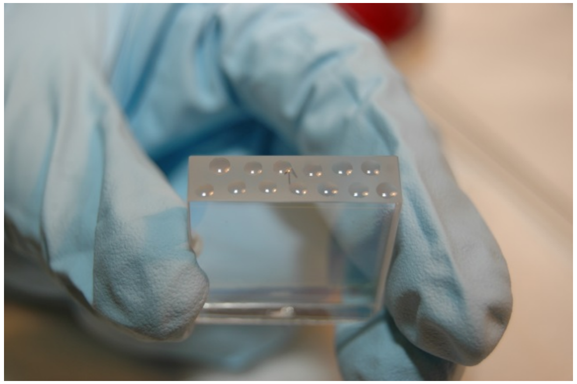
    - Iodine standard
    - EBB and EM
- Conclusion

Assembly Integration Technologies

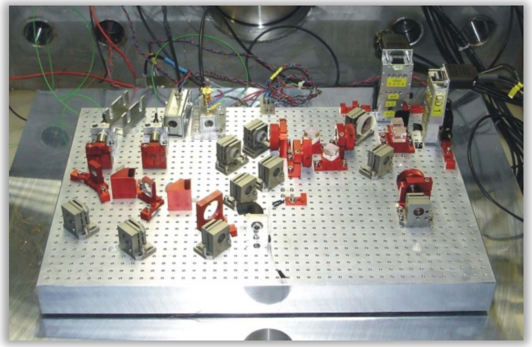


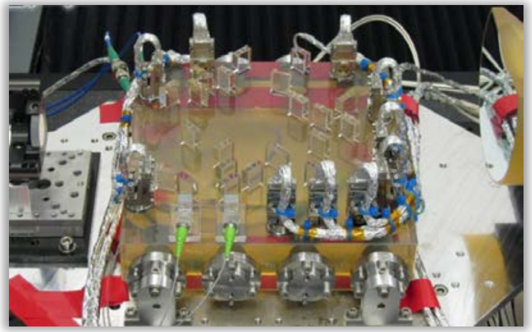
Assembly Integration Technologies

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 setups	HC bonding/ optical 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

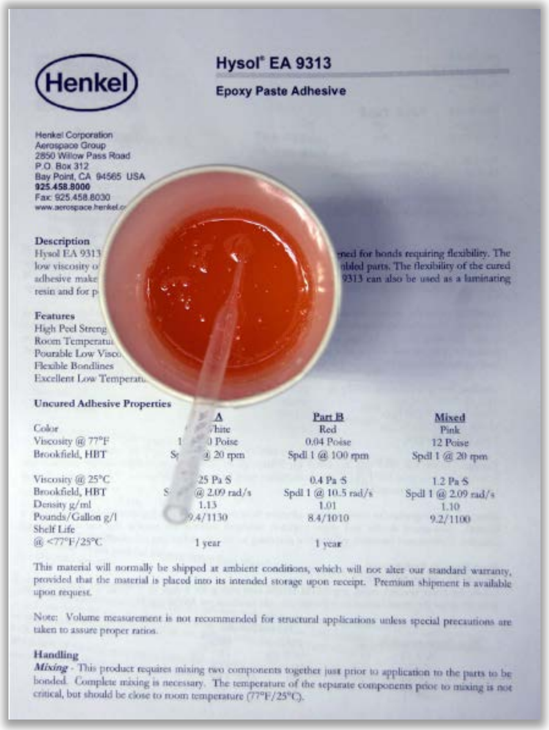
Overview

	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**



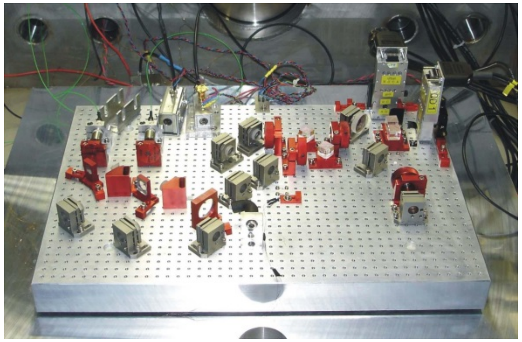
- Optical Components requirements
    - 2 arcsec right angle
    - $\lambda/10$ surface at the bottom

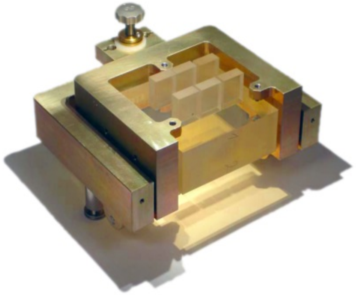
Interferometer

Assembly Integration Technologies
Interferometer

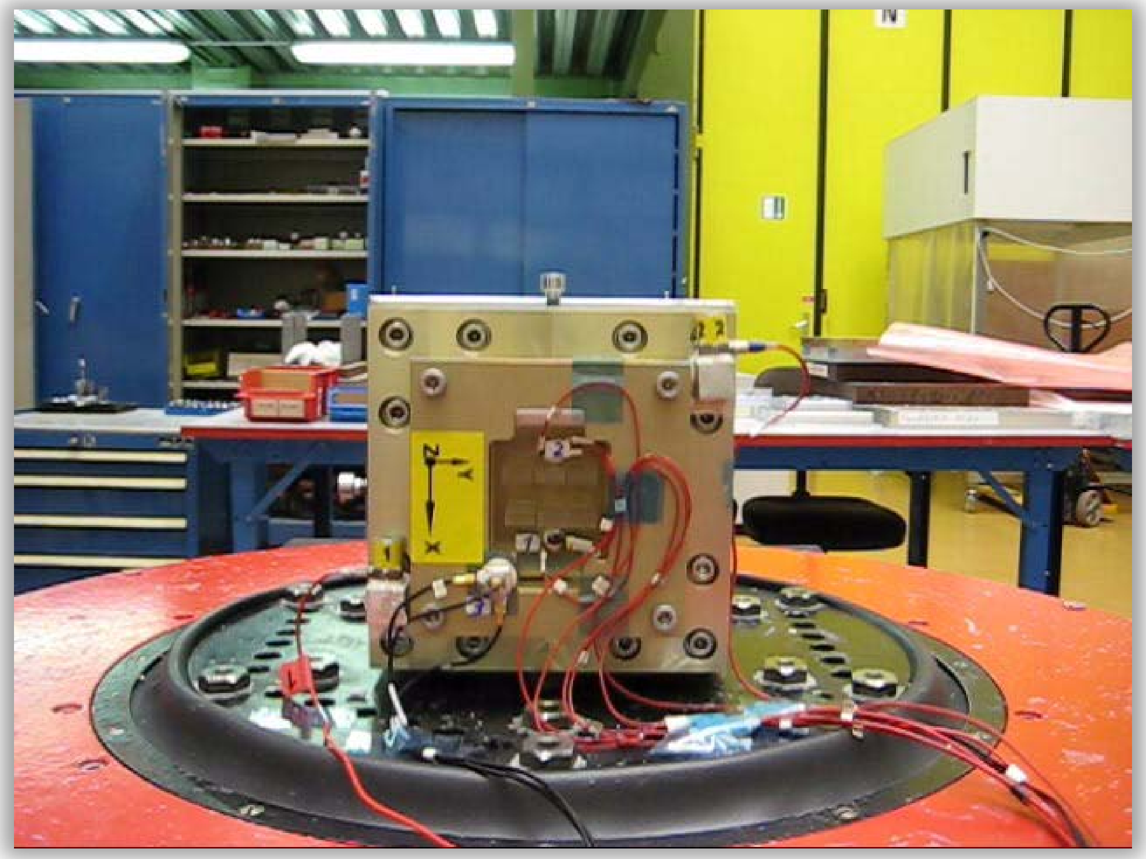
- Starting with a compact laboratory setup of a heterodyne interferometer (ORO)
- Testboard: Adhesive vs. HC Bonding
  - Shaker test (shock/sine/random)
  - Thermal test (-20°C to 50 °C)
  - Long time stability

  → 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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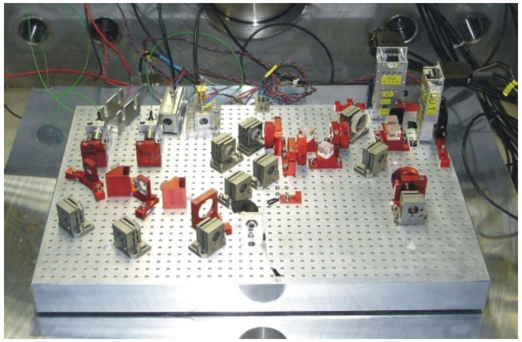
Assembly Integration Technologies
Interferometer



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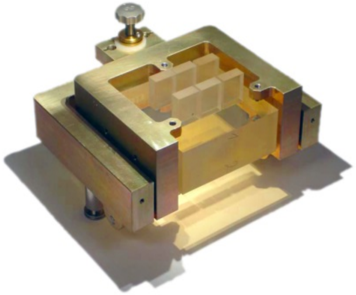
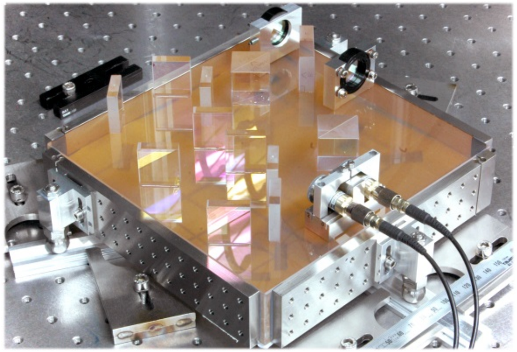
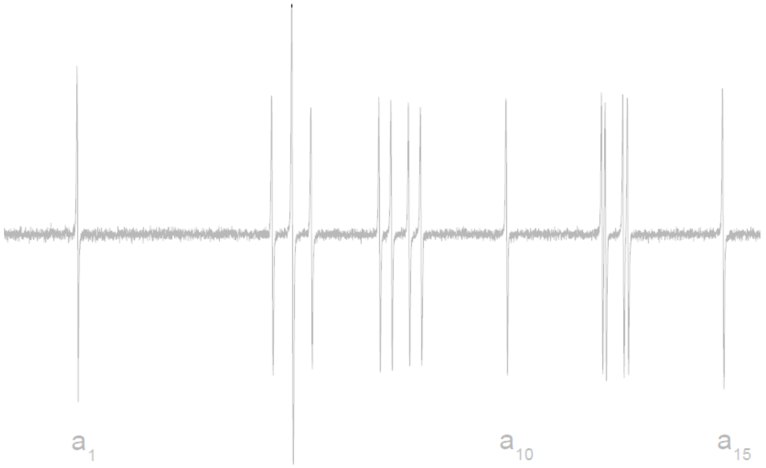


- Built up a Zerodur based interferometer using adhesive bonding
    - 17 components
    - Noise performance in the pm range, close to the LISA requirement



Iodine Standard

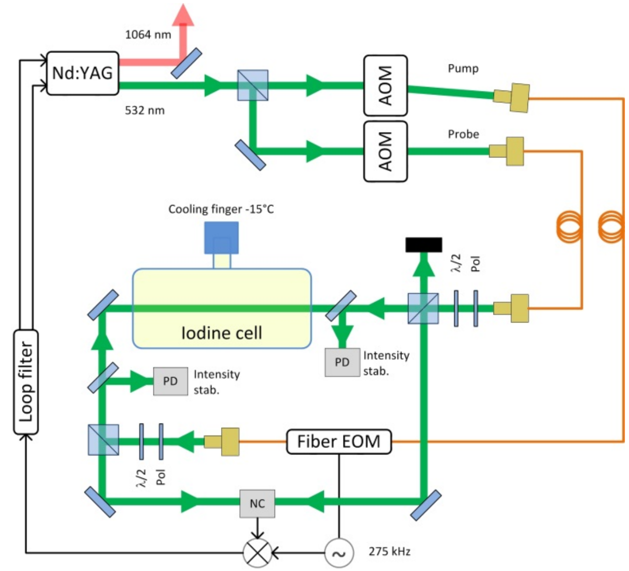


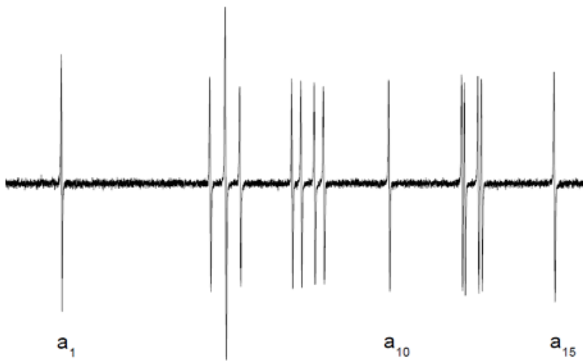
Iodine Standard
Planned mSTAR mission

- 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

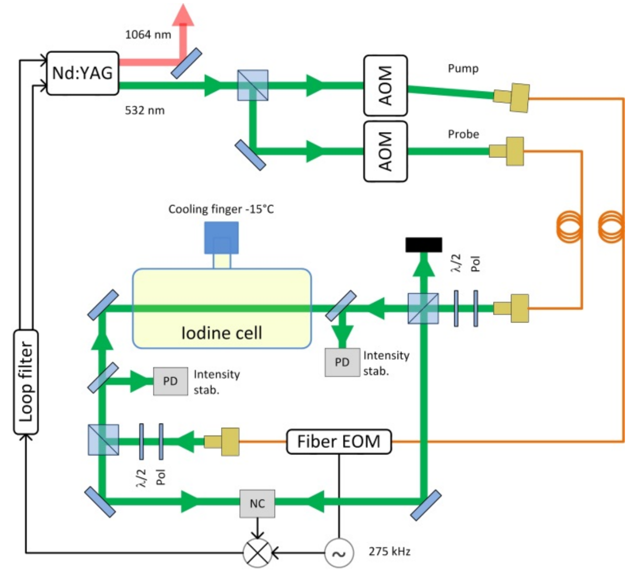


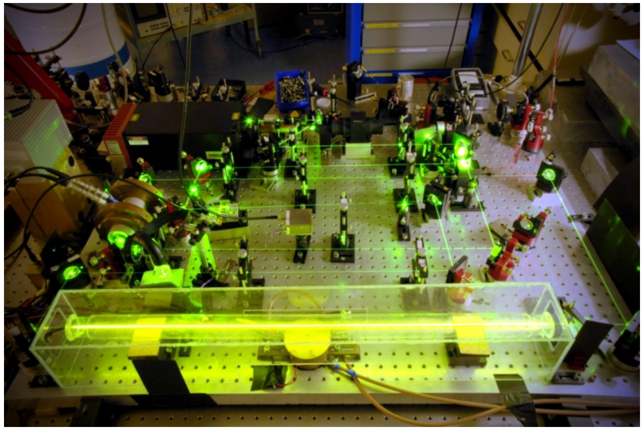


Iodine Standard

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^3





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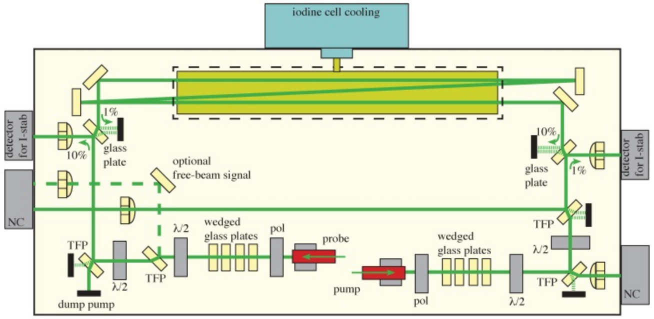
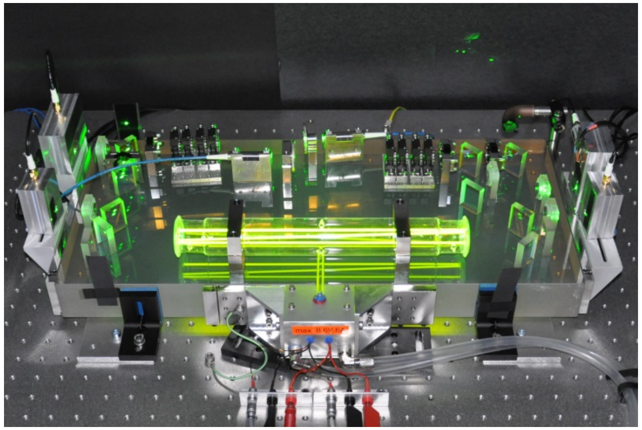
Iodine Standard
Elegant Breadboard level

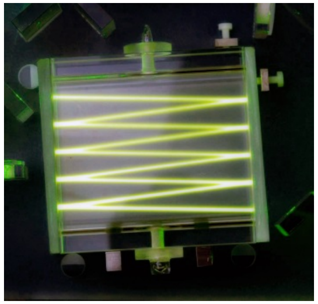
- Realization of an iodine frequency reference on EBB level
- compact and robust spectroscopy setup
  - dimensions: (60 x 30 x 10) cm^3
- 30 cm long iodine cell in triple-pass configuration (interaction length 3 x 30 cm)
- use of a baseplate made of ultra-low expansion glass ceramics
  - *Clearceram-HS*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

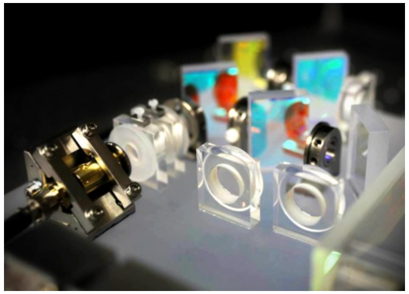


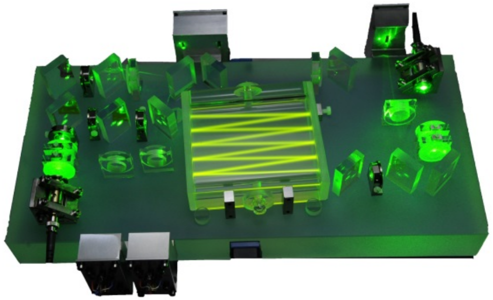


Iodine Standard
Engineering Model

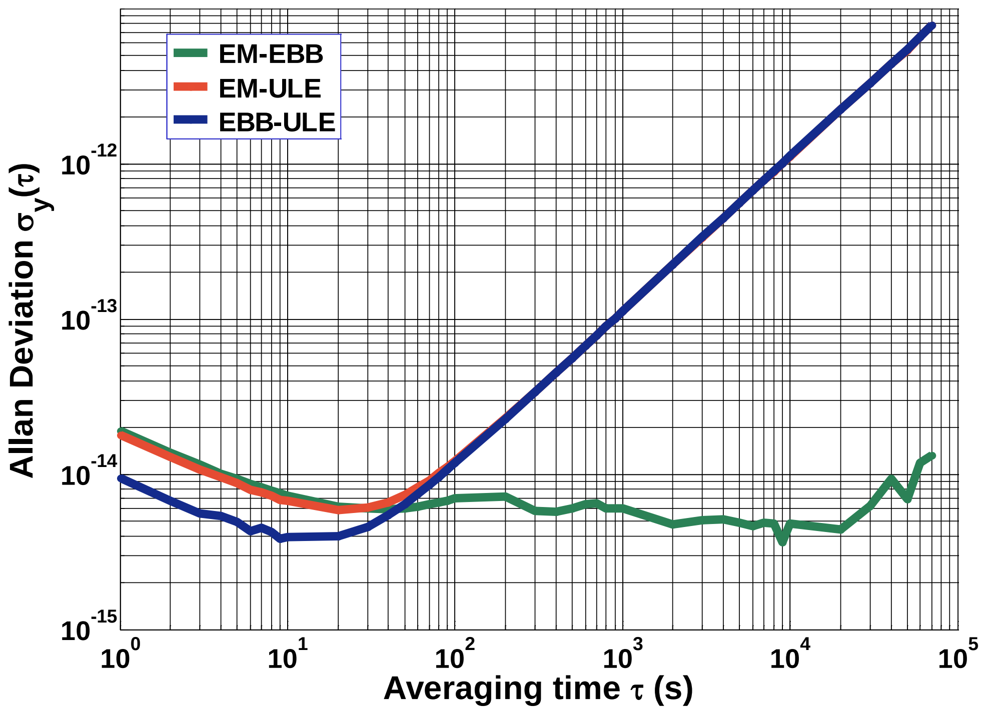
- Based on EBB design
- iodine cell in nine pass configuration (interaction length 9 x 10 cm)
- More compact setup: 38 x 18 x 10 cm^3
- Modulation either using fiber-EOM or AOM
- Balanced detection
- Commercial fiber collimators (Schäfter & Kirchhoff)
- Baseplate, iodine cell, optics made of fused silica
- Mounts for collimators, waveplates, polarizers made of Invar

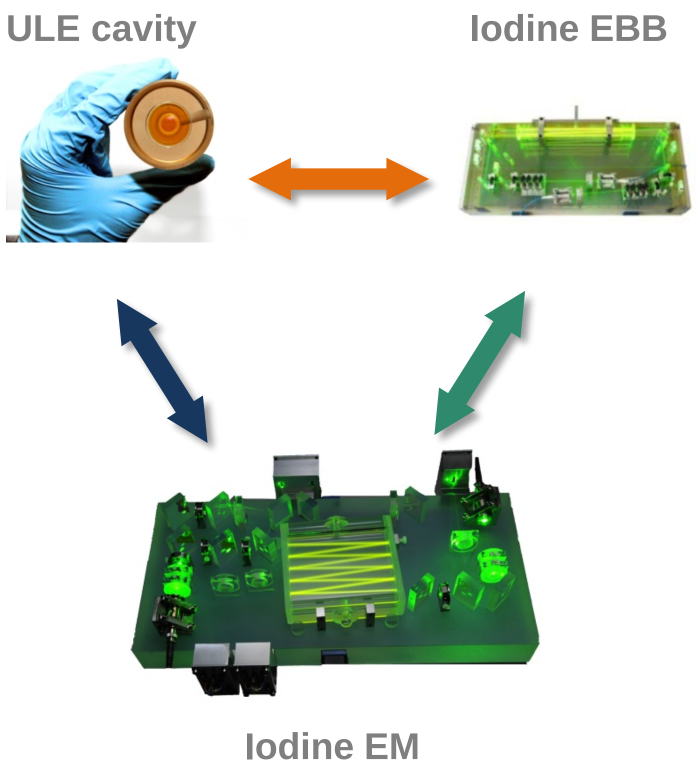






Iodine Standard
Performance measurements





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

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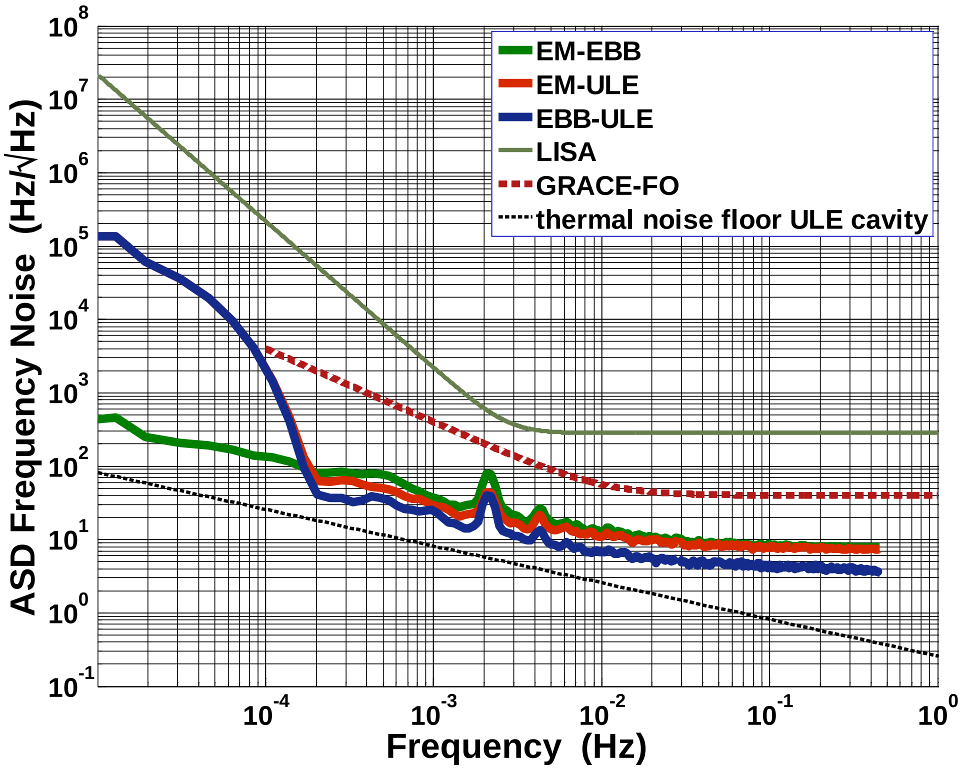
Iodine Standard
Performance measurements



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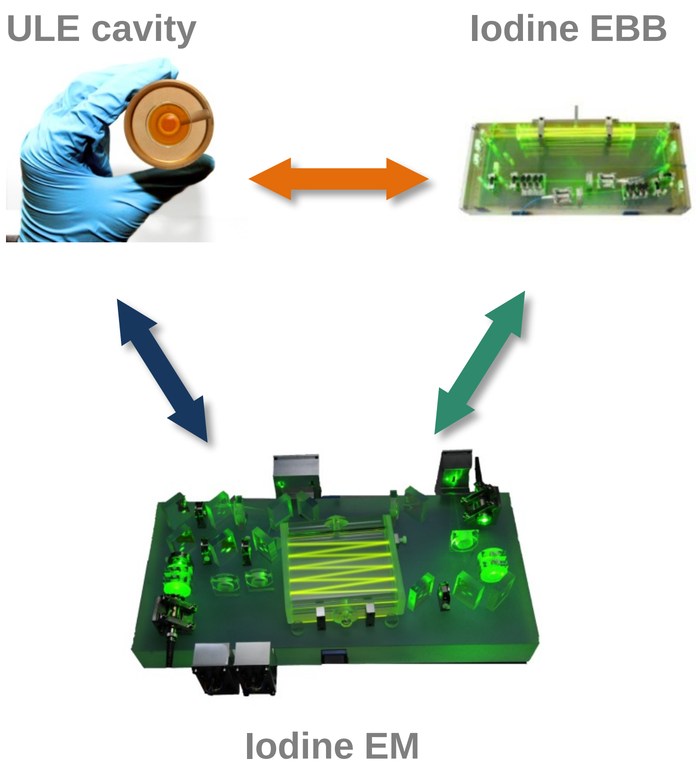

Conclusion

- 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: 4×10^{-15} at 1000 s integration time
  - Compact setup: 38 x 18 x 10 cm^3 (opt. part)

Thanks for your attention

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