Australian National University

LSC

[Towards an] in-vacuum OPO squeezer

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Overview

- Motivation
- Background
- Design
- Construction
- Preliminary results
- Characterisation & next steps

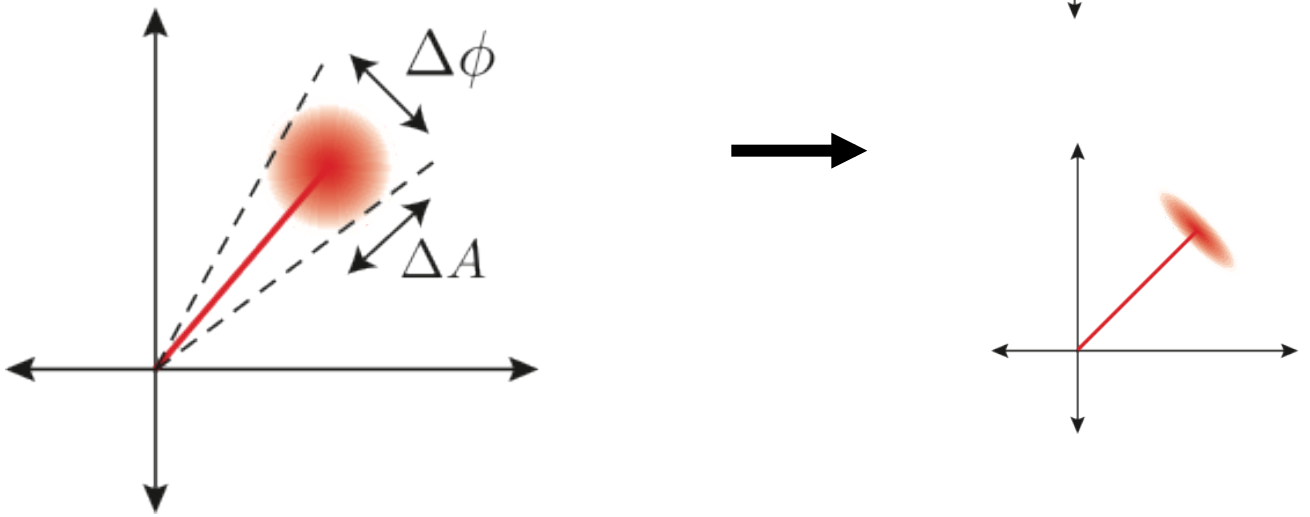
Motivation

- Develop a robust squeezed light source for aLIGO, in collaboration with MIT

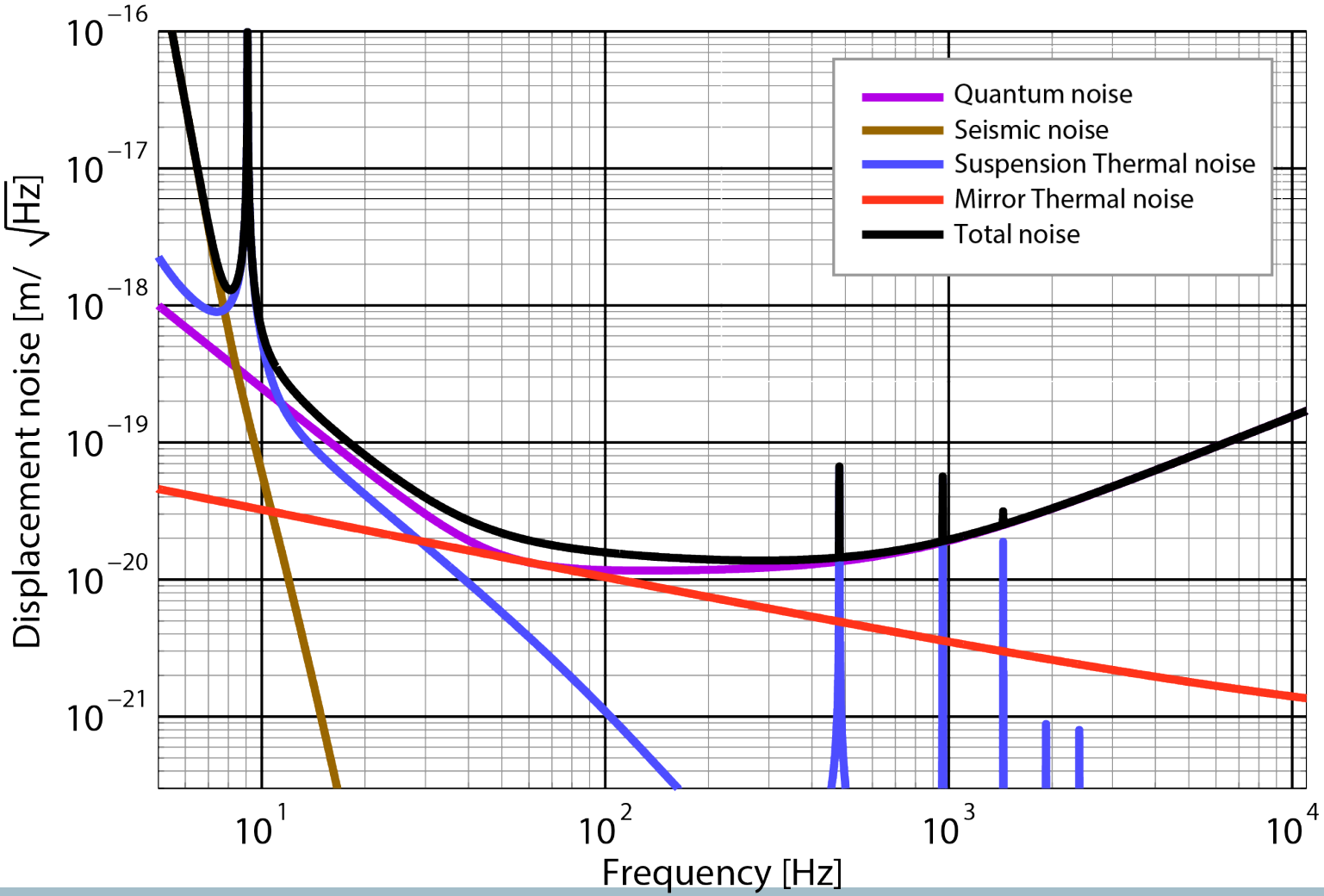
Squeezed light

- Uncertainty principle for electromagnetic waves:

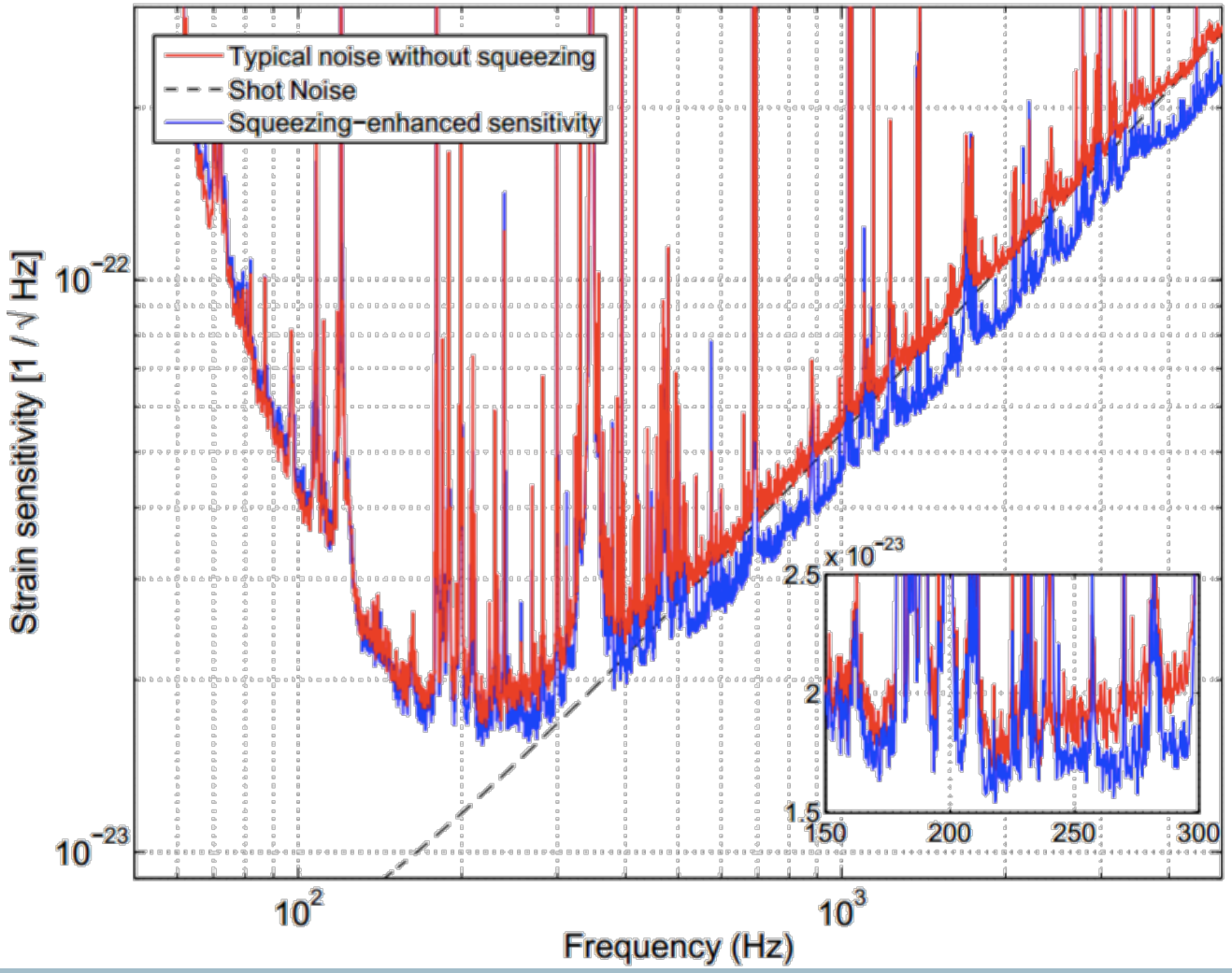
$$\Delta A \Delta \phi \geq 1$$



Quantum noise in GW detectors

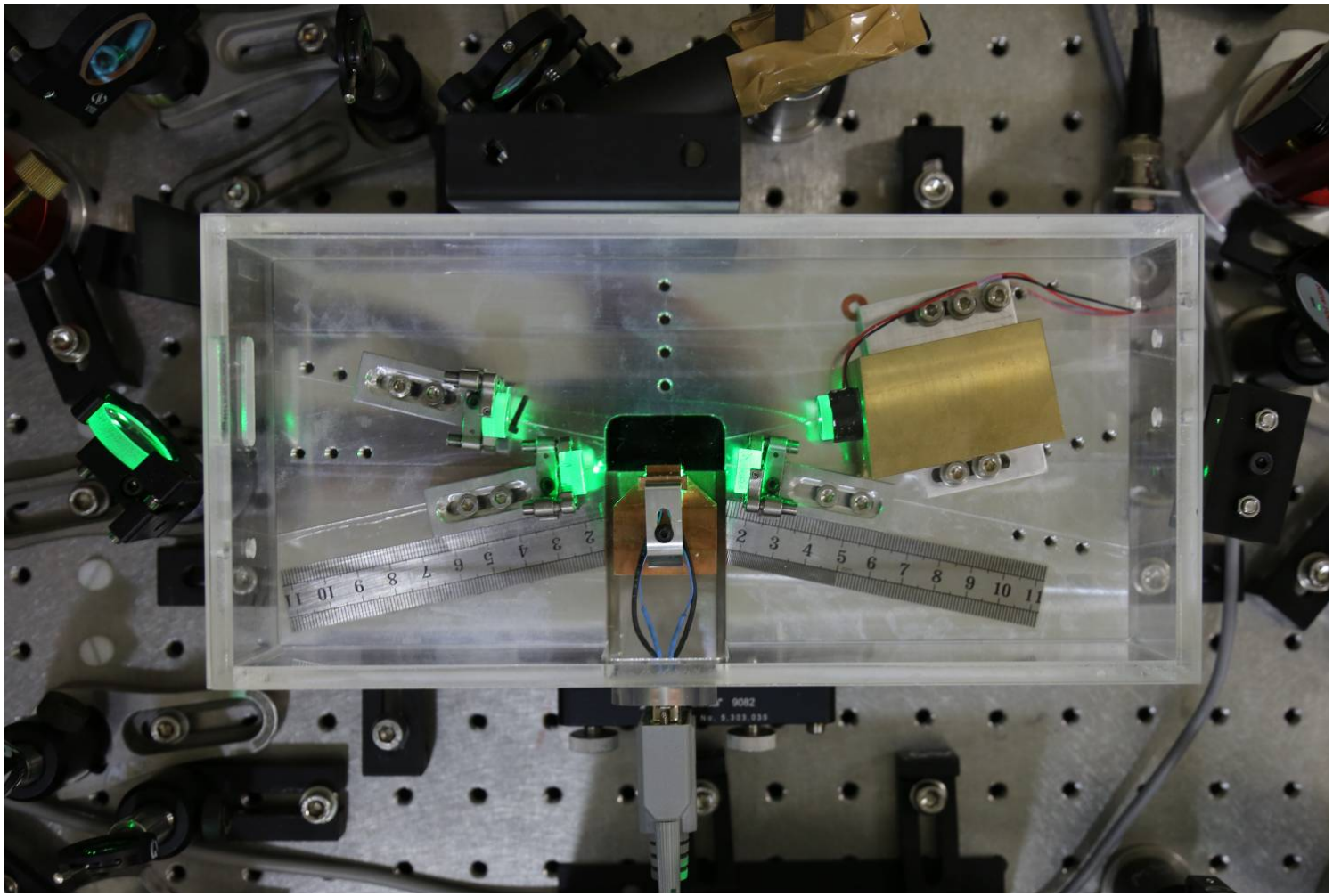


Squeezing and LIGO

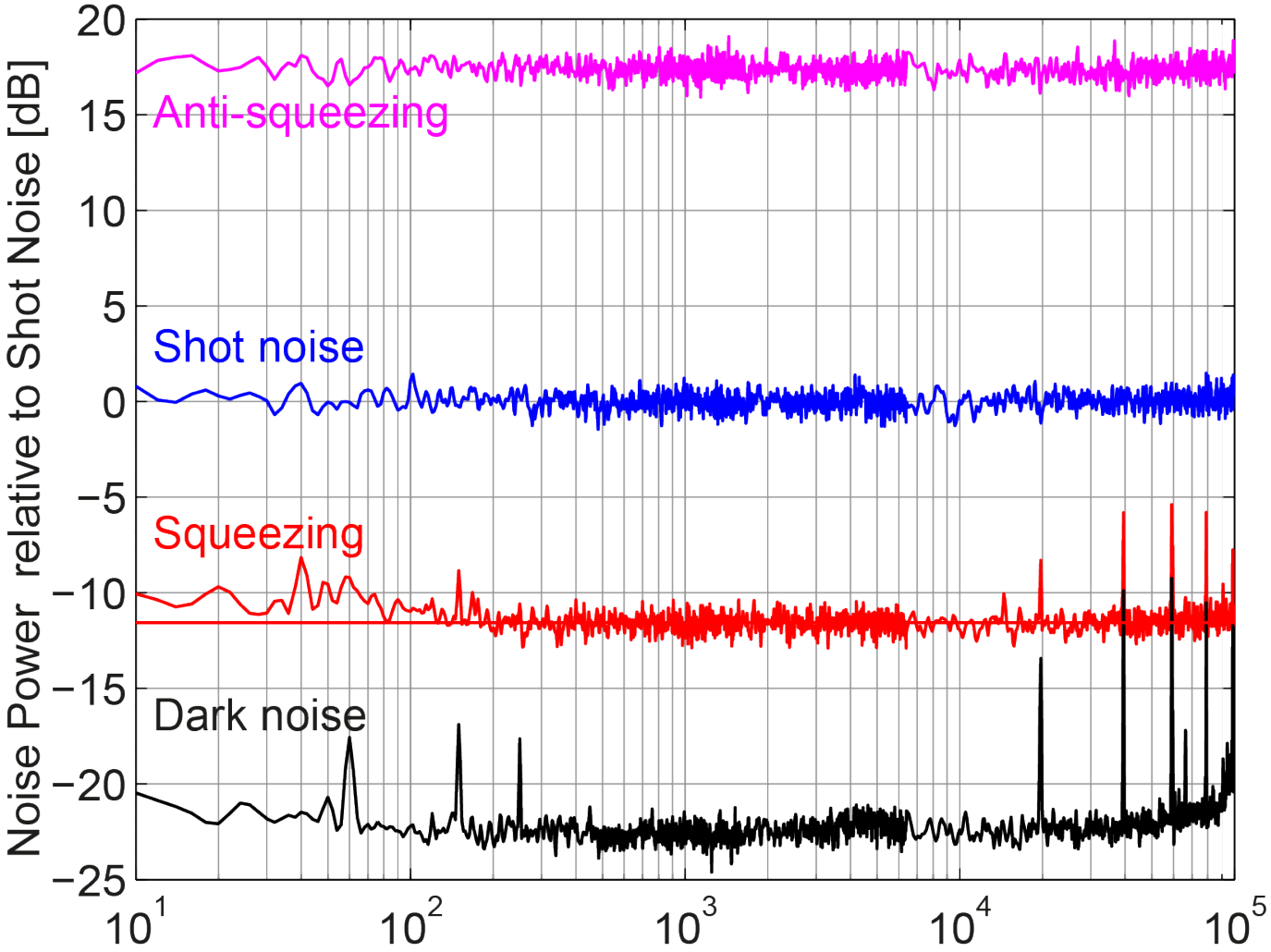


Nature Photonics, **7**, 613–619 (2013)

ANU aluminium squeezer



ANU aluminium squeezer performance



- Sources of loss
  - Poor mode matching between OPO and interferometer
  - Faraday isolator
- Sources introducing squeezing phase noise
  - Cavity length fluctuations
  - Pointing between OPO and interferometer

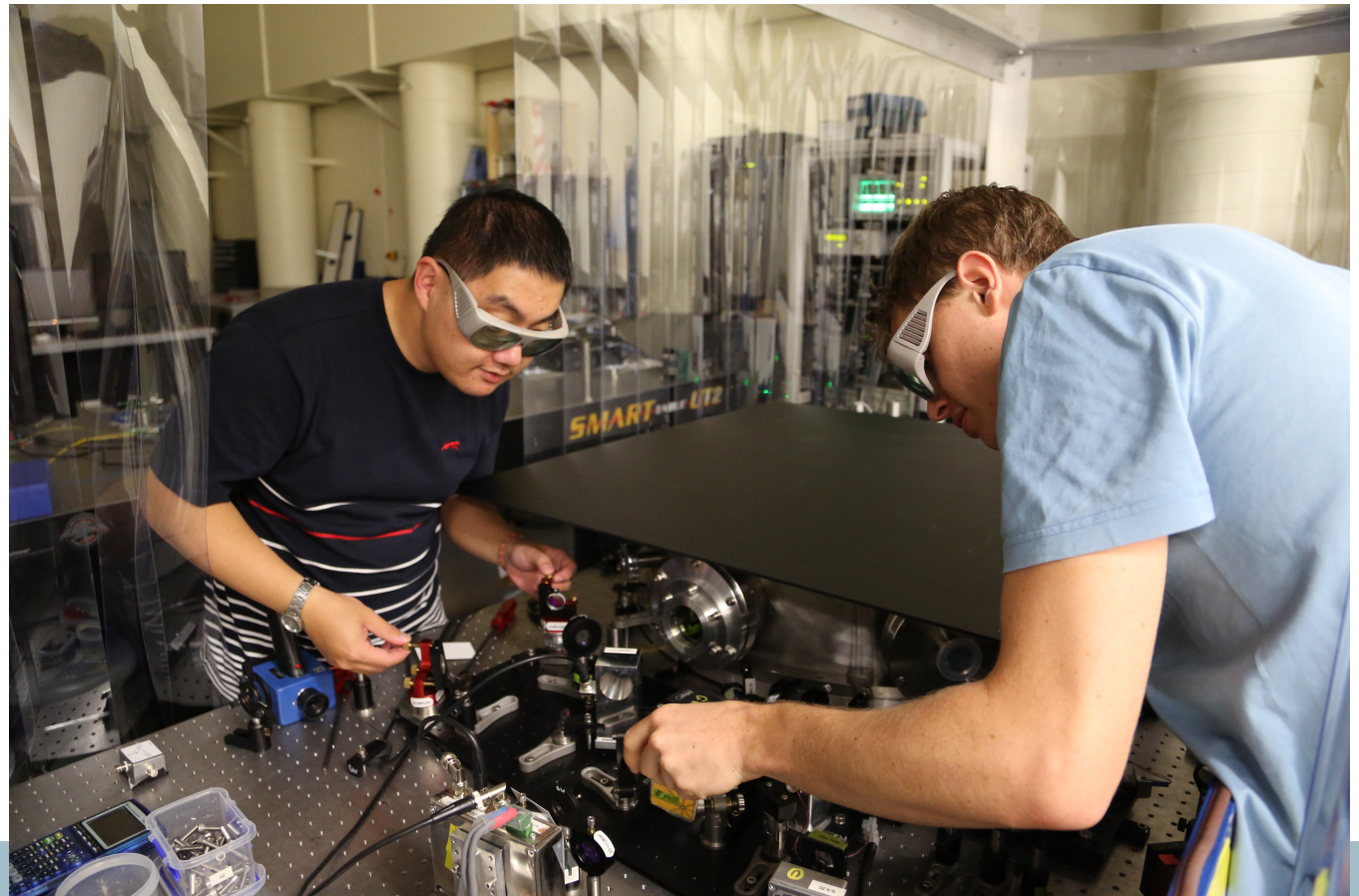
Prototype vacuum-compatible OPO

- Constructed on glass
  - Like aLIGO OMC - low cavity length noise <1x10^{-15} m/ Hz$^{-1/2}$
  - →Low cavity phase noise (~0.1 mrad)[1]
  - Long term alignment stability

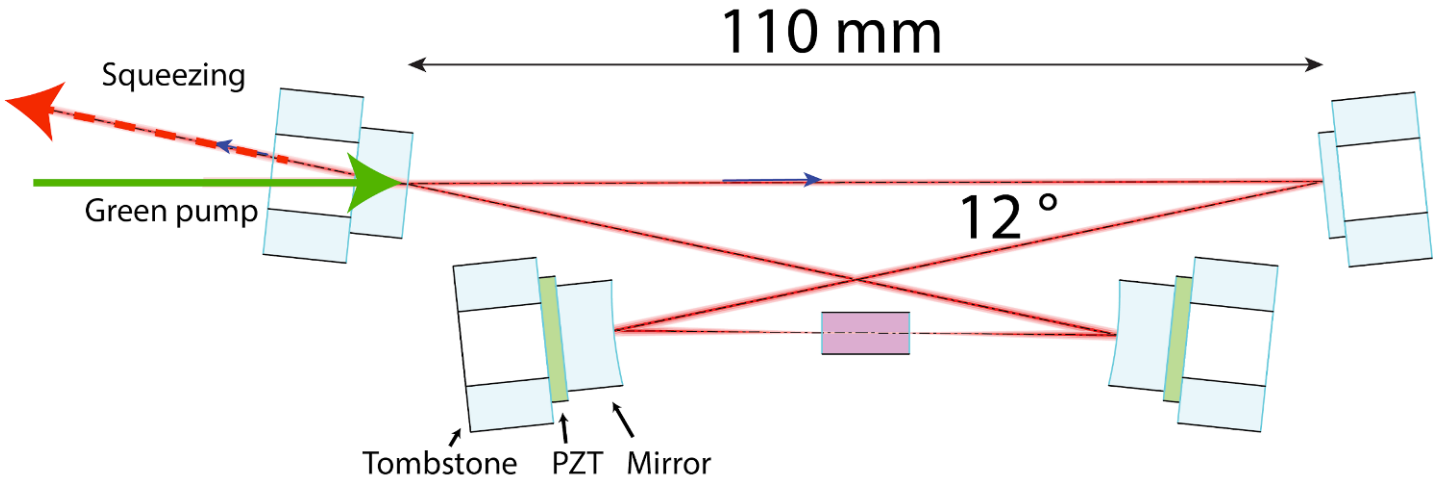
- In vacuum system
  - Reduce jitter between cavity and interferometer
  - Acoustic isolation
  - Mitigates scattered light

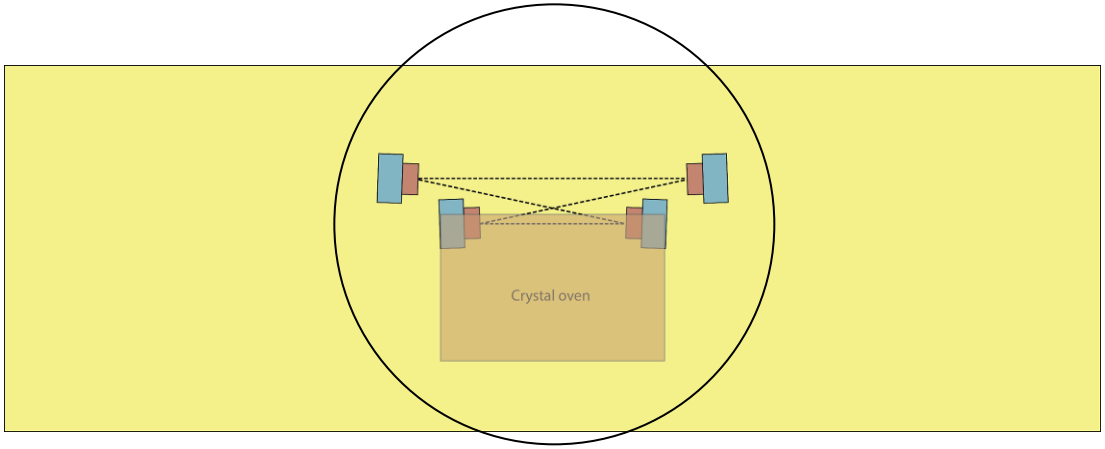
[1]E. Oelker, LIGO-P1400064-v2 (2014)

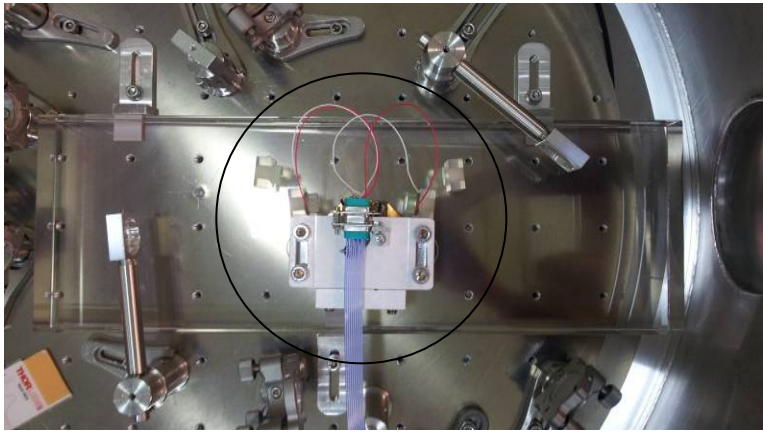
Design & construction

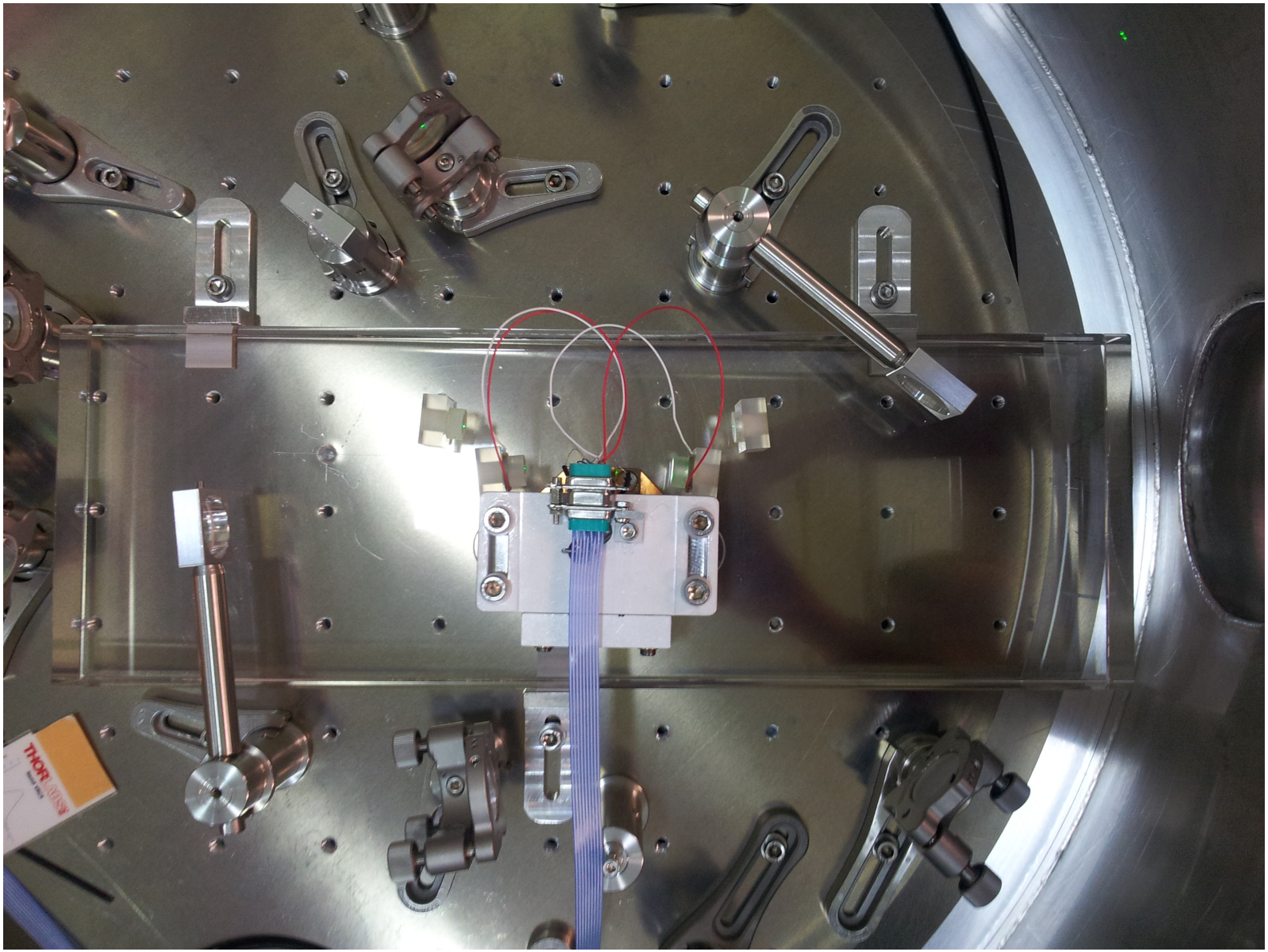


Cavity layout





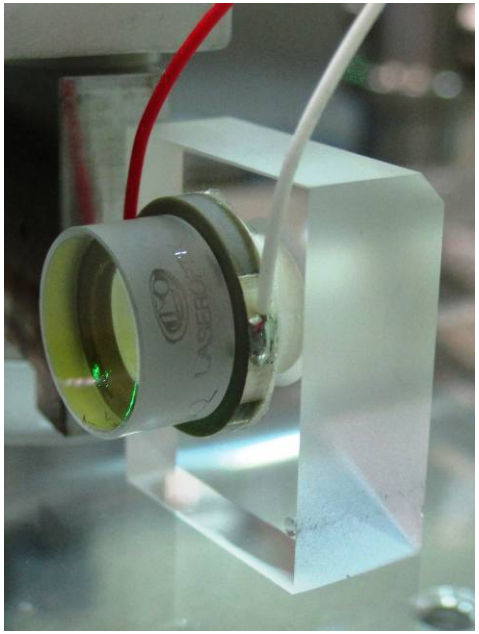



THOR

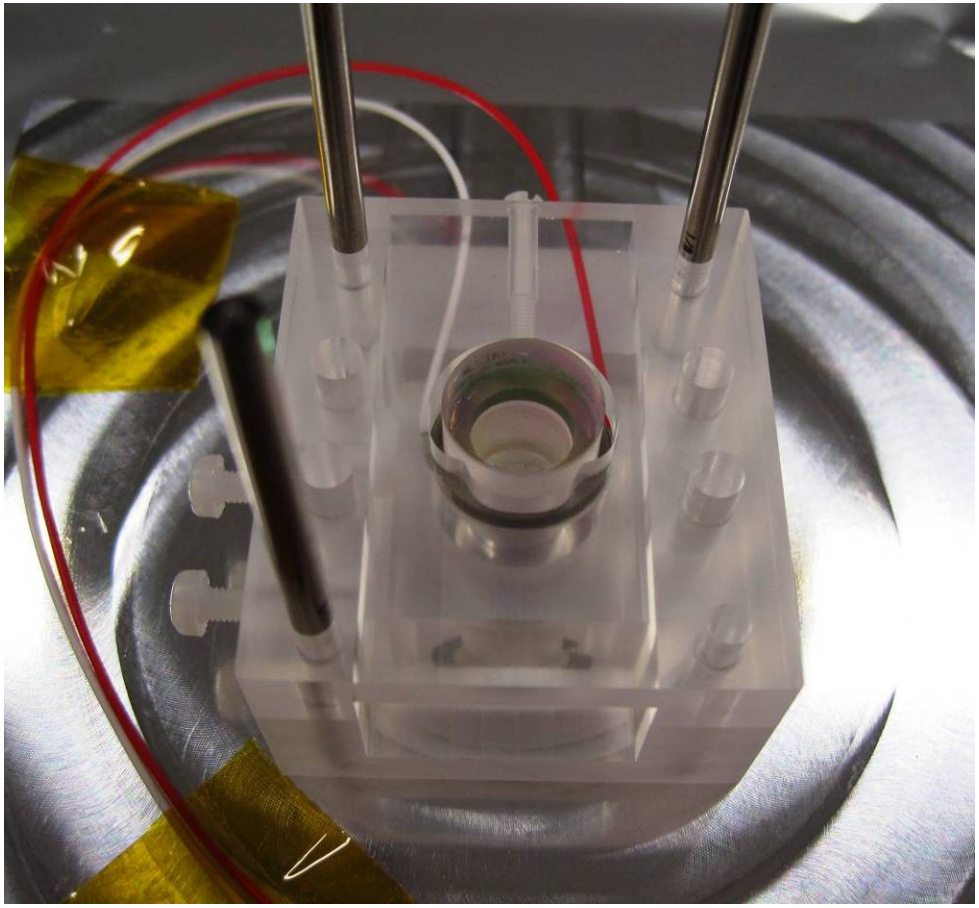
Cavity parameters

- Bow tie cavity
- Round trip length: 345 mm
- Resonant at 1064 nm and 532 nm
- Non-linear crystal: PPKTP
- Finesse: 35 @ 1064 nm, 16 @ 532 nm

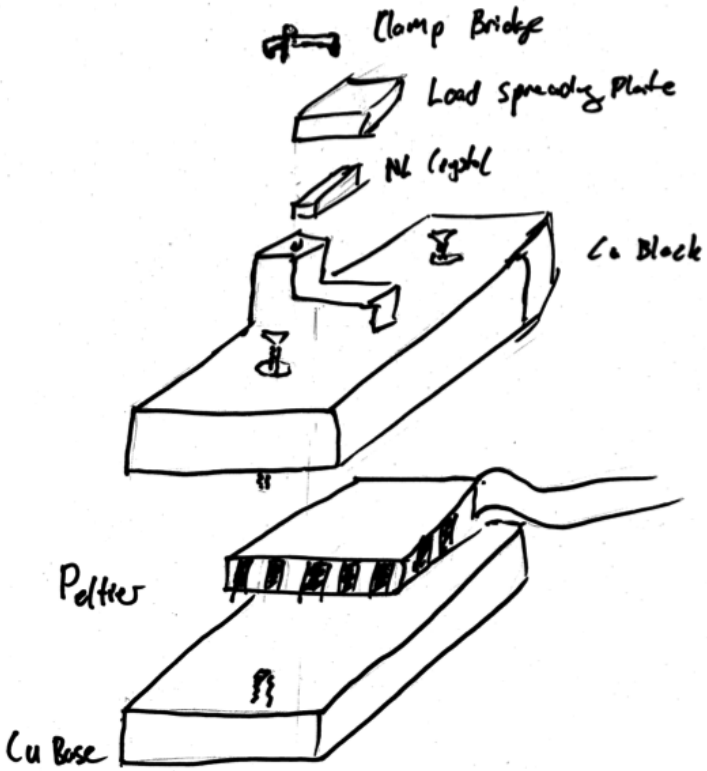
Gluing cavity mirrors

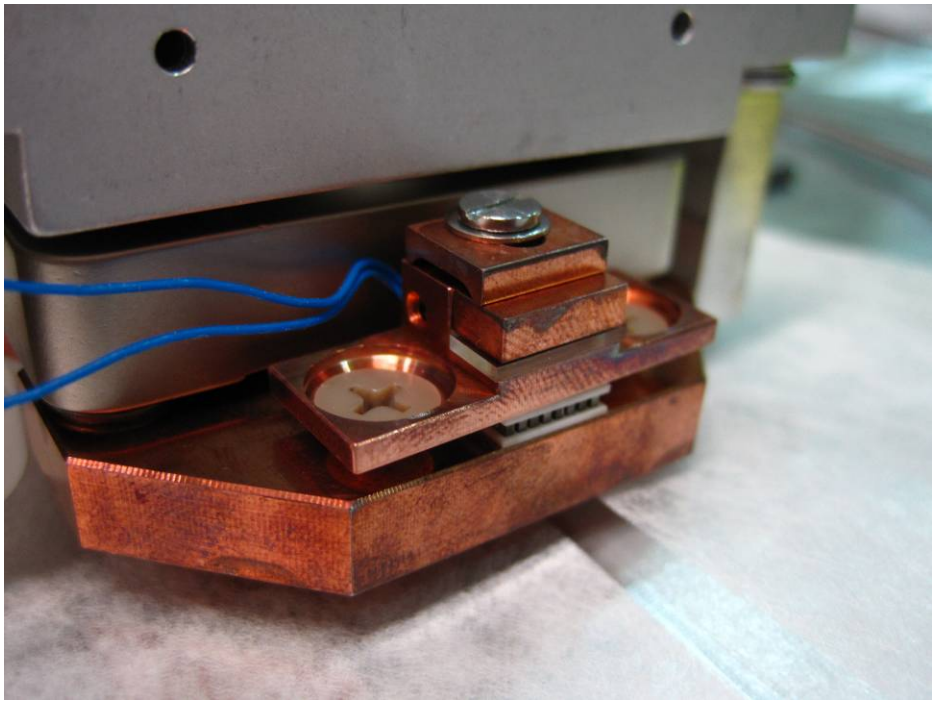


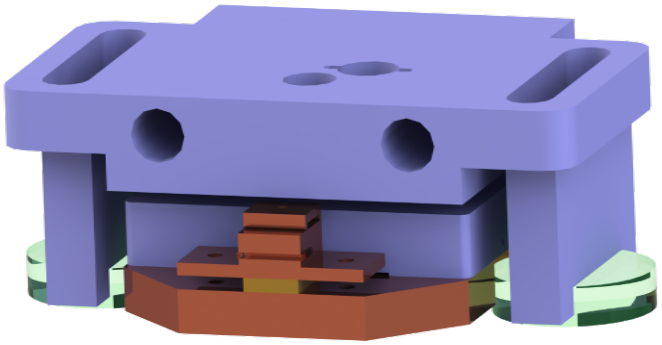
Mirrors glued to tombstones with degassed MasterBond EP30-2 adhesive



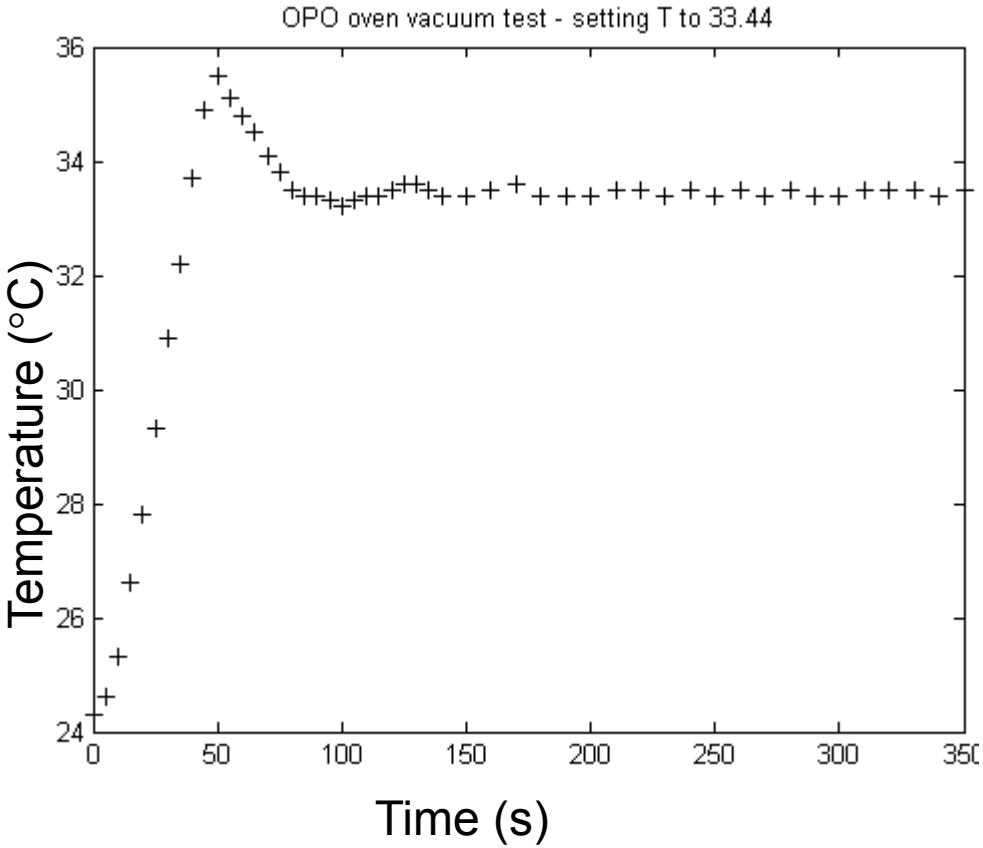
Crystal oven

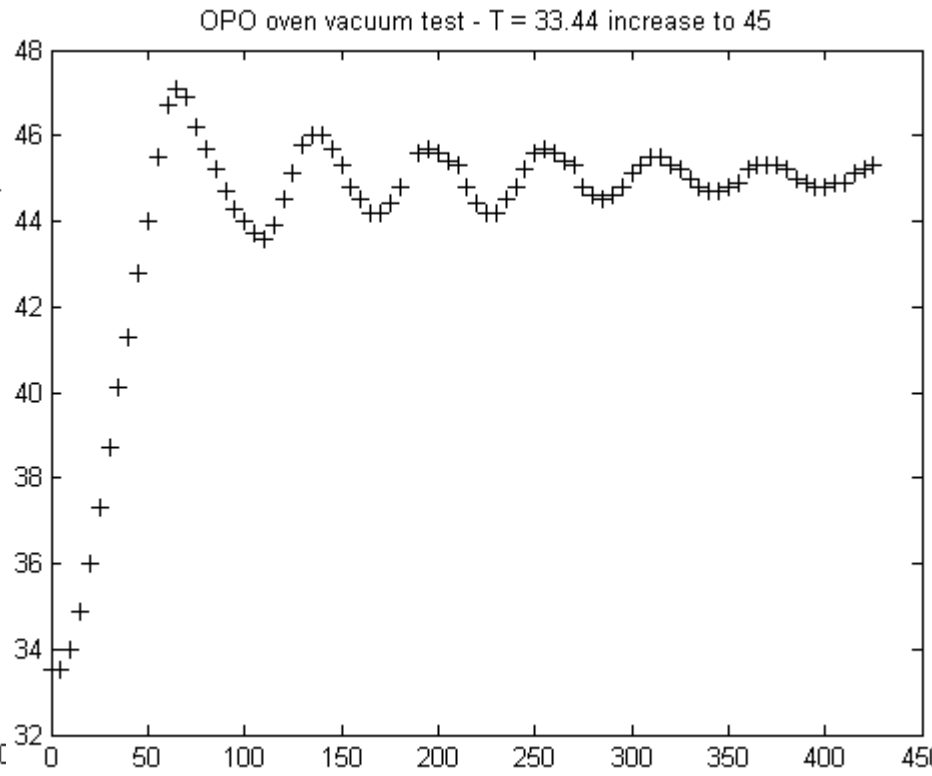






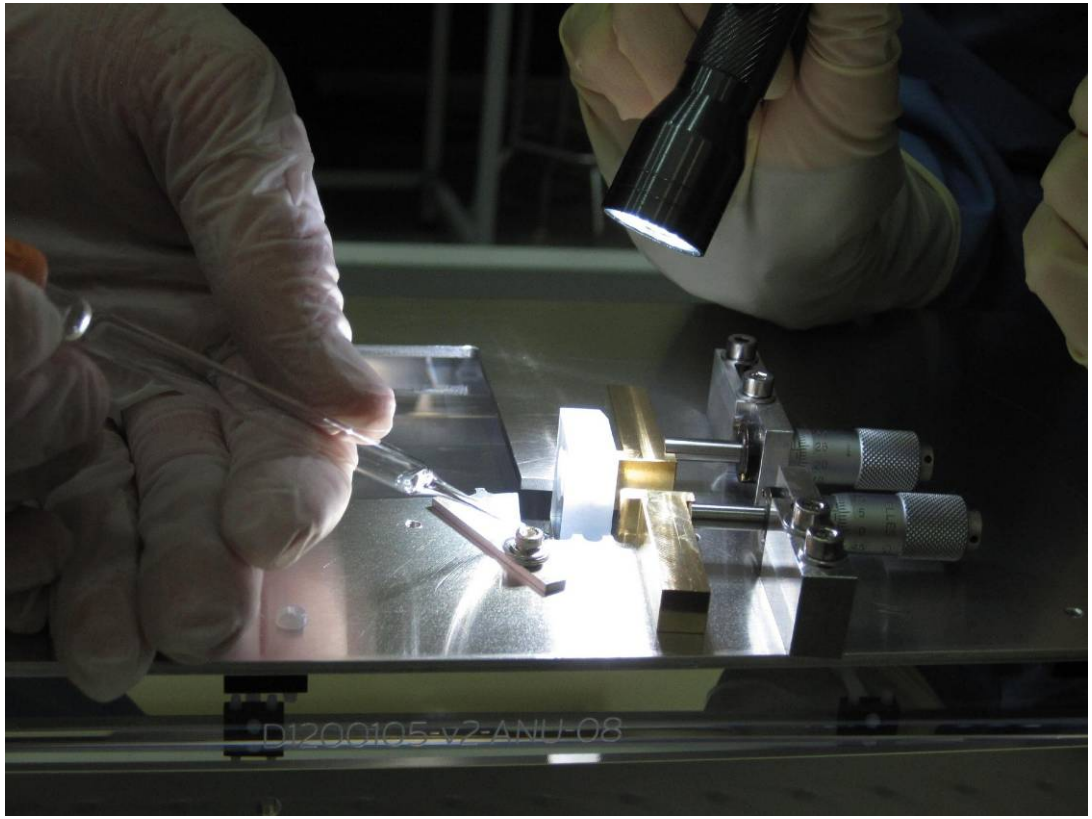
Oven testing in vacuum



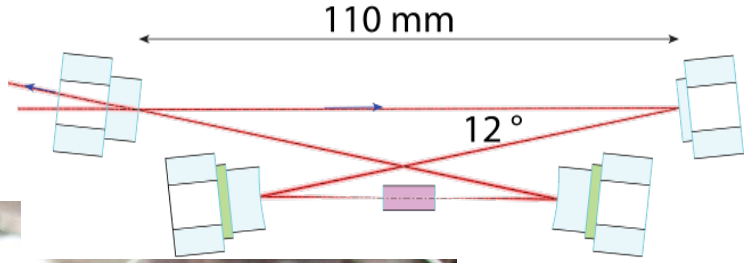


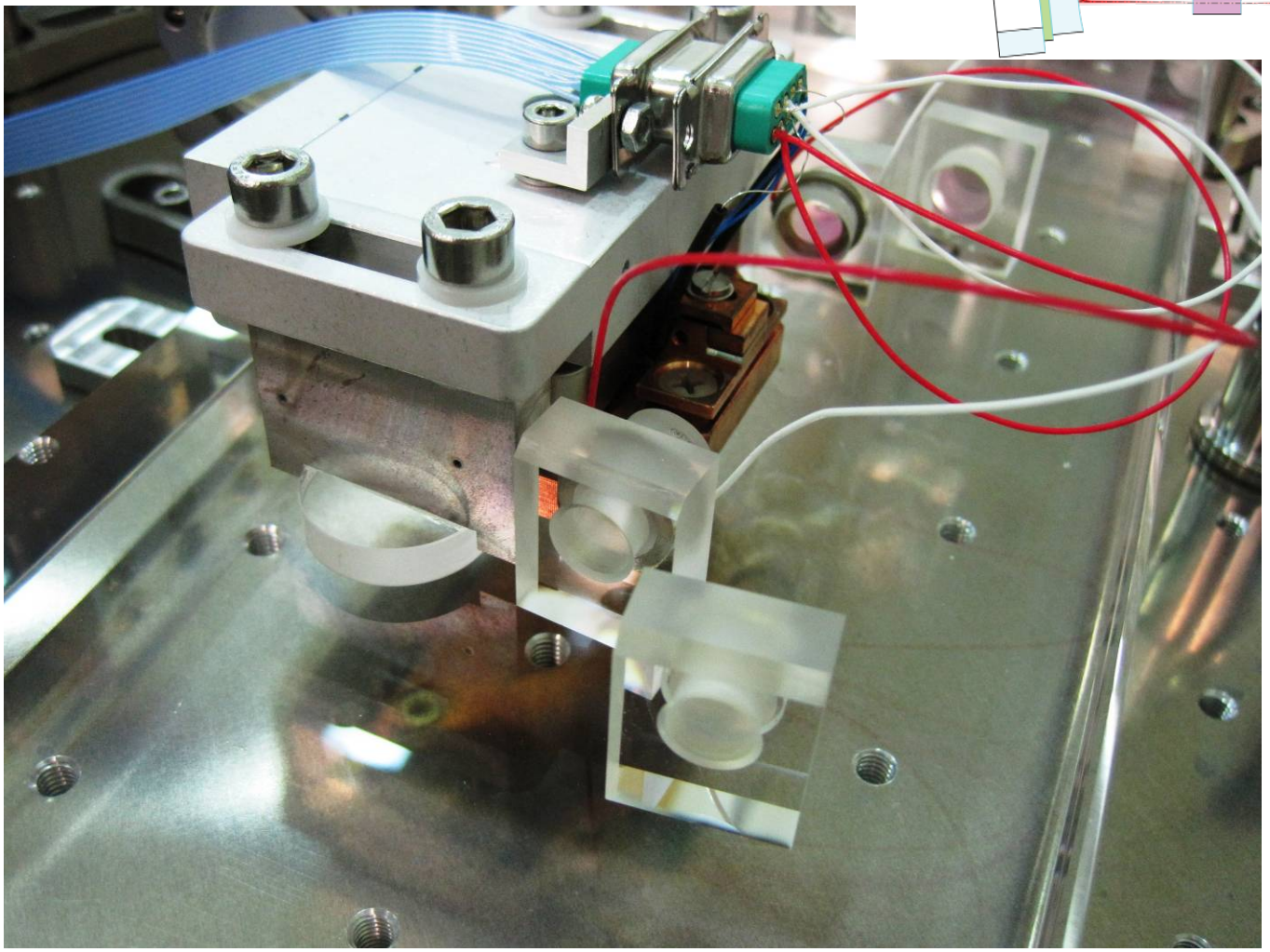
Cavity construction – optical contacting

- Two very flat surfaces (λ/10)
- Drop of methanol between them
- Shear strength ~0.13 MPa
- Reversible

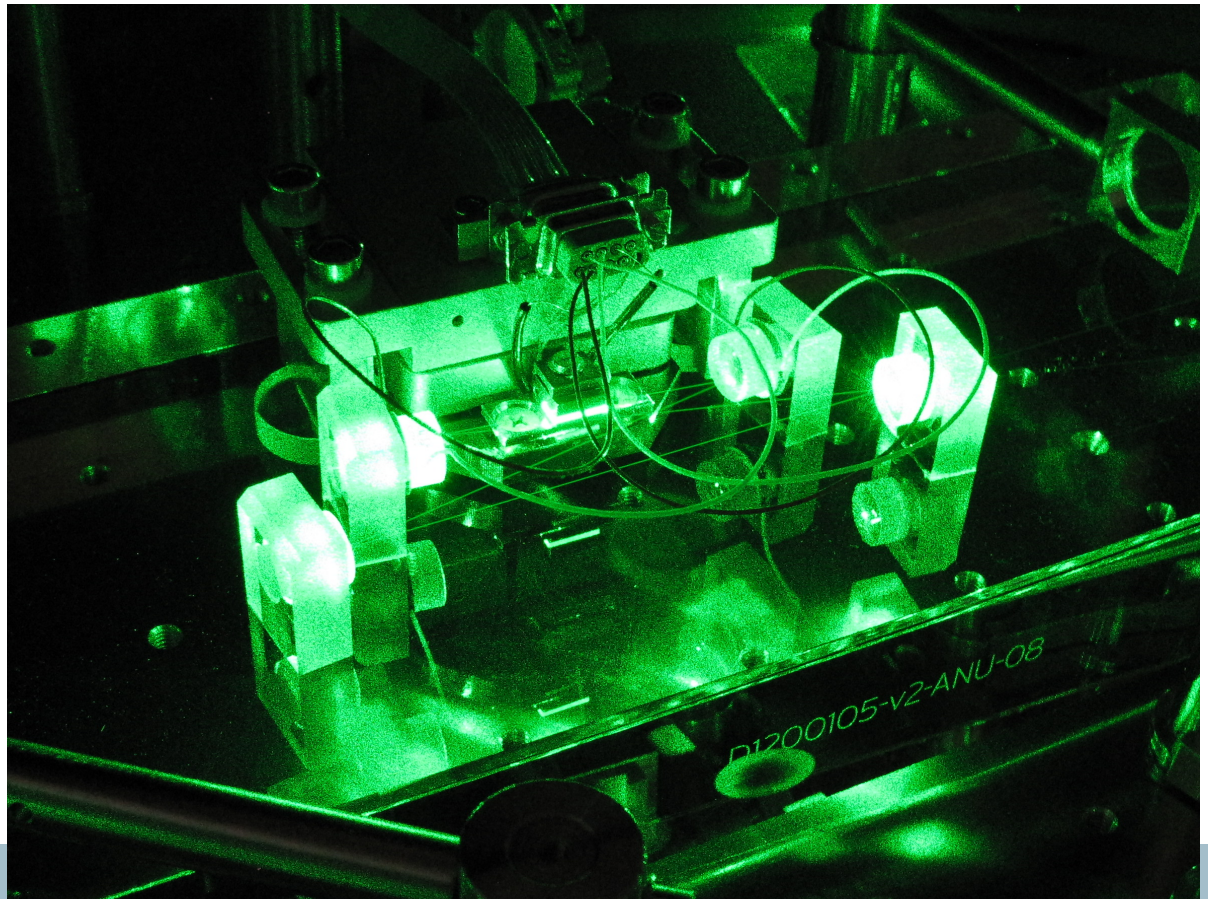


Cavity construction

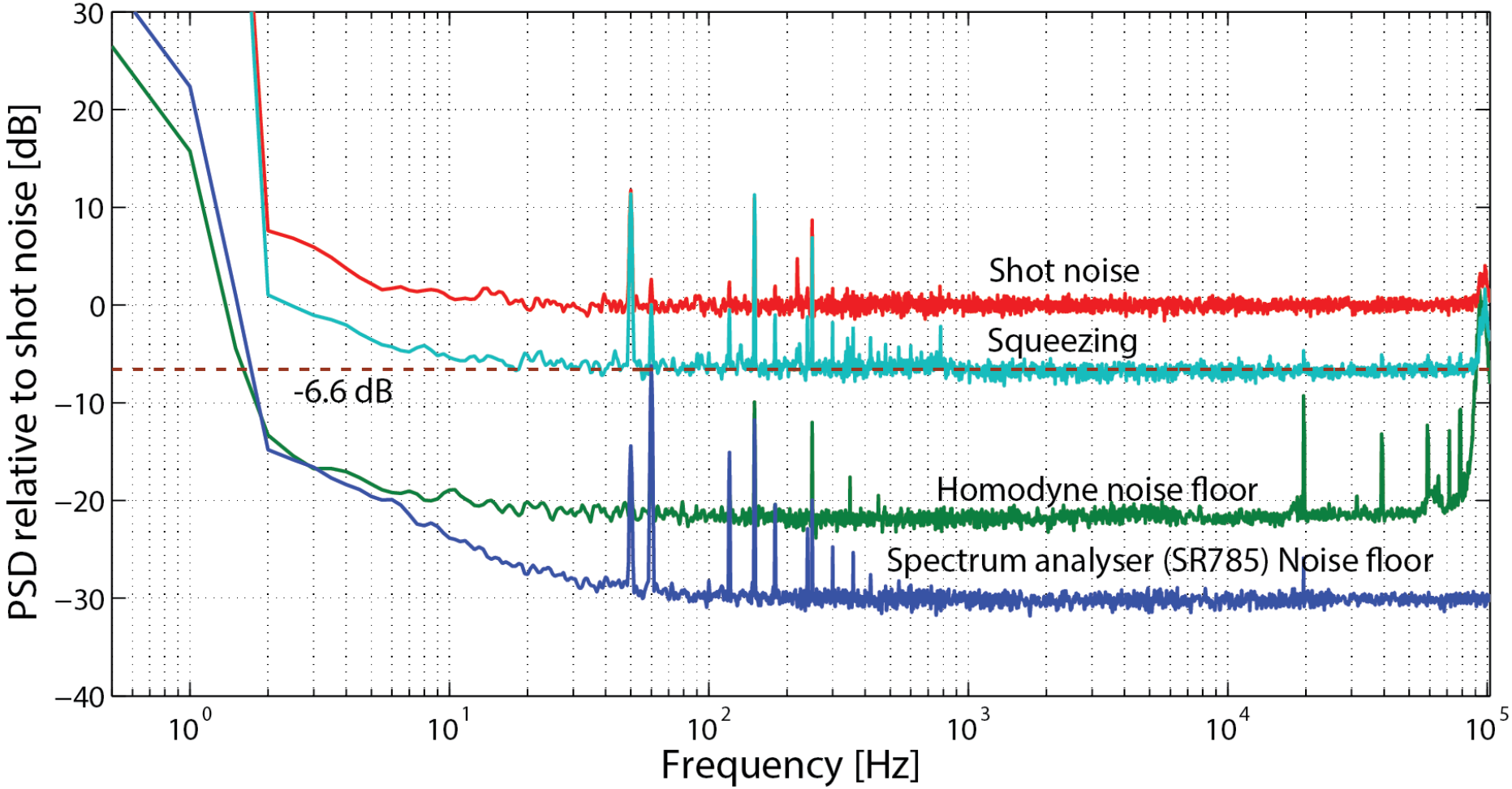




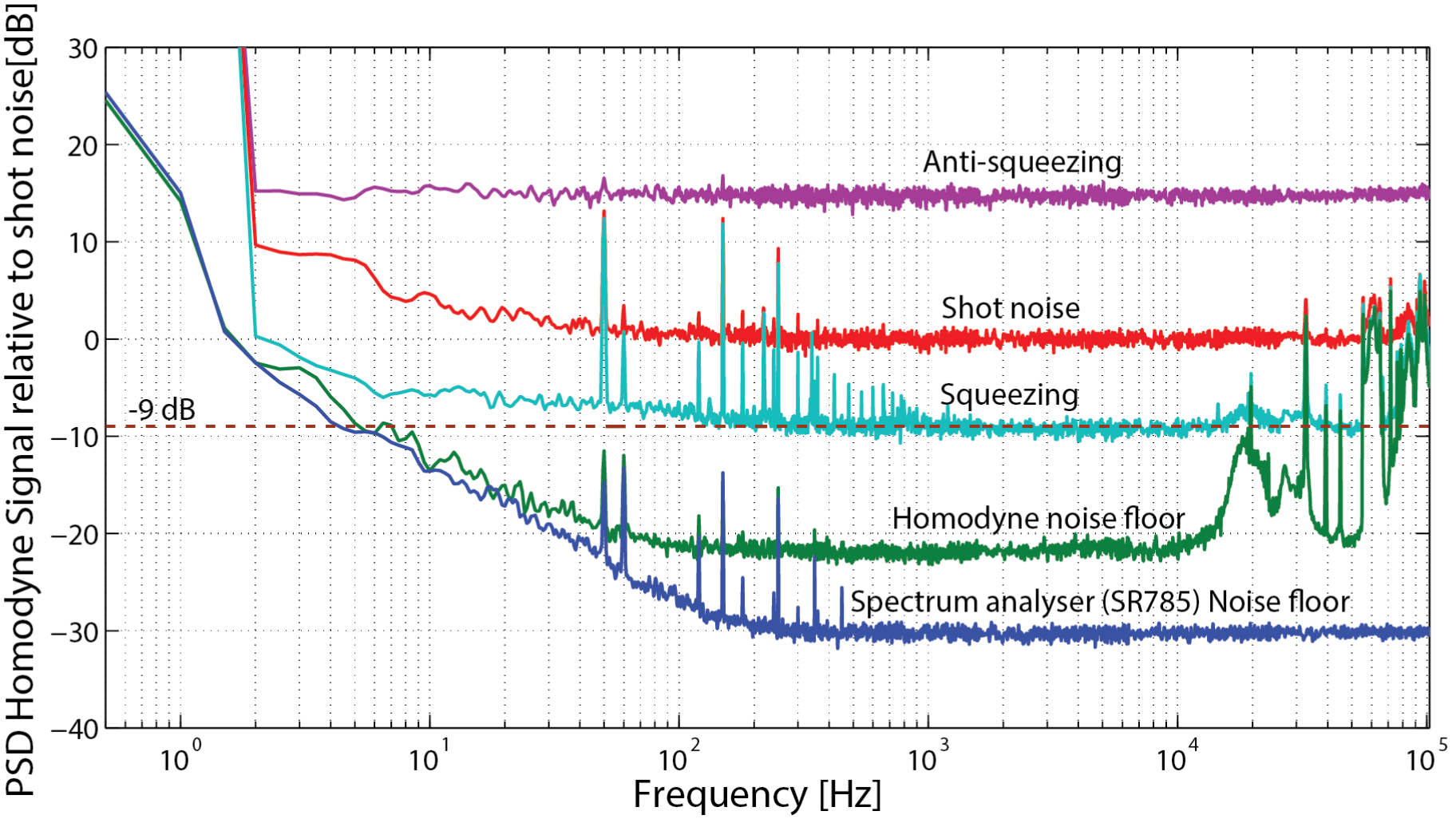
Results (so far)



In-air results (preliminary)



In-air results (preliminary)

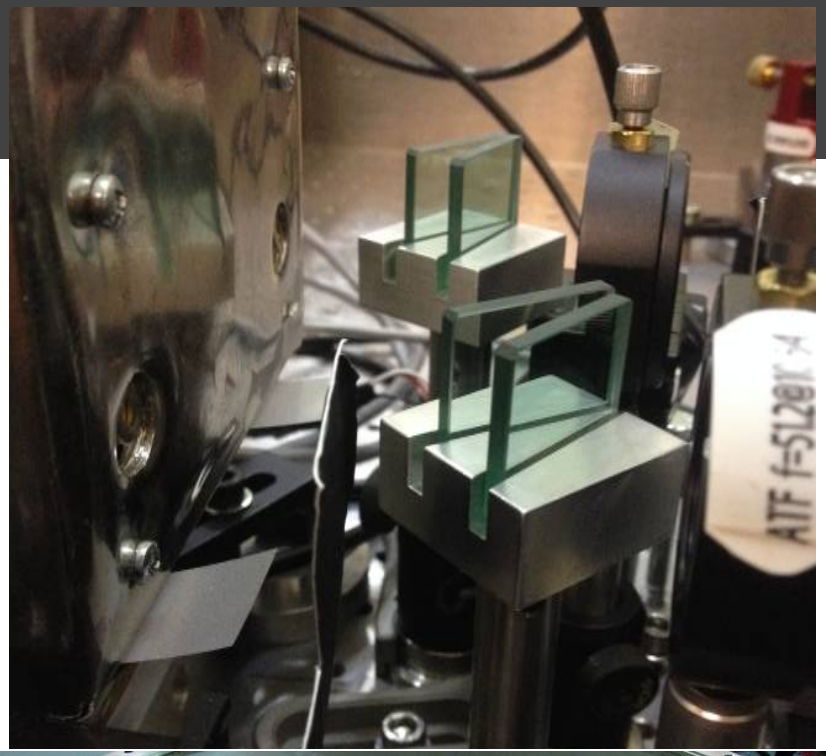


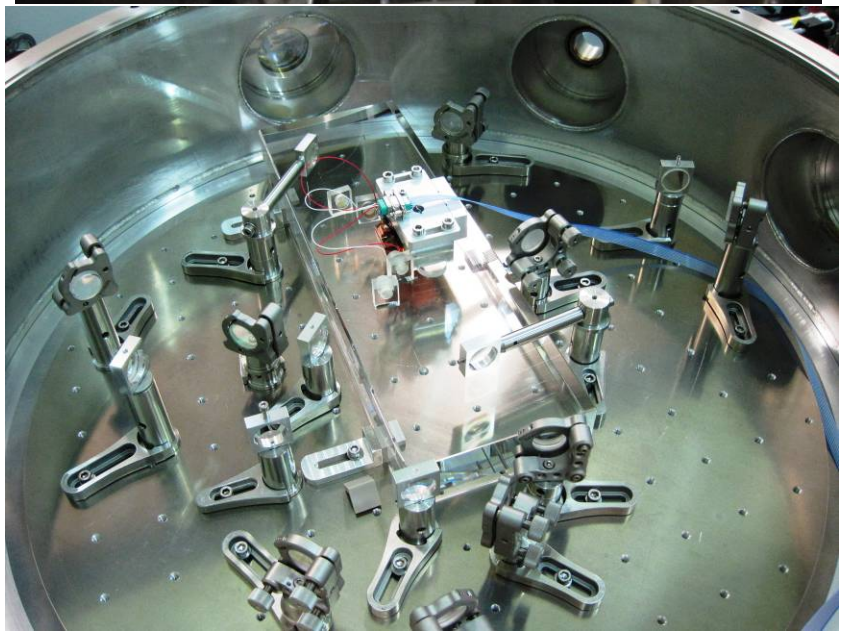
Current status

- Producing 9 dB squeezing
- Scatter mitigation underway
- Working towards

$\geq$ 10 dB

- Vacuum preparation ongoing





Current issues

- Grounding issues
- Lower than expected nonlinear gain
- Fringe visibility
- Vacuum tank leak issues

Next steps

- Measure cavity escape efficiency
- Improve squeezing level
- Run squeezer under vacuum
- Compare with previous AI cavity (phase noise, cavity loss)
- Long term measurements

- Populate glass breadboard
- In-vacuum homodyne detector