Towards the Quantum Limit

An update from the AEI 10m Prototype

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LIGO-G1300741

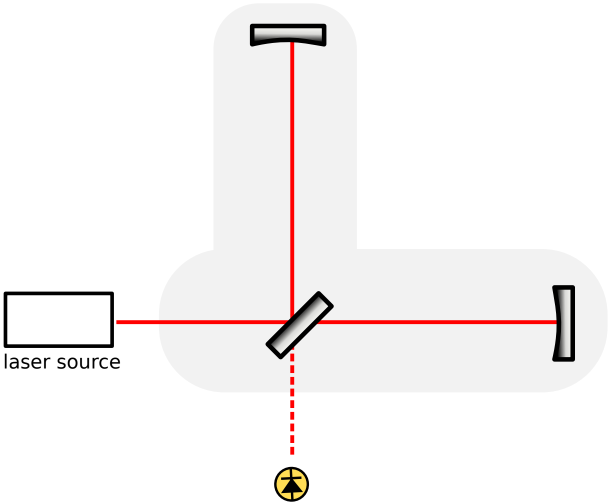
The mission(s) of the 10 m Prototype facility:

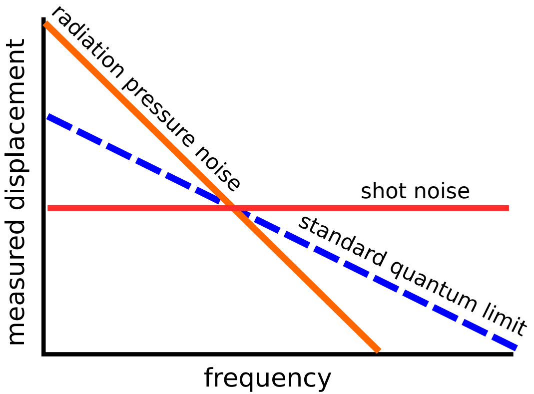
- Reach the **standard quantum limit** (m=100g, f=200Hz) with a Fabry-Perot Michelson interferometer

- Provide a prototype **test-bed facility** with ultra-low displacement noise, high vacuum, & flexible configuration for **additional experiments**.

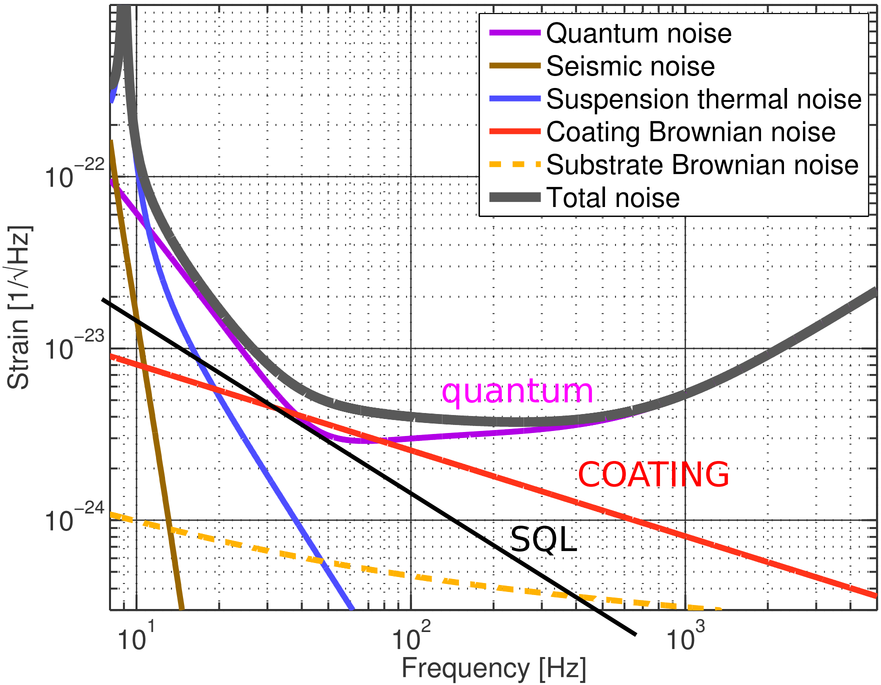
located at the AEI in Hannover, Germany

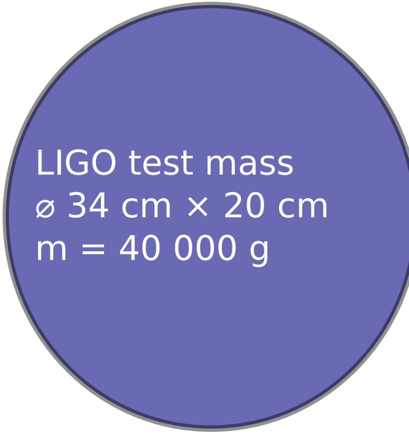
What is the Standard Quantum Limit?





Quantum noise in advanced GW detectors

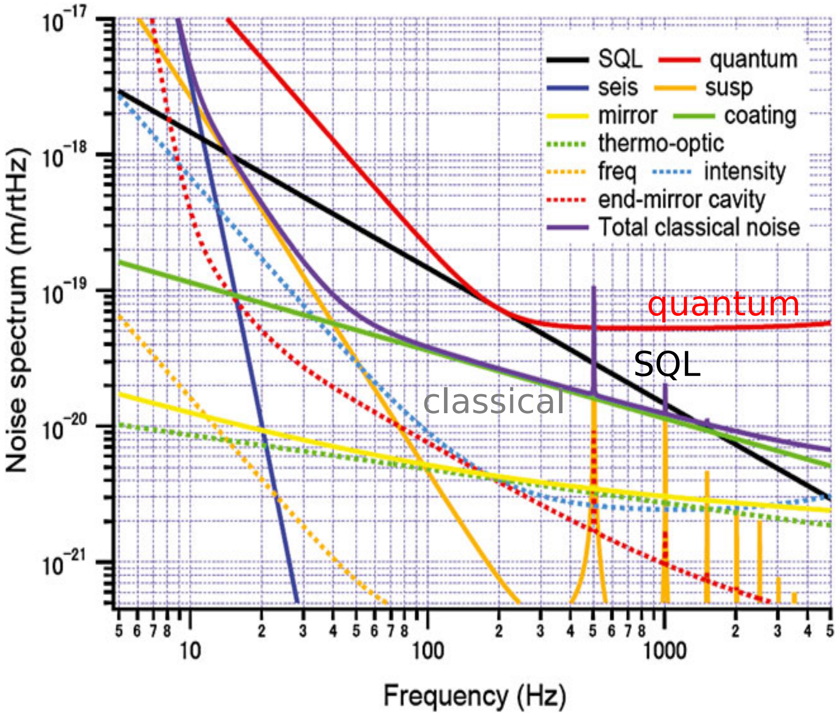


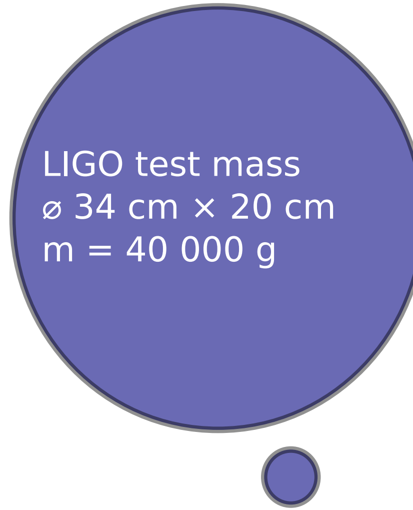


Sample Advanced LIGO noise budget

L = 4 km, m = 40 kg

10m Noise Budget





10m Prototype
⌀ 4.6 cm × 2.7 cm
m = 100 g

(Many other design considerations too..)

T. Westphal et al, "Design of the 10 m AEI prototype...", App Phys B, Vol 106, Issue 3 (2012)

Kentaro Somiya et al, "Conceptual design of an interferometer with a sub-SQL sensitivity." (LIGO-G0900438, LIGO-T0900069)

L = 10 m, m = 100 g

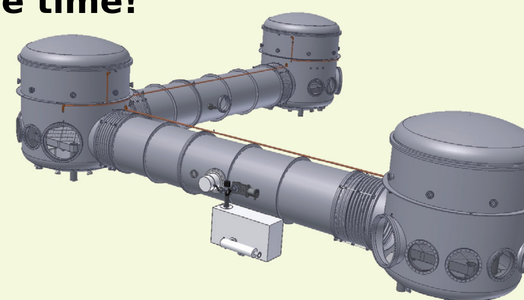
Vacuum system

Volume: 100 m^3 - **Luxuriously large tanks!**

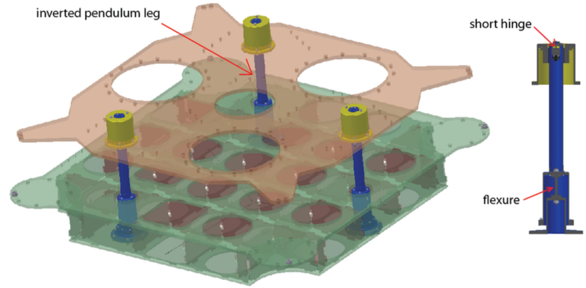
Pumpdown to 1e-6 mbar in 6 hours - **Fast cycle time!**

Best pressure ~1e-7 mbar

Installed and working! ✔



1 mbar = 100 Pa ≈ 0.75 Torr

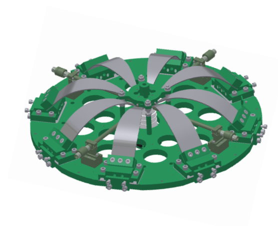


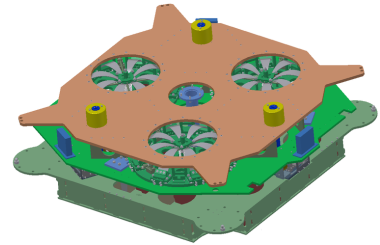
AEI SAS

Soft passive plant...

- 1 stage vertical, 1 stage horizontal

- 100 mHz horizontal resonance
- 270 mHz vertical resonance
- 400 mHz tilt resonance





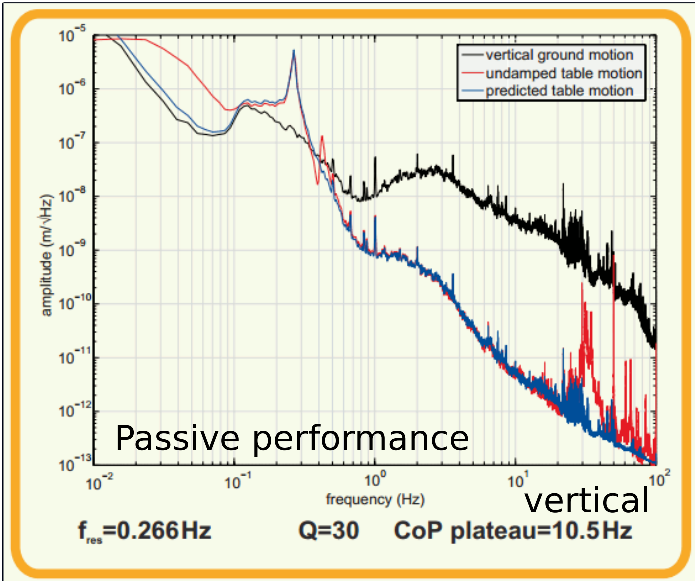
...but with the usual complement of sensors and actuators

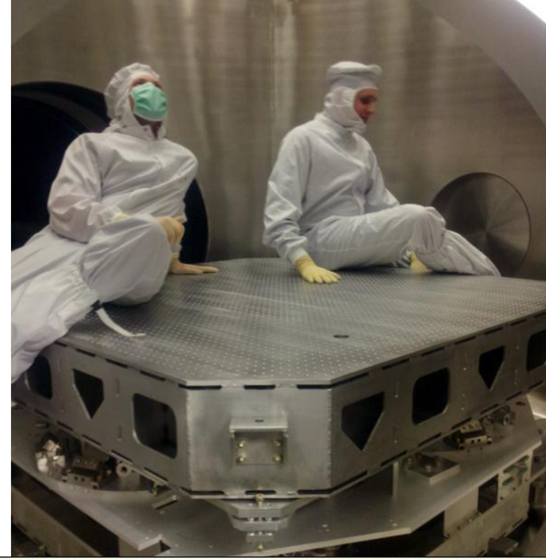
- 6X **inertial sensors**: monolithic accelerometers (Horiz); geophones (Vert)
- 6X **displacement sensors**: LVDTs
- **feed-forward** from ground motion (STS2 seismometer)
- 6X **voice-coil actuators**

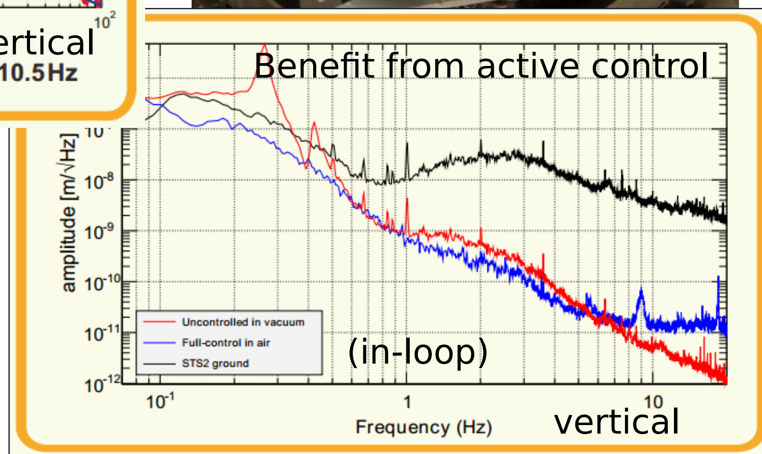
Installed and working!
(two of three tabels)

Poster by
Gerald Bergmann

SAS preliminary results



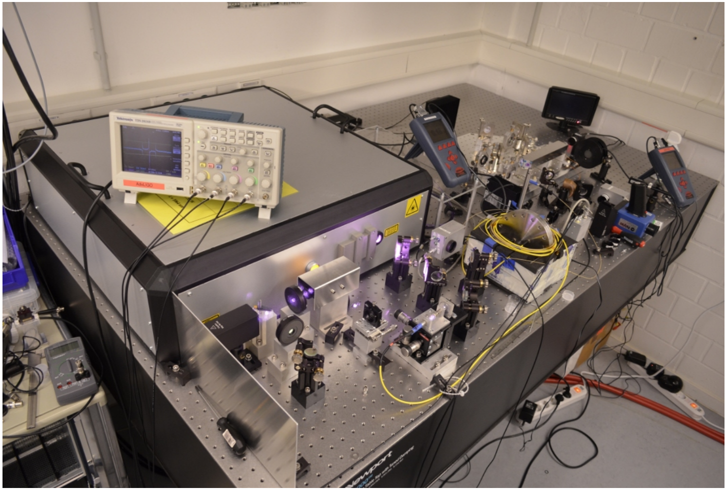


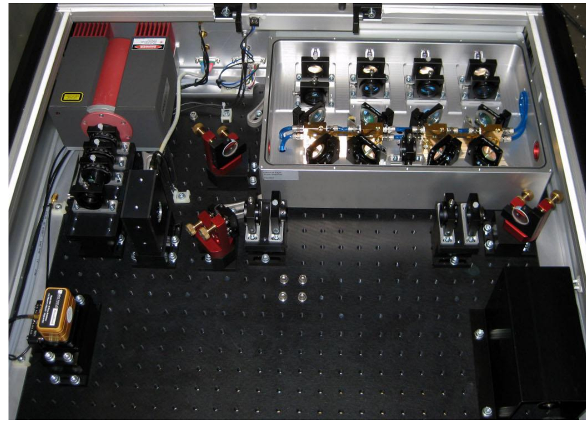


From the poster by Gerald Bergmann, Conor Mow-Lowry, and Alexander Wanner (G1300715)

Laser System

Advanced LIGO 35 W laser



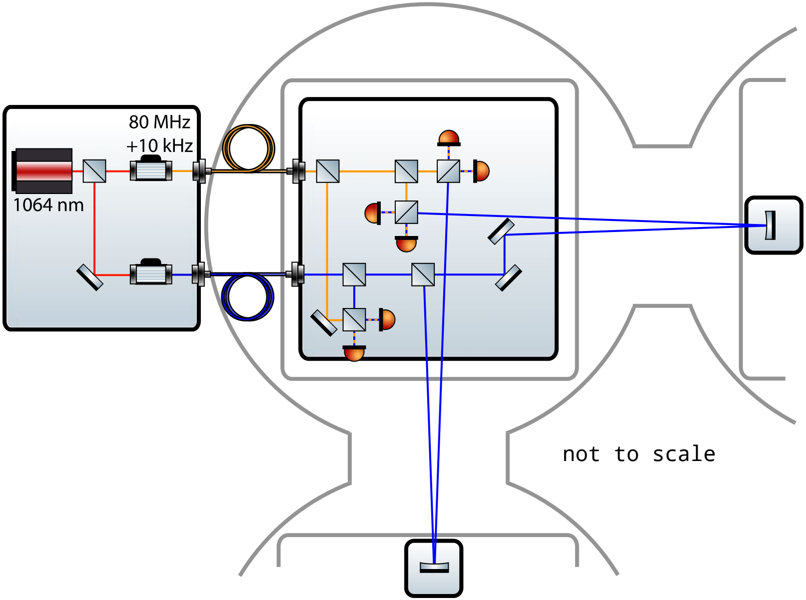


- Coupled into vacuum by photonic crystal fiber
- In-vacuum pre-mode-cleaner (PMC)
- We'll use 8 Watts for initial experiments

Installed and working! ✓

Talk by Benno Wilke

Suspension Platform Interferometer



Idea: link the table platforms via sensing and feedback

Mach-Zender for high dynamic range.

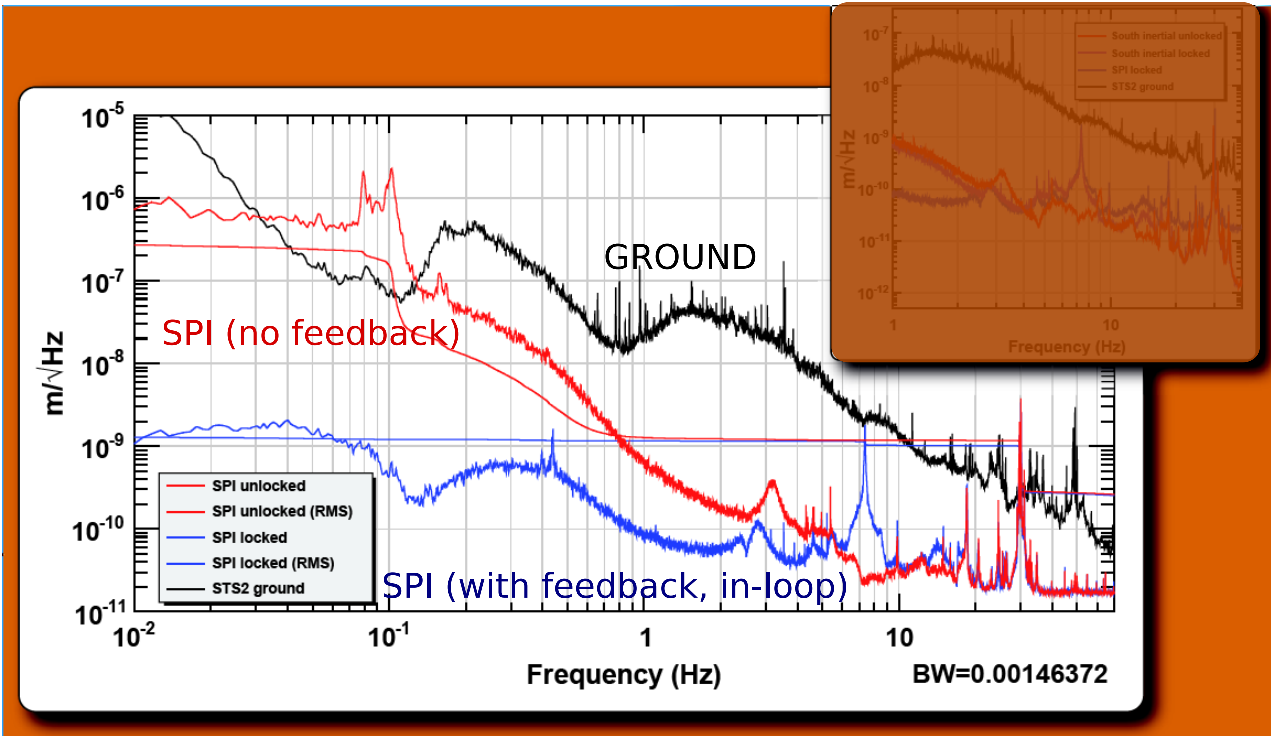
Uses **LISA phasemeter** and monolithic construction.

Achieved sensing noise:
10 nm/√Hz below 10 mHz
10 pm/√Hz above 1 Hz
+ frequency noise?

Installed and working!
(one degree of freedom)

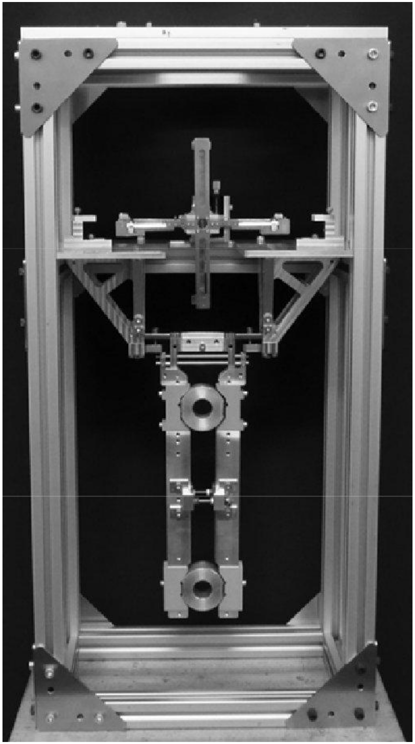
Poster by
Sina Köhlenbeck

SPI preliminary results



From the poster by Sina Köhlenbeck, Katrin Dahl, and Conor Mow-Lowry. (G1300718)

Monolithic suspensions



- Three pendulum stages
- Two vertical blade-spring stages
- Lower stage all glass for lower thermal noise

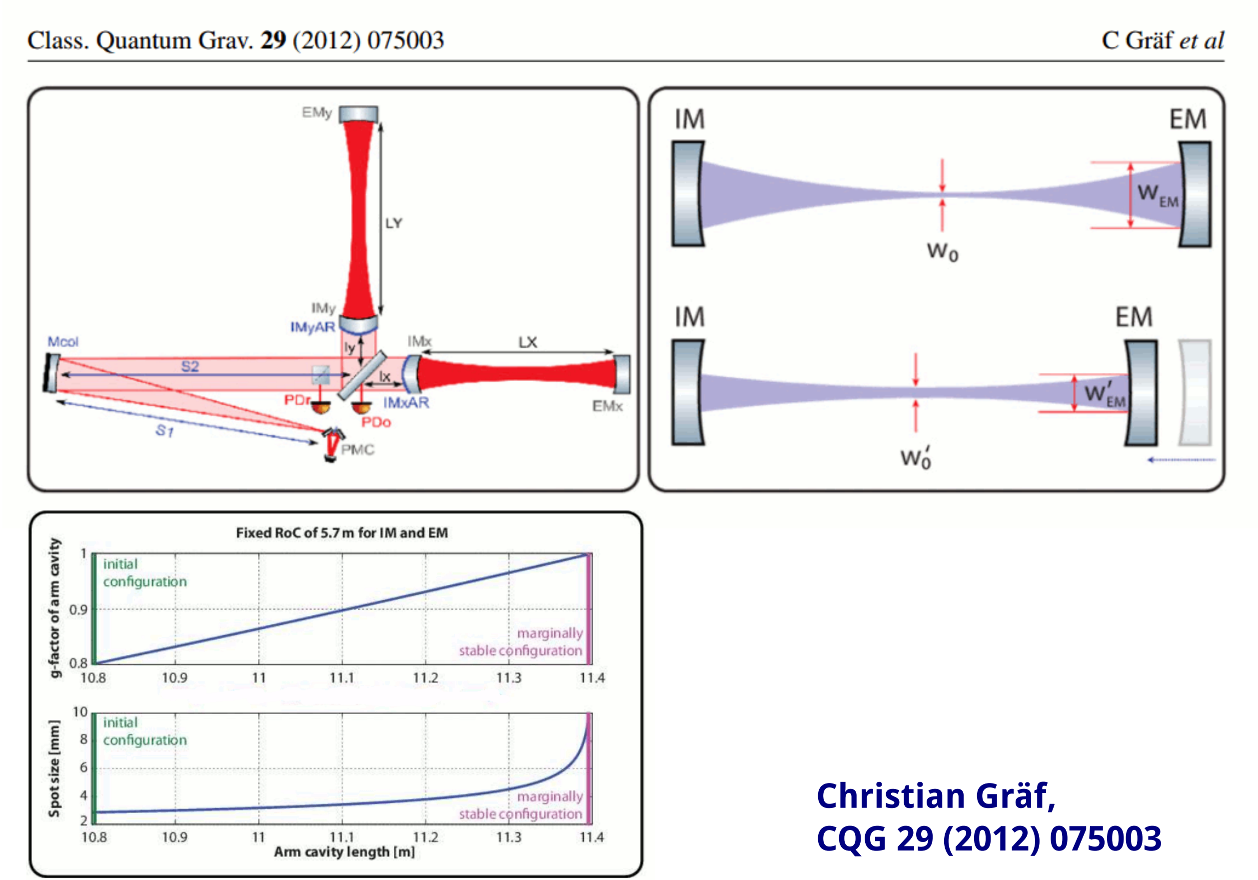
Builds on experience from GEO and aLIGO.

60 mm X 0.3 mm !

Talk by
Giles Hammond

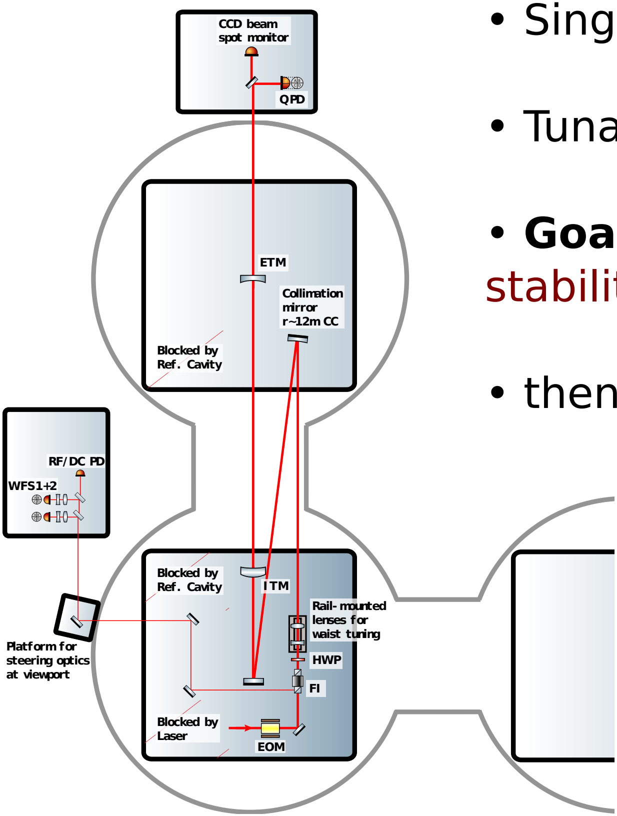
Designed, prototyped, & now in fabrication.

Tunable Configuration

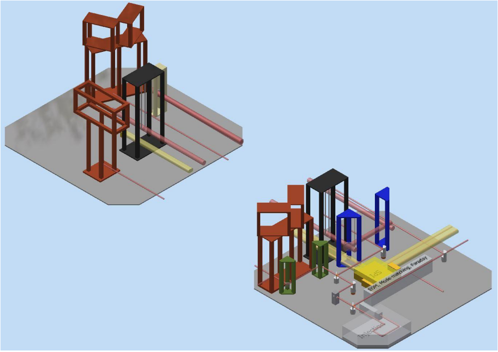


Christian Gräf,
CQG 29 (2012) 075003

Single Arm Test



- Single, impedance-matched cavity
- Tunable stability
- **Goal:** Learn to cope with marginal stability
- then: move to full FP-Michelson



Outlook

Amaldi 2007 - Sydney - Consensus to build GEO-squeezer

Amaldi 2013 - Warsaw - GEO uses squeezed light every day,
also demonstrated at LIGO

Amaldi 20xx - ???????? - Frequency dependent squeezing at the SQL

Amaldi 20xx - ???????? - ... in a GW-detector

Let's do it at the 10m prototype.

Thanks for listening!

10m posters

Gerald Bergman - Seismic isolation

Michael Born - Control and data system

Manuela Hanke - Frequency reference cavity

Fumiko Kawazoe - Frequency reference cavity

Sina Kohlenbeck - Suspension platform interferometer

Tobias Westphal - Thermal noise interferometer