The GEO600 detector: Status and Plans

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for the GEO-Collaboration

LIGO-T070067-00-Z

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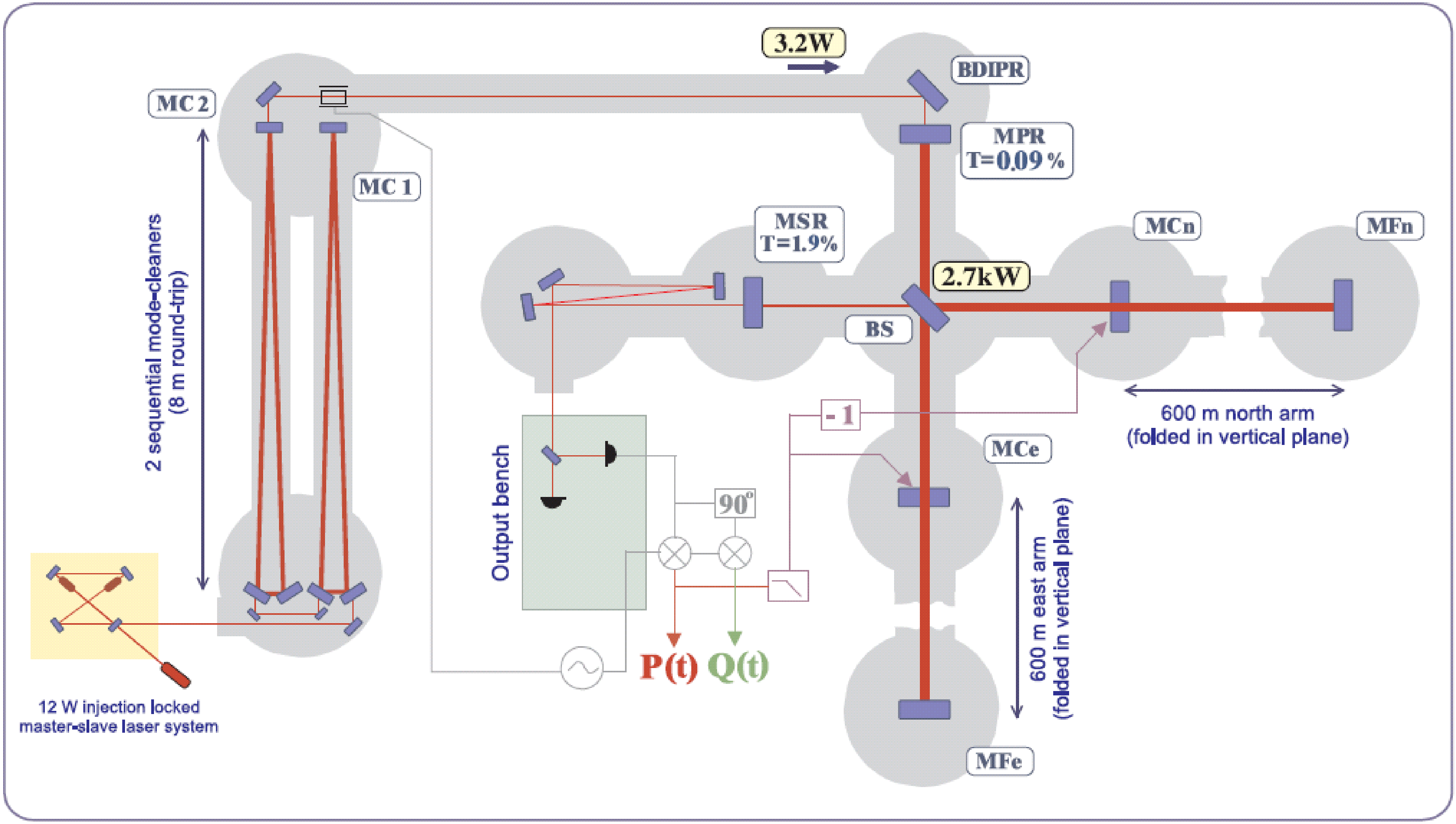
IGR
Universitat de les Illes Balears
Cardiff University

Overview

- **The GEO600 detector**
- **Participation / Performance in S5**
- **Recent efforts**
  - gain understanding of detector
  - improving the detector / reduction of glitches
  - necessary maintenance work
  - test mass discharging
- **Plans for the future**

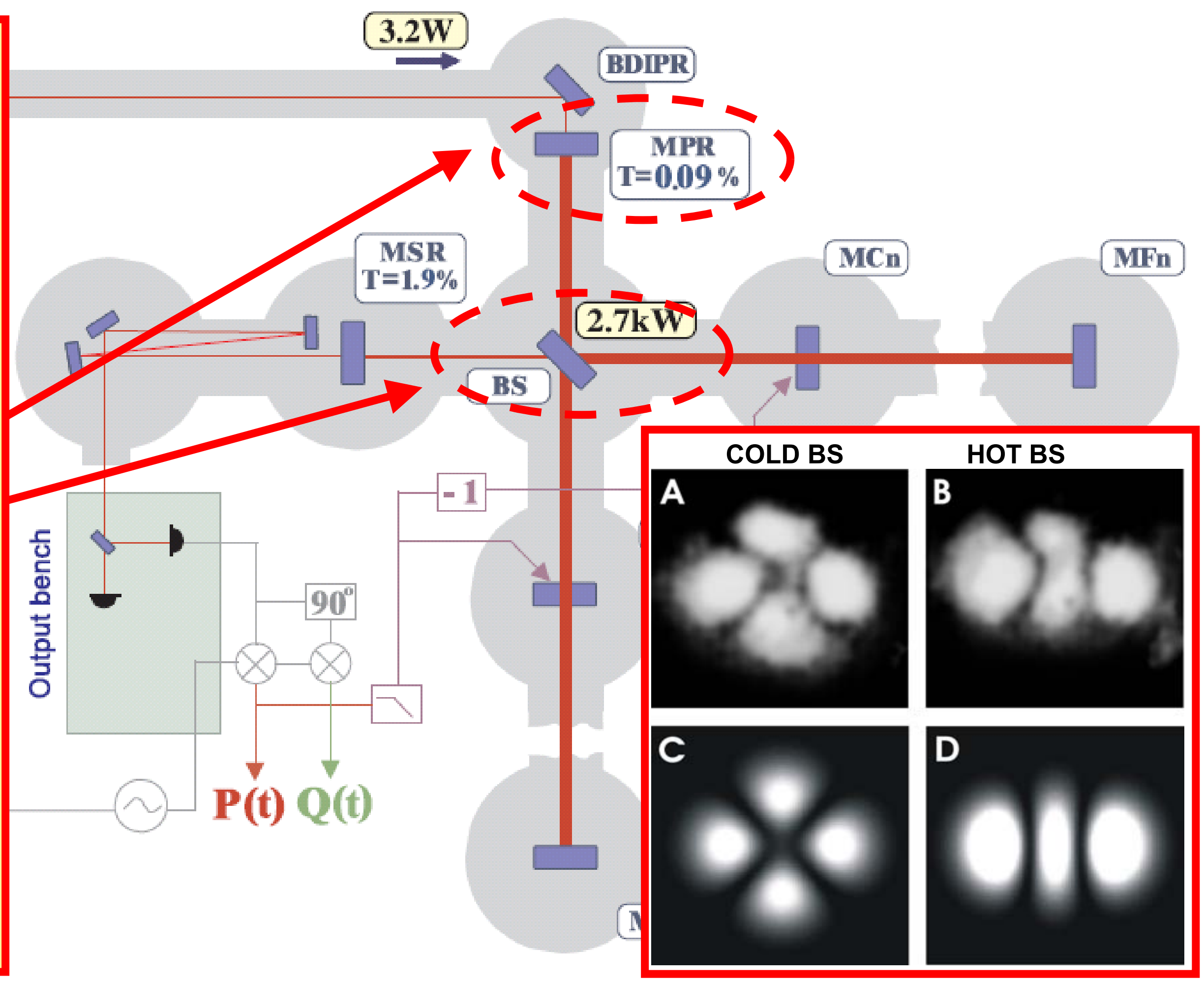
The GEO600 Interferometer



The GEO600 Interferometer

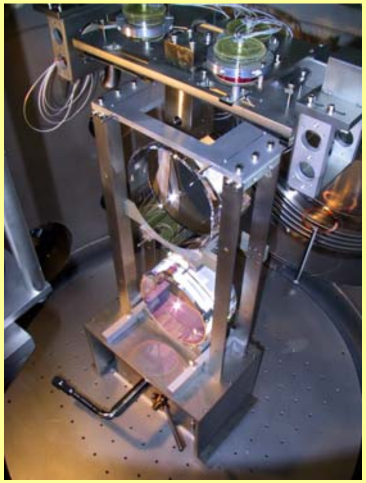
<u>No arm cavities, but folded arms:</u>

- **High PR factor (~1000)**
- **High power in BS substrate (~kW)**
- **Very low absorp-tion of BS substrate (< 0.25 ppm/cm)**

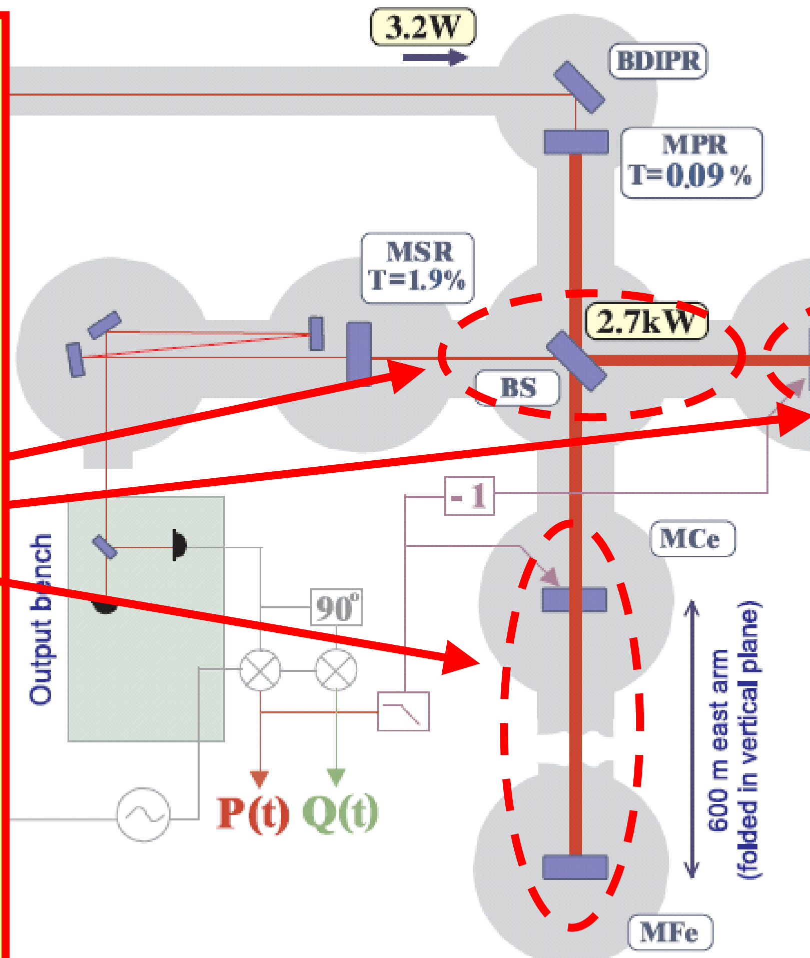


The GEO600 Interferometer

Triple suspensions:



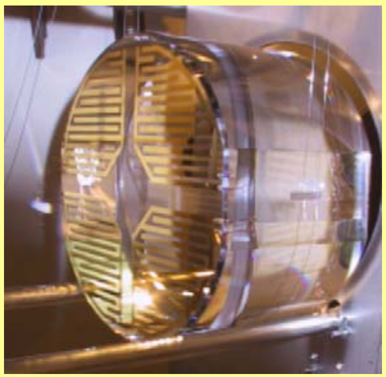
- **Monolithic stages**
- **Split-feedback (3 stage hirachical control)**



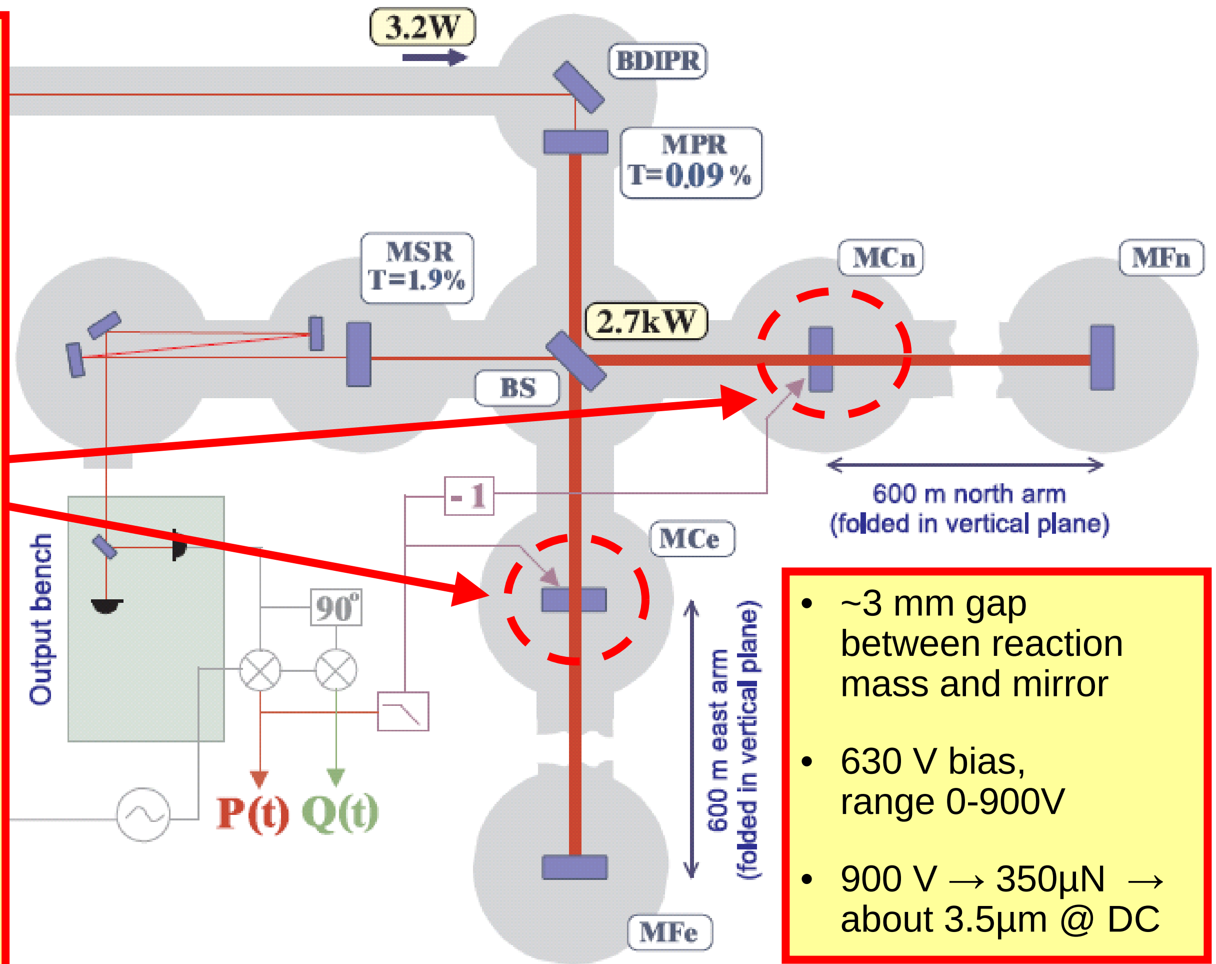
The GEO600 Interferometer

<u>Electro-Static Drives:</u>

- **Used for fast control of diff. armlength**



- **Near future: also used for autoalign-ment.**

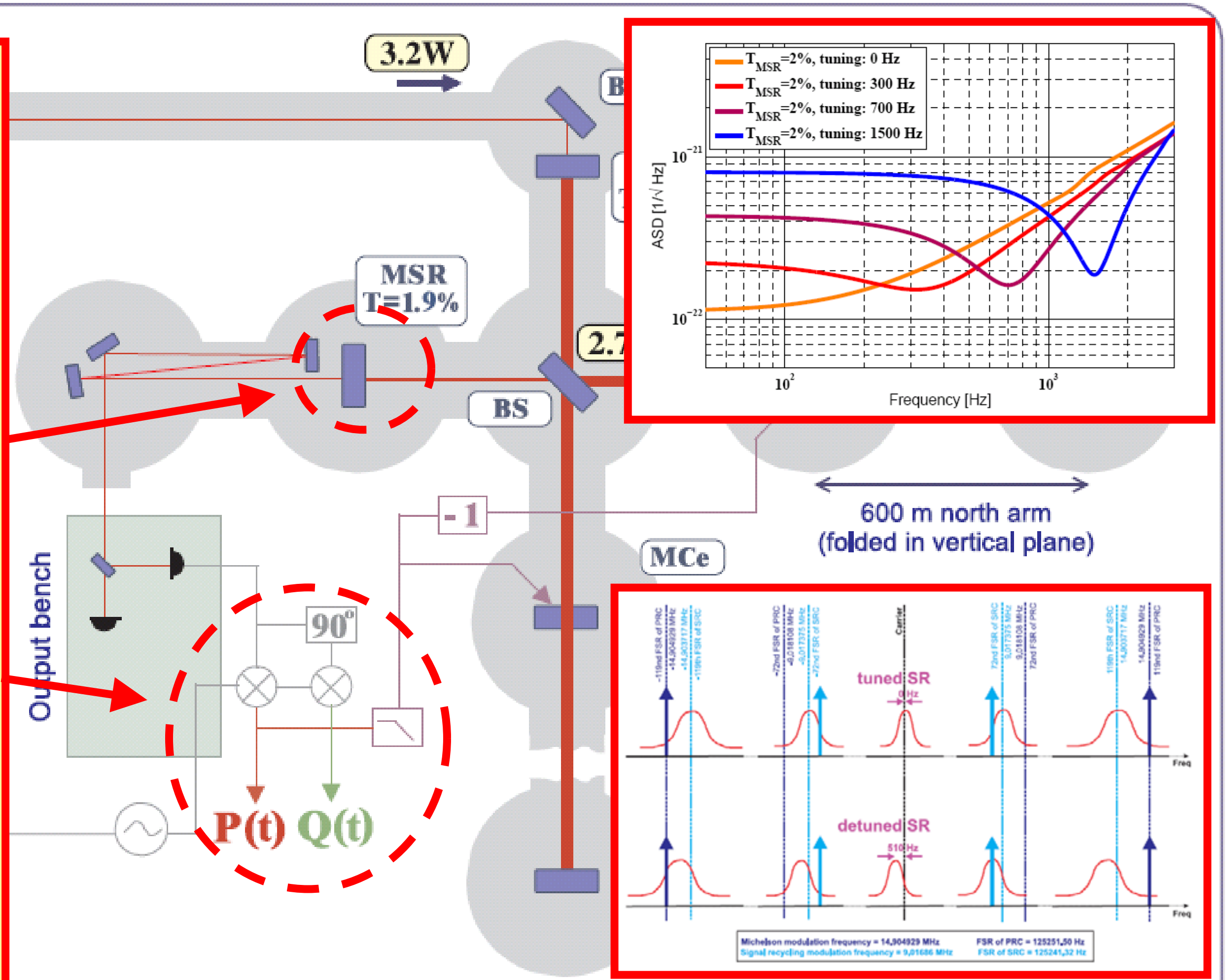


- ~3 mm gap between reaction mass and mirror
- 630 V bias, range 0-900V
- 900 V → 350µN → about 3.5µm @ DC

The GEO600 Interferometer

Signal-Recycling:

- **Shaping detector response**
- **Complicated detector (resonance conditions with detuned SR)**
- **GW signal is spread over both quadratures *P* and *Q*.**



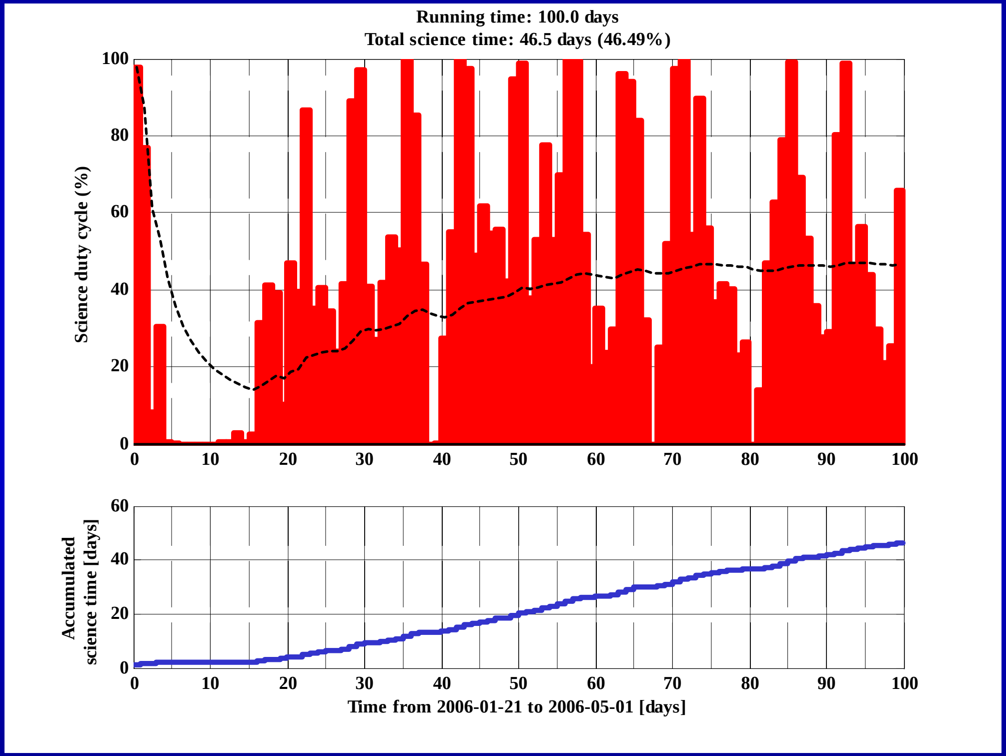
GEO600 in S5

Most of 2006 GEO600 participated in S5.

<u>O&WE-mode 1:</u>

20th January – 1st May

Science time = 46.5%



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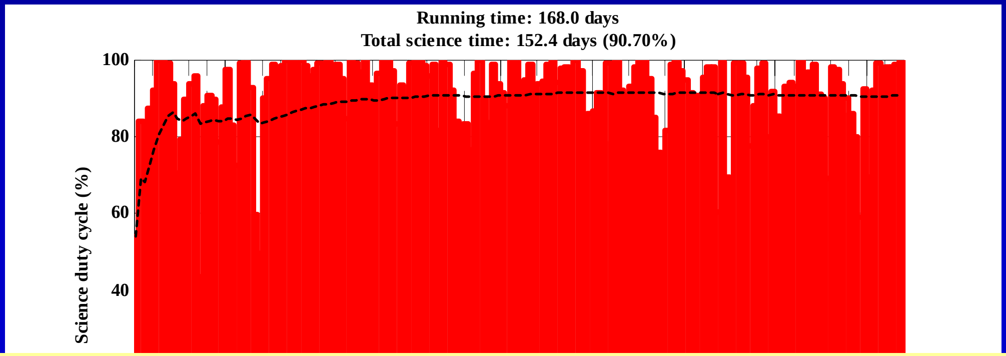
<u>24/7:</u>

1st May – 16th October

Science time = 90.7%



<u>Strategic Decision @ October GEO-meeting:</u>

- **Input:** LSC data analysis groups, LSC operations committee, Benefit/Risk-analysis from commissioning team.
- **Result:** O&WE-mode period 2
  - Gain understanding of the detector
  - Improving GEO600
  - Maintenance work required to prepare GEO for a long science run in 2008

GEO600 in S5

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24/7:

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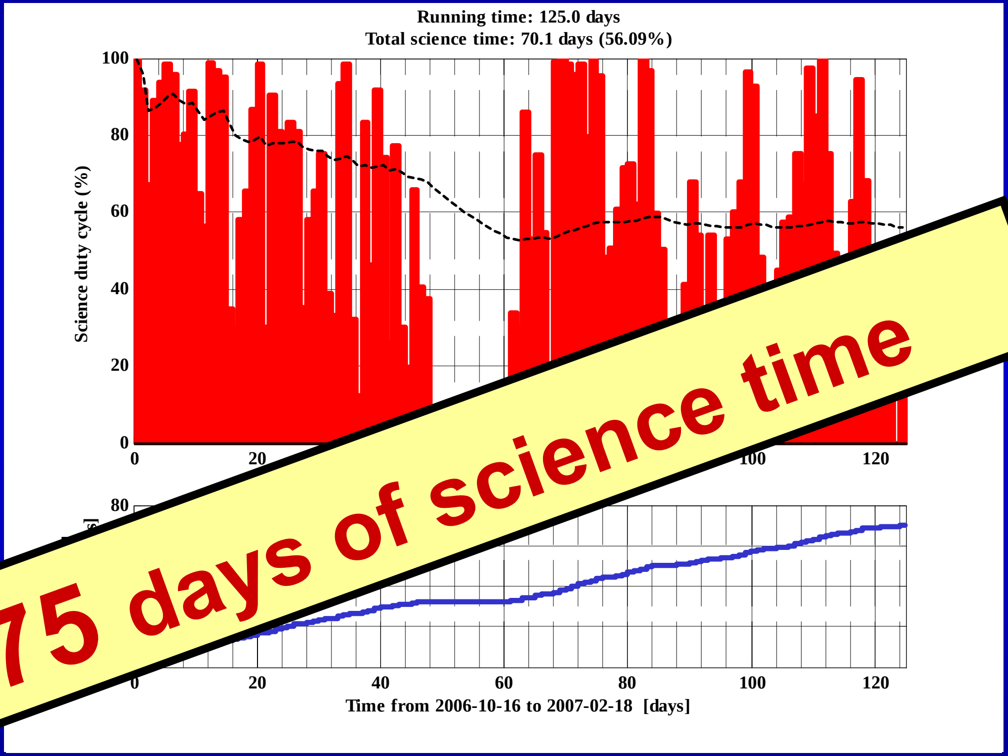
O&WE-mode 2:

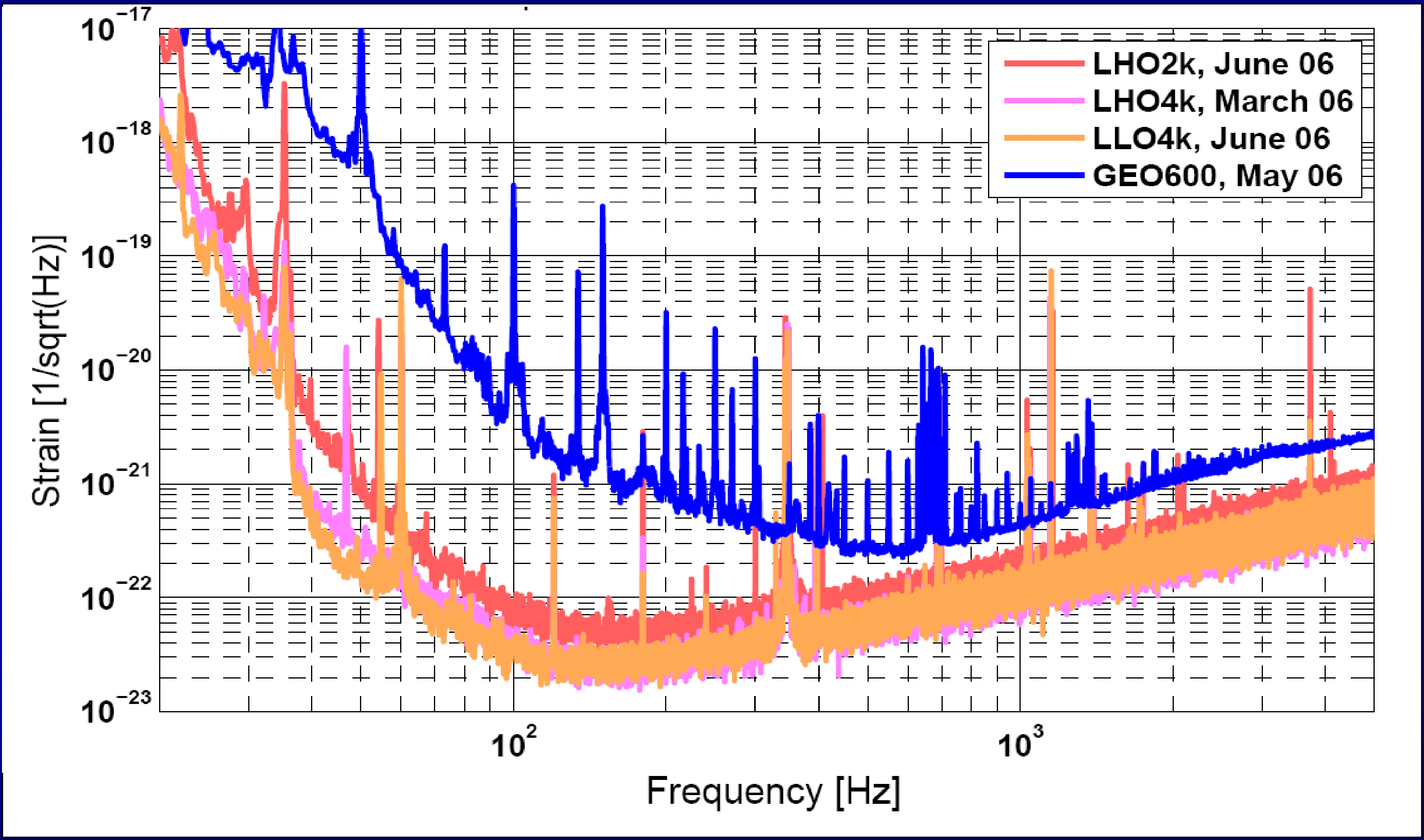
16th Octo

Sc .1%

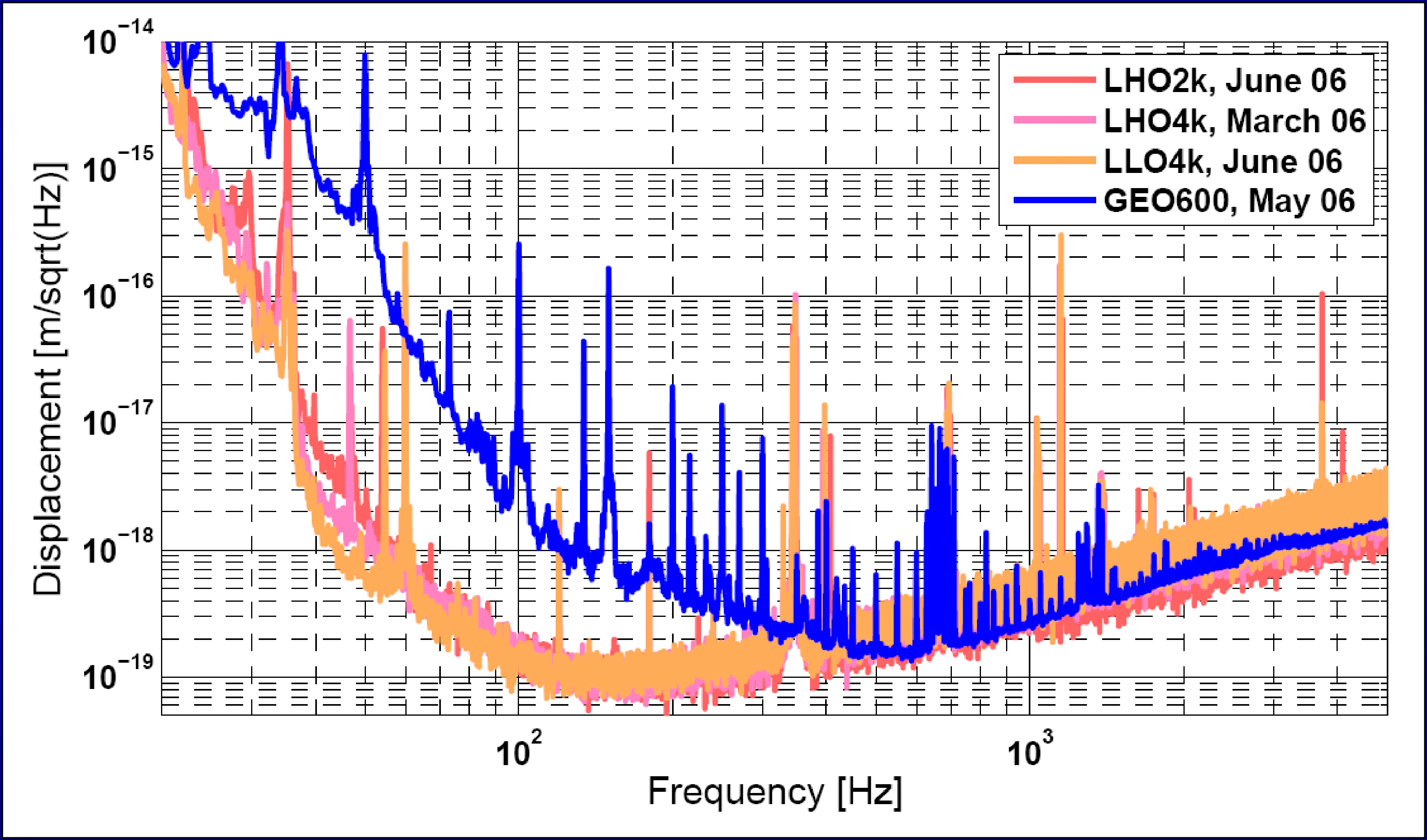


Overall about 275 days of science time

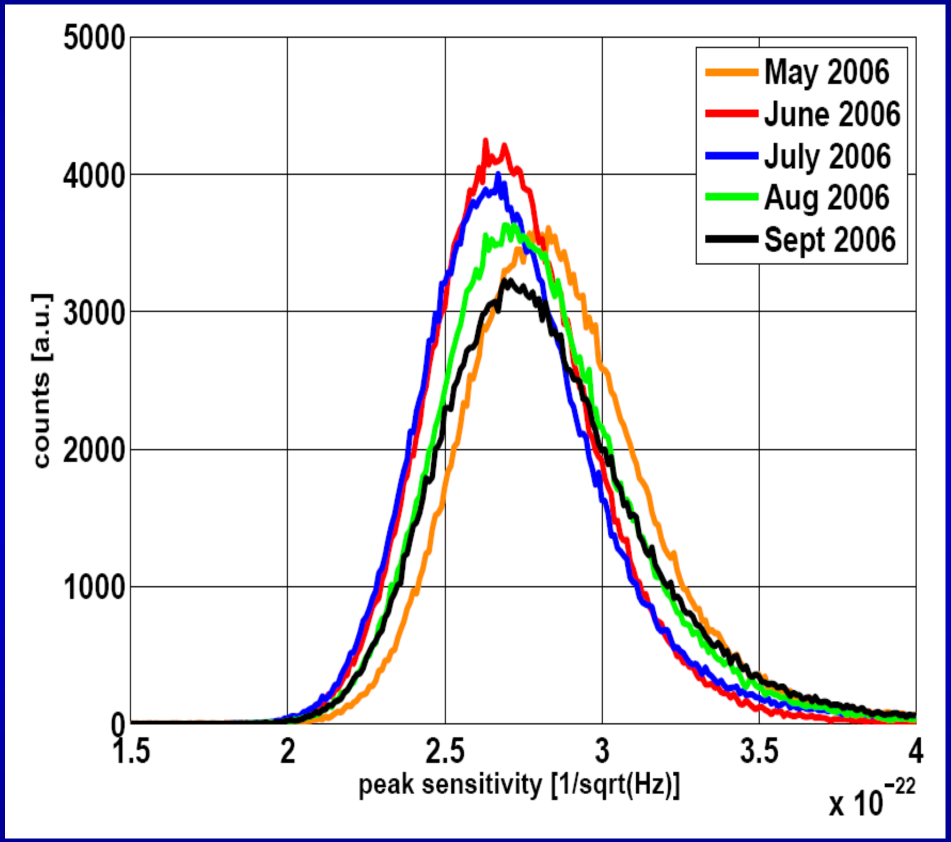
Strain sensitivity of LSC IFOs in S5



Displacement sensitivities in S5

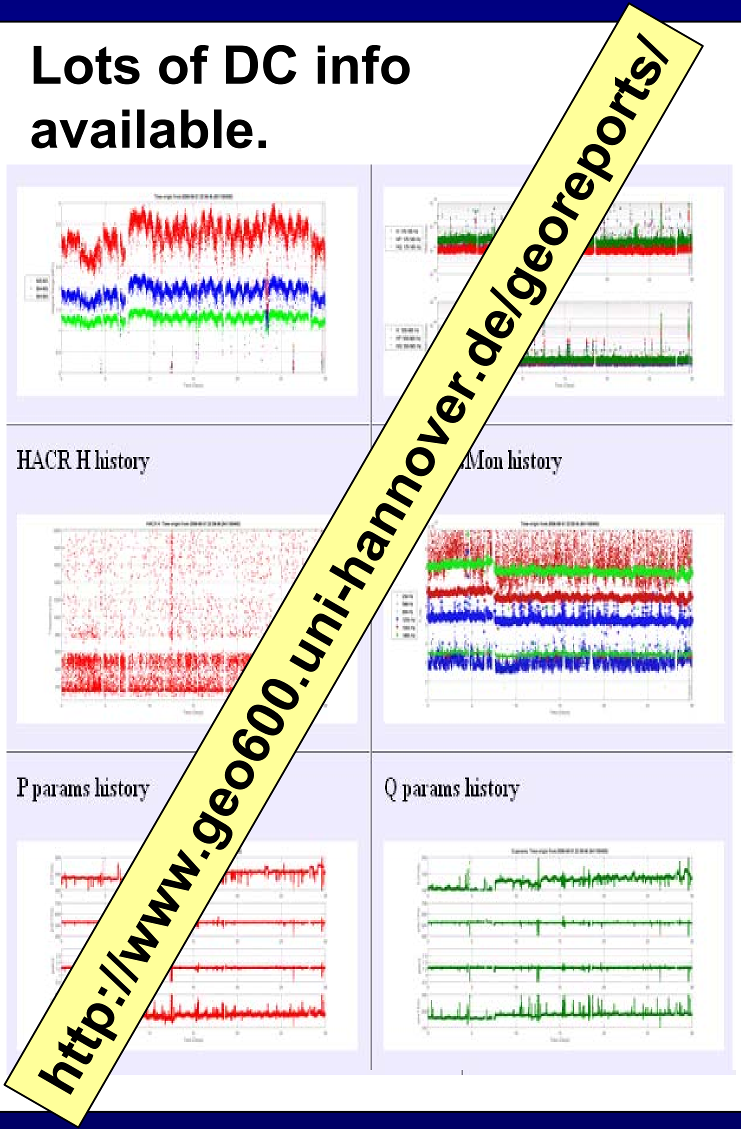


Detector stability in S5

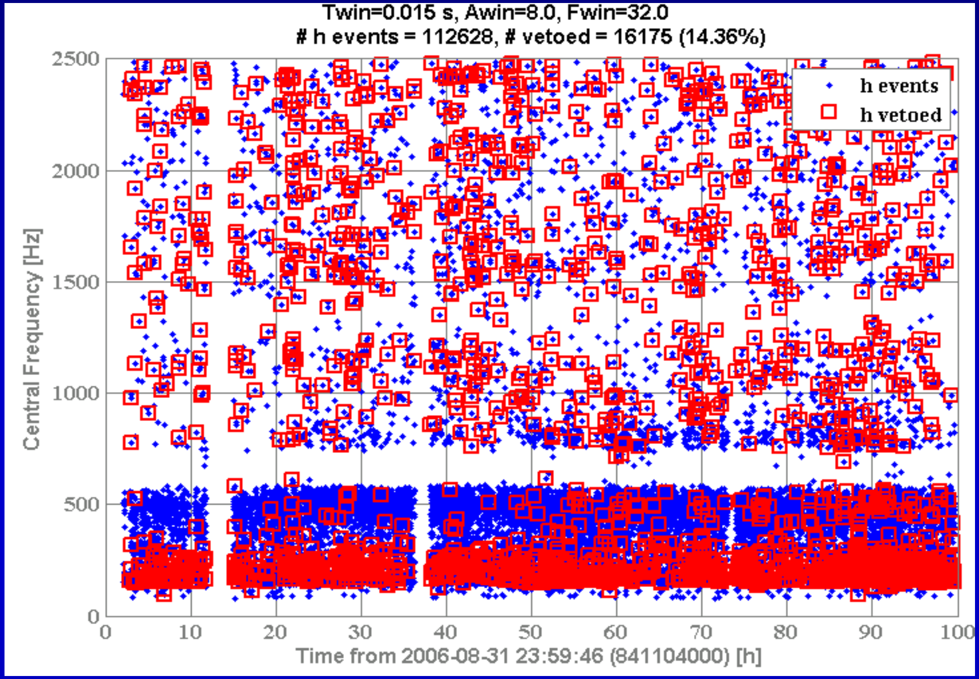


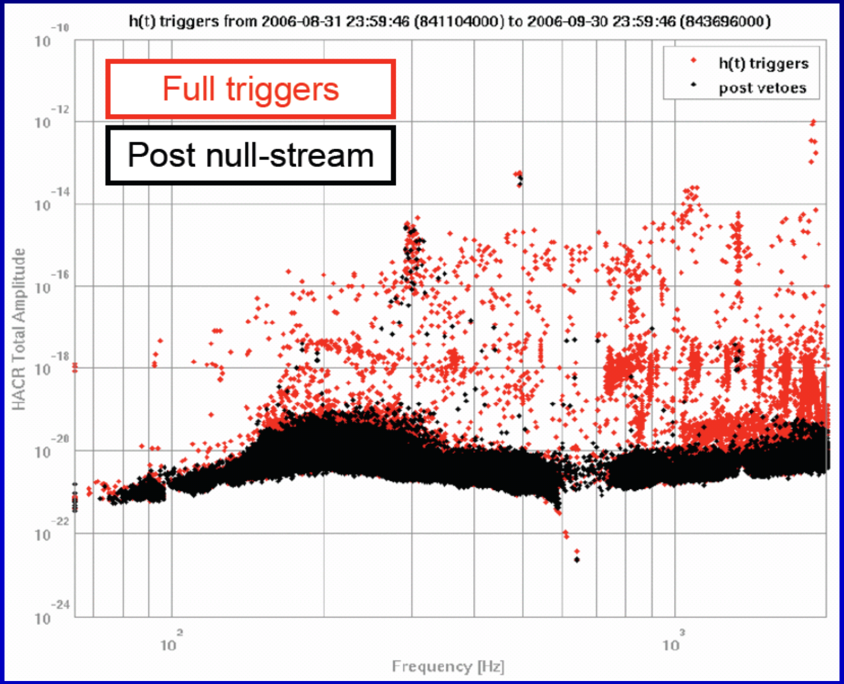
Average peak sensitivity better than 3e-22/sqrt(Hz)

Lots of DC info available.



Glitches and vetoes





- Nullstream veto
- Chi^2 veto
- Noise projection vetos
- Statistical vetos

M Hewitson et al: Using the null-stream of GEO 600 to veto transient events in the detector output, CQG 22 No 22, 4903-4912

M Hewitson: Detector and data characterisation at GEO 600, in preparation

P Ajith et al: Robust vetoes for gravitational-wave burst triggers using known instrumental couplings, CQG 23 No 20, 5825-5837

S Hild et al: A statistical veto employing an amplitude consistency check, submitted to CQG

Overview

- **The GEO600 detector**
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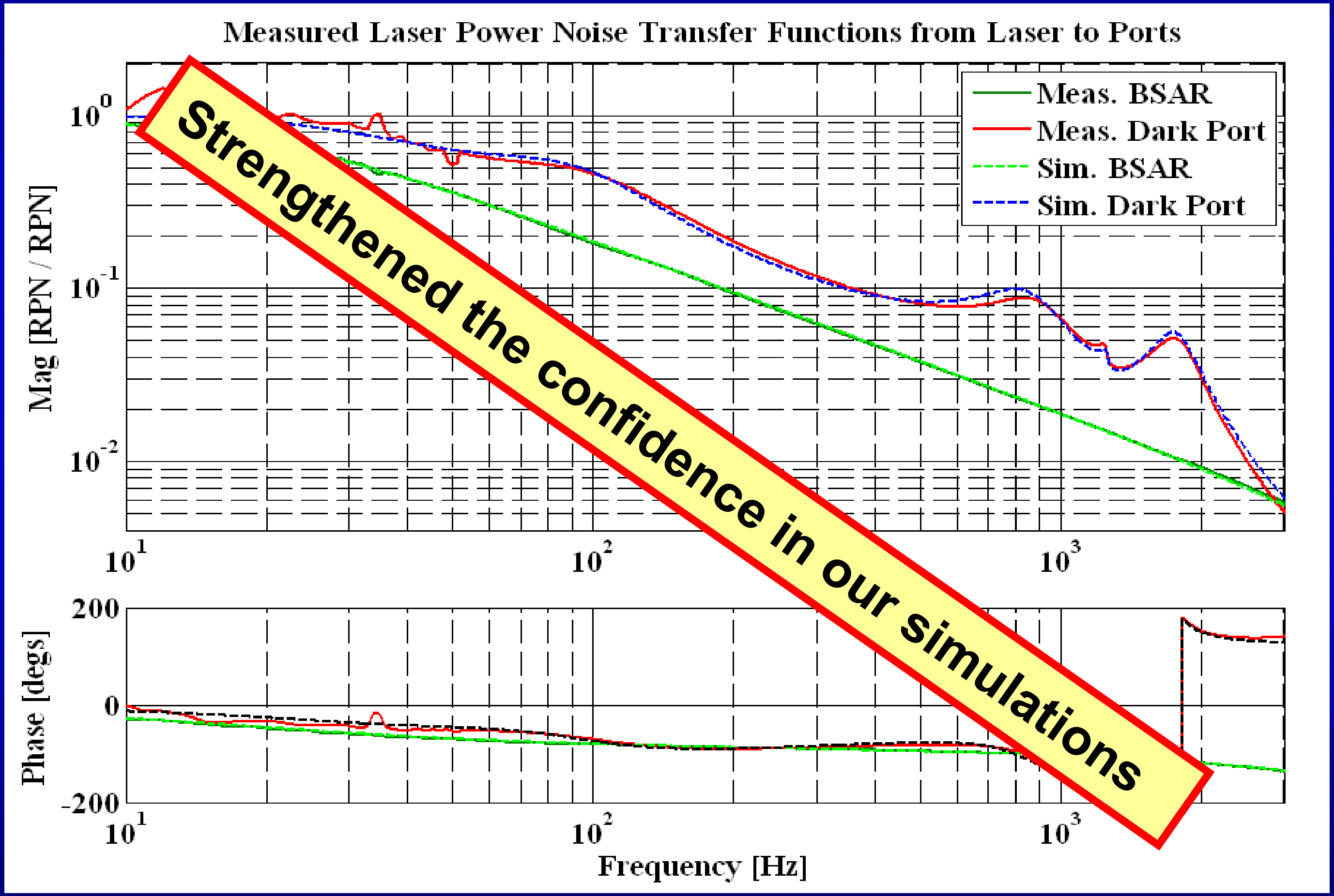
Improved understanding of the detector: Laser power noise coupling

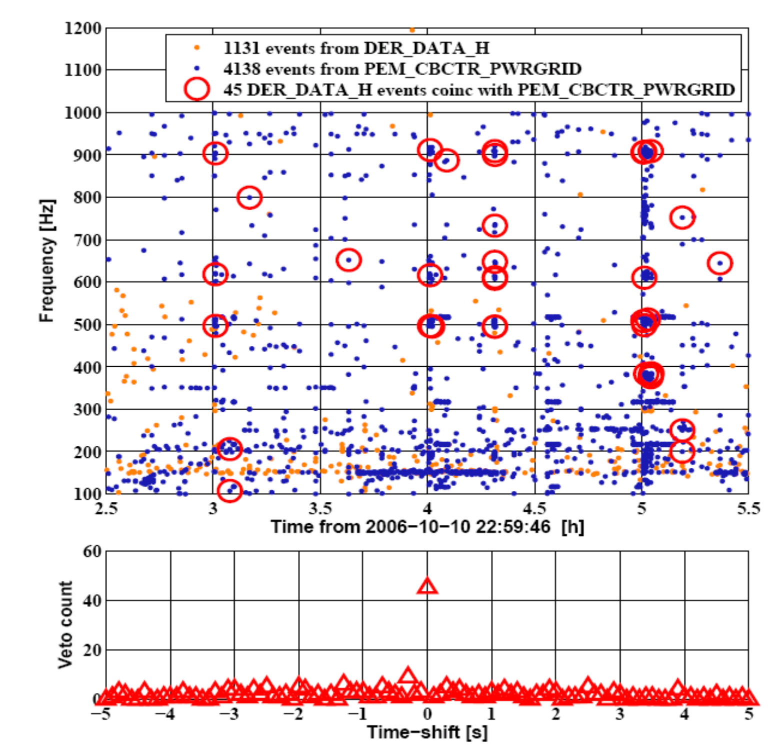
Laser power noise TFs using FINESSE match our measurements.

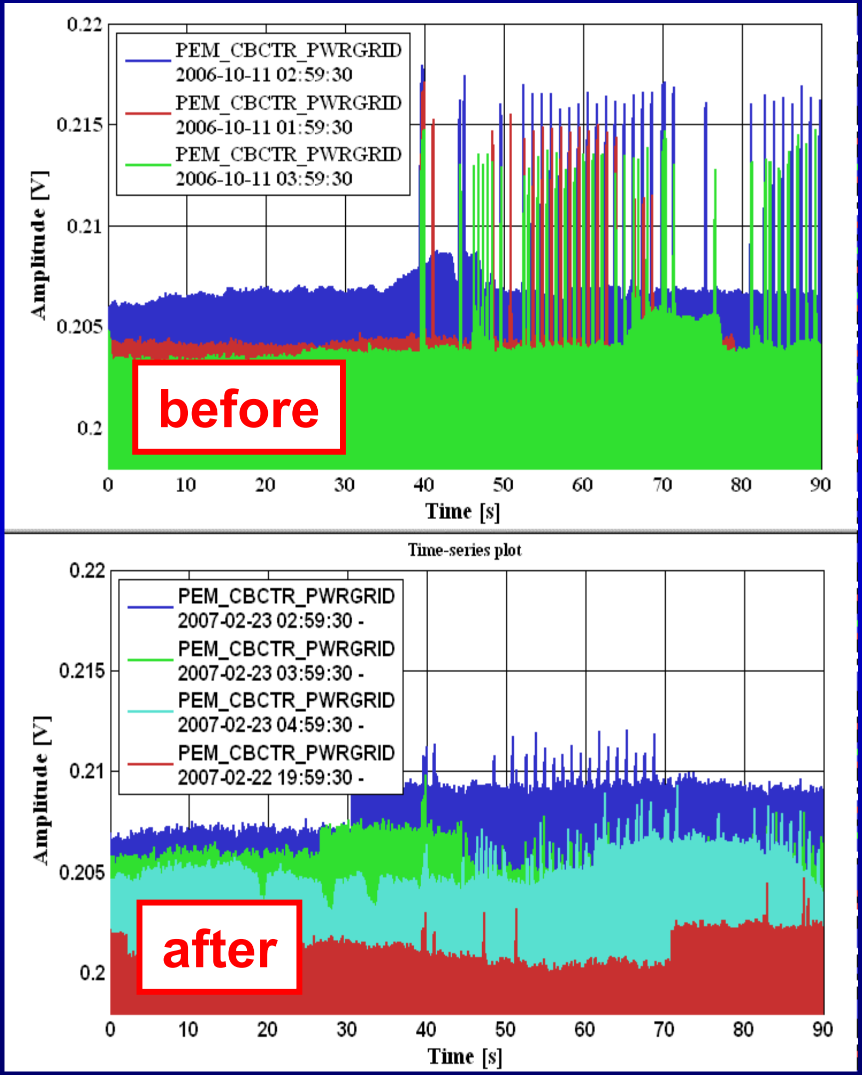


"Laser power noise coupling in GEO600" , JR Smith, A Freise, H Grote, M Hewitson, S Hild, H Lück, KA Strain, B Willke, in preparation

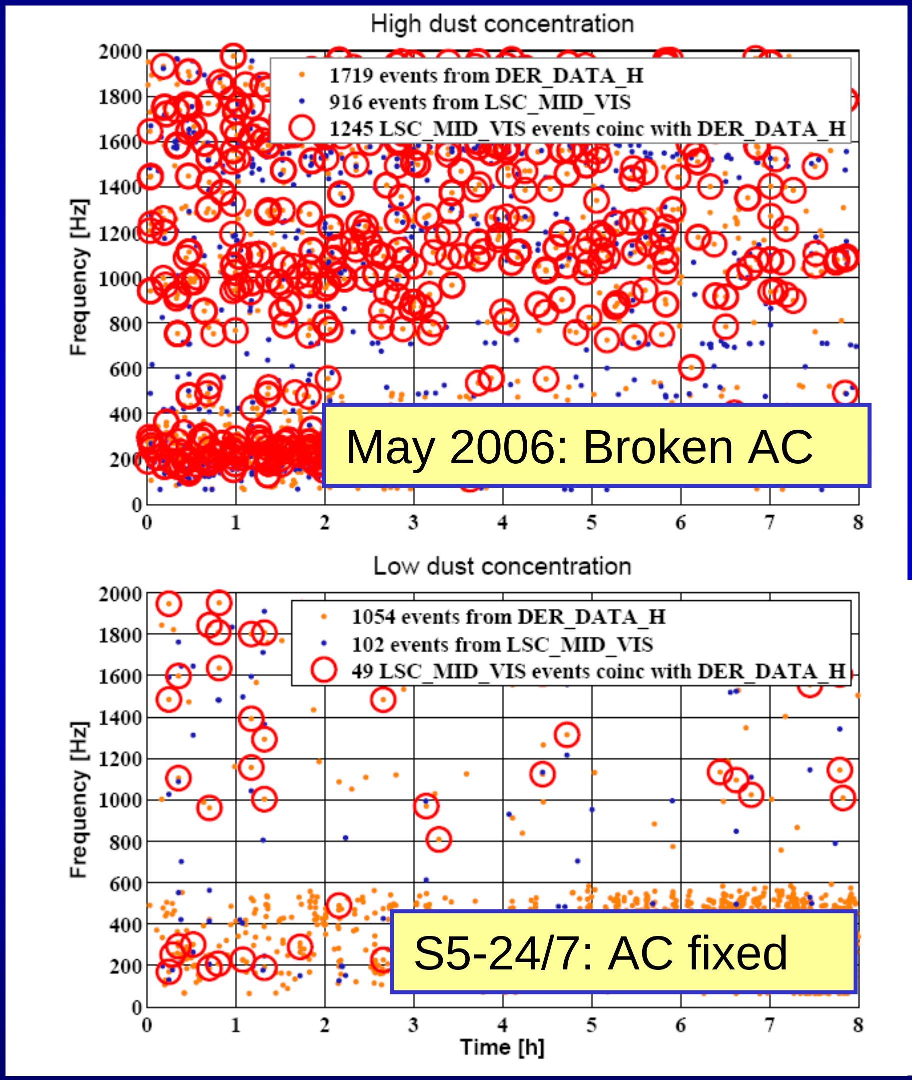
Installation of mains filter

- Found many glitches in GW signal at hour boundary (10 sec after)
- Coincident events in mains monitors
- Control signals created by power companies.
- Solution: Installation of mains filter.





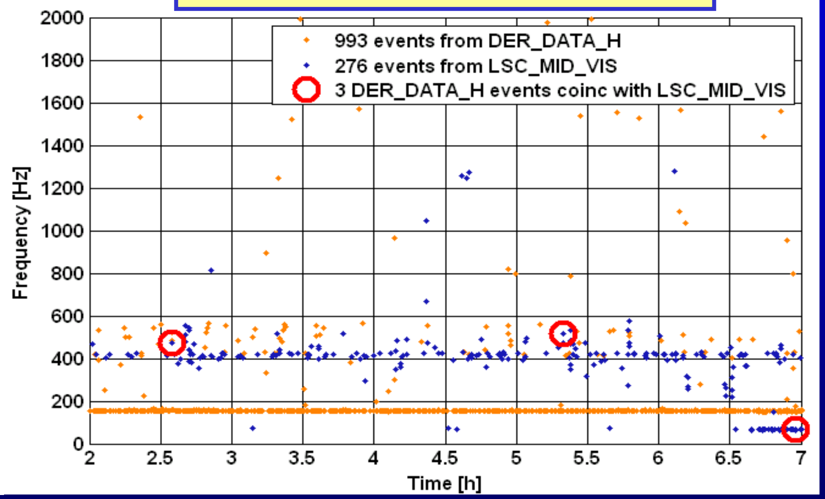
Reduction of particle concentration in the cleanroom



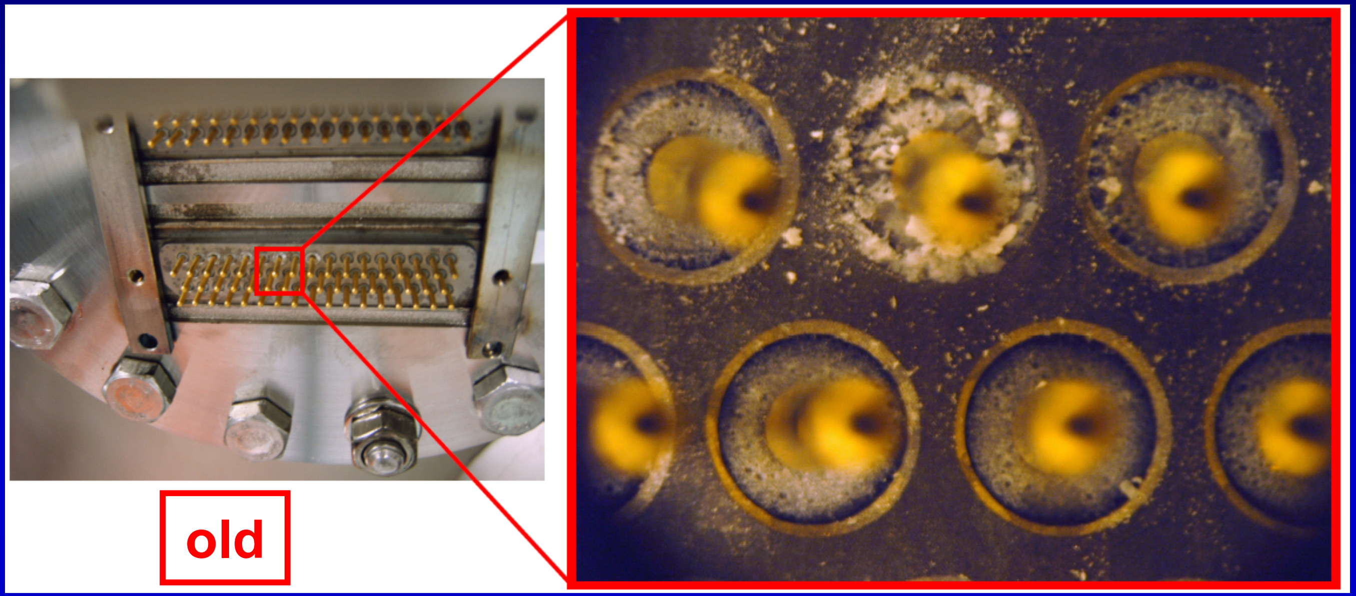
Glitches caused by dust falling through the laser beam in front of main photo diode.

(veto available for dust glitches)

January 2007:
Improved dust filtering



Exchanged HV-feedthroughs

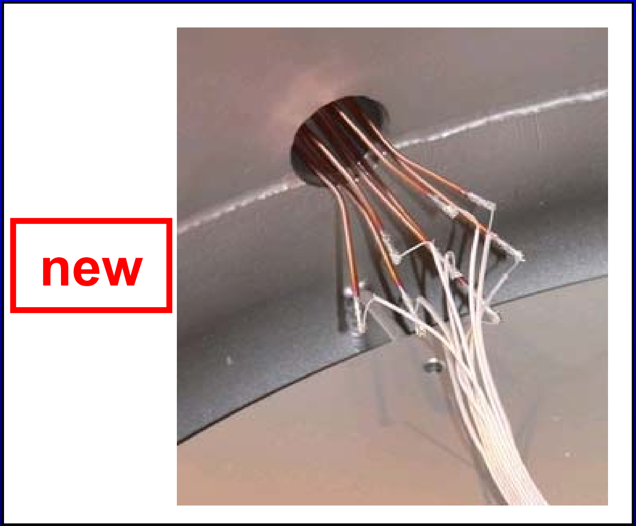


Installation in March 2001

Failed due to corrosion in August 2004

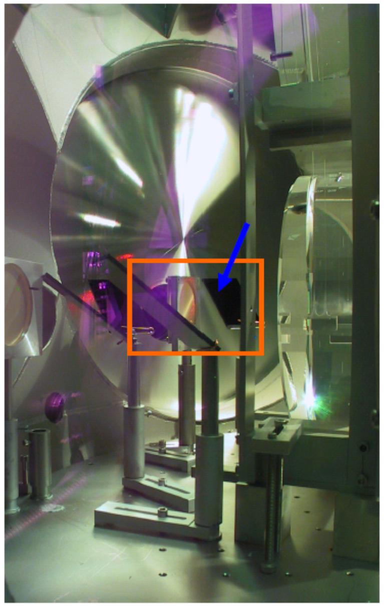
Since then using the spares !!

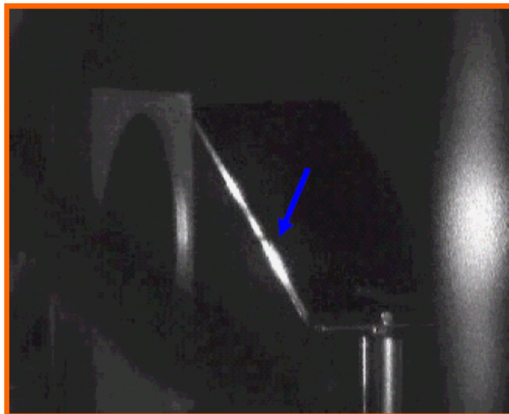
Replaced in Febuary 2007

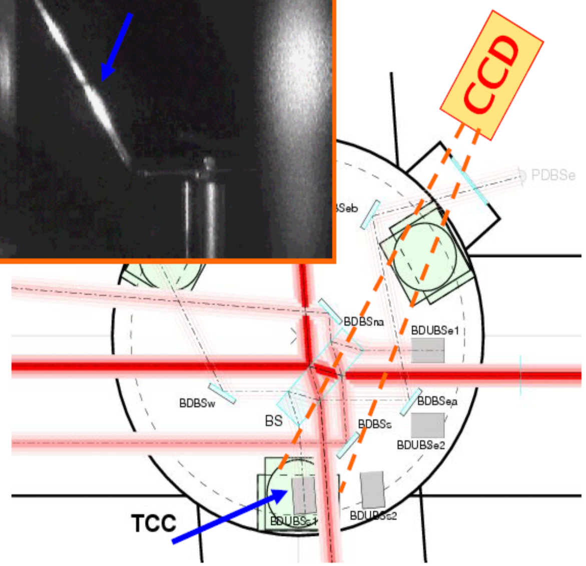


Fixed beam clipping inside Signal-Recycling cavitiy

old







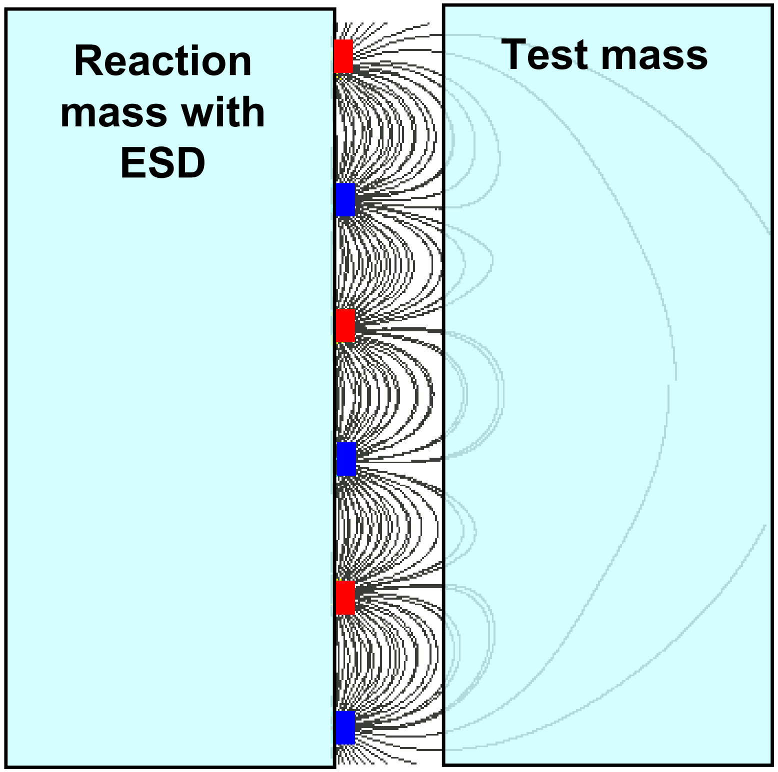
Suspect the beam dump to clip the beam (blue arrows)

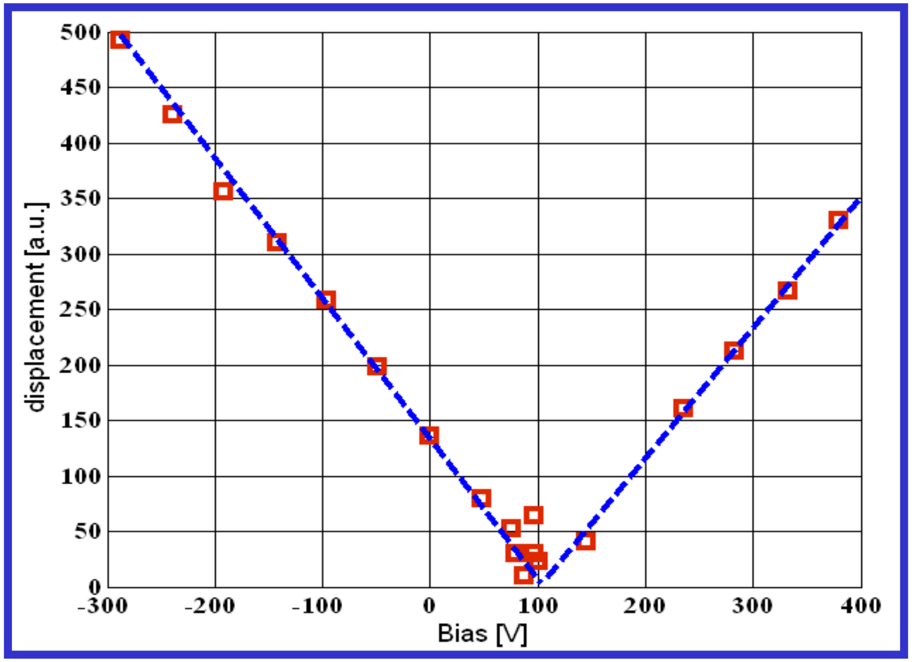
new

Solution: Beam dump on translation stage

- Piezo actuator
- Range of 28 mm
- Load: up to few 100g

Charges on test masses after vacuum work





$$F = U^2\, \varepsilon_0\, \varepsilon_r\, d^{3/2} A = (U_{bias} + U_{signal})^2 \cdot const$$
$$= F_{Offset} + U_{bias} \cdot U_{signal} \cdot const + U^2_{signal} \cdot const$$

After the vacuum work we found the test masses to be charged (+100V/+30V)

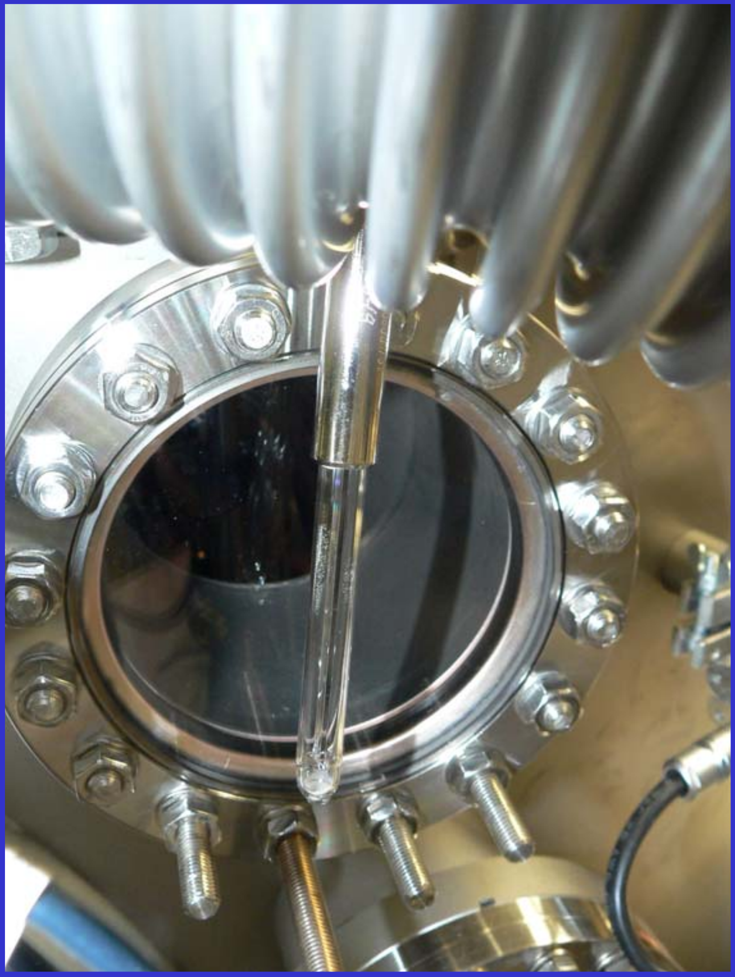
Uncharching test mass by UV light

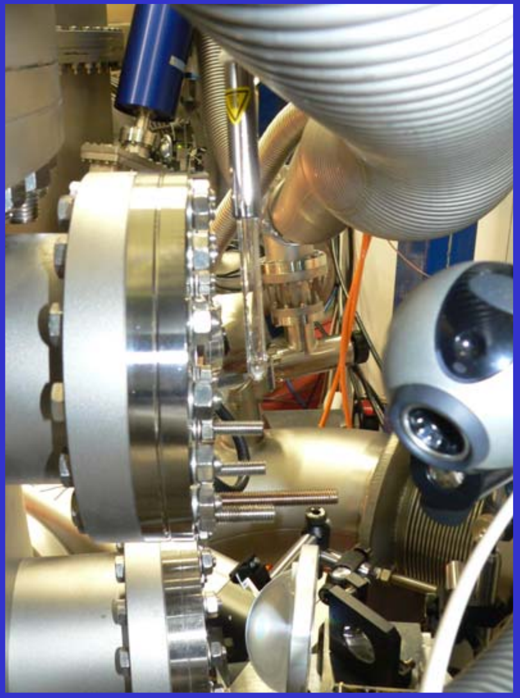
S. Rowan et al, CQG. 14 1537–1541 (1997):

Discharging by use of UV light to free electrons.

<u>In our case:</u>

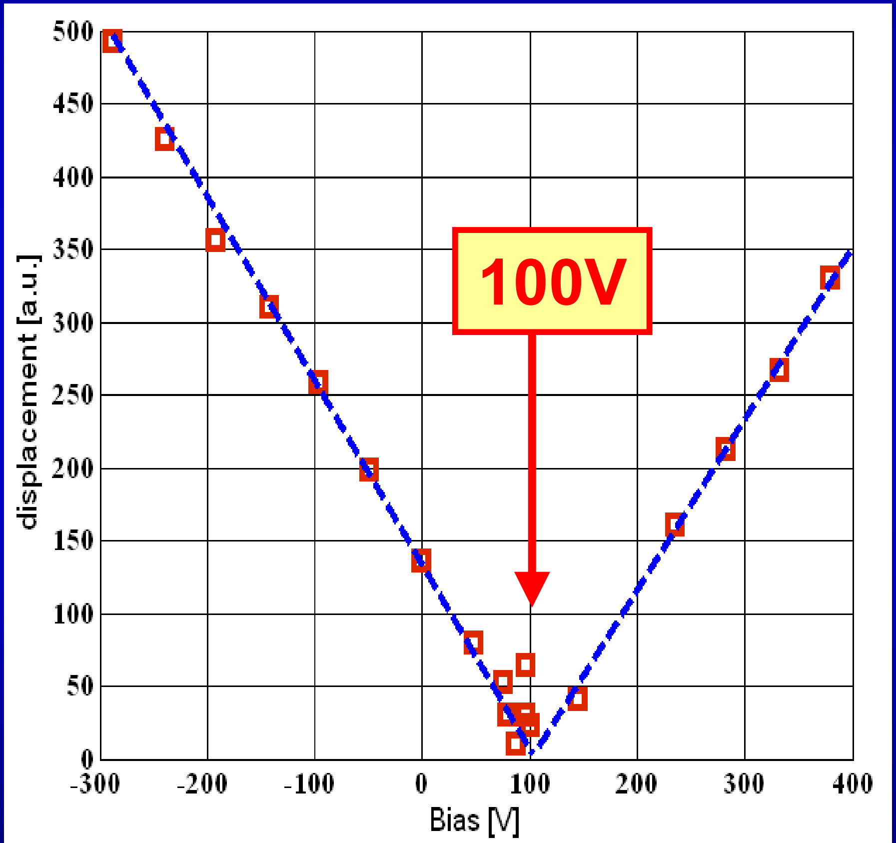
- UV transmitted through test mass
- electrons are freed of the ESD electrodes
- electrons compen-sate positive charge on test mass



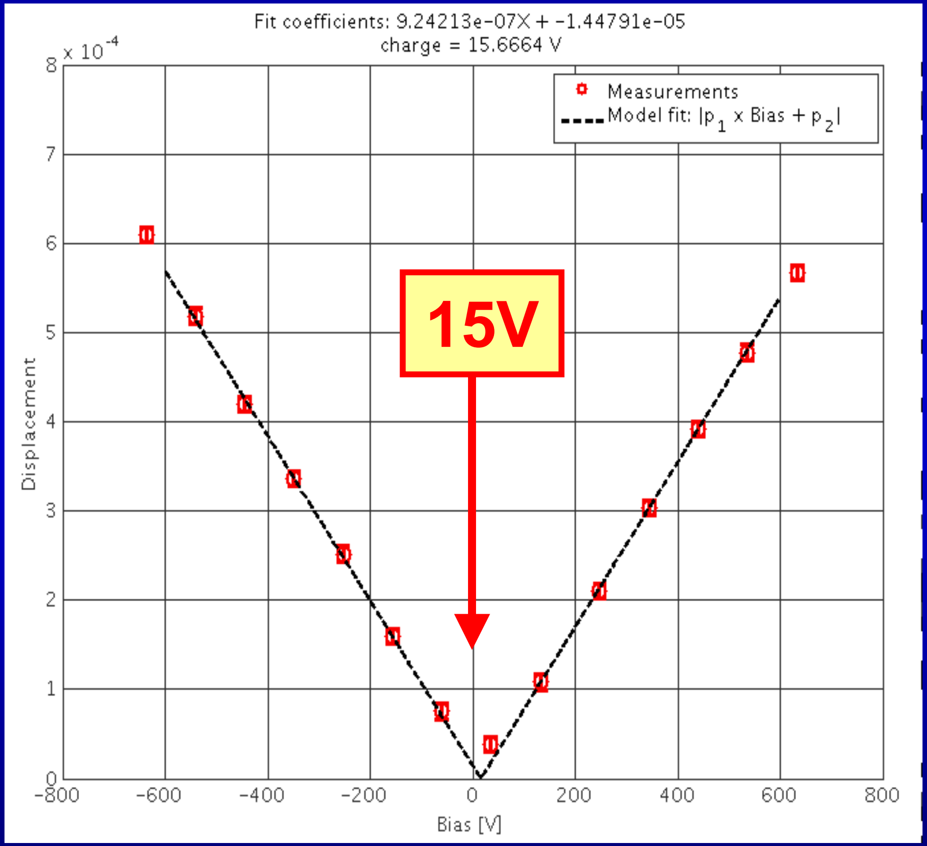


Sucessfully discharged the test masses

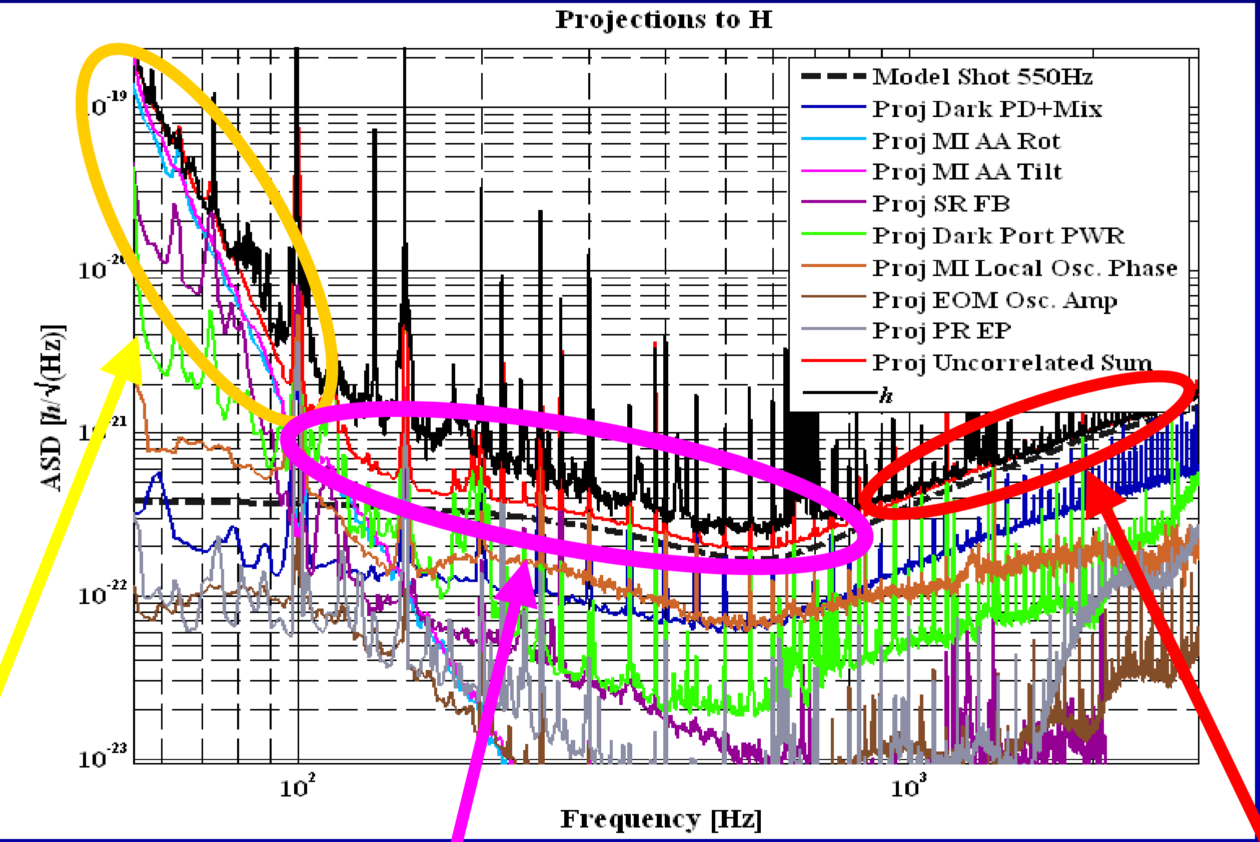
BEFORE



AFTER



Noise projections



Feedback noise

⇒ ESD for fast AA

unexplained

⇒ Strong indication for scattering

⇒ larger viewports in the endstations

Shot noise

⇒Increase light power

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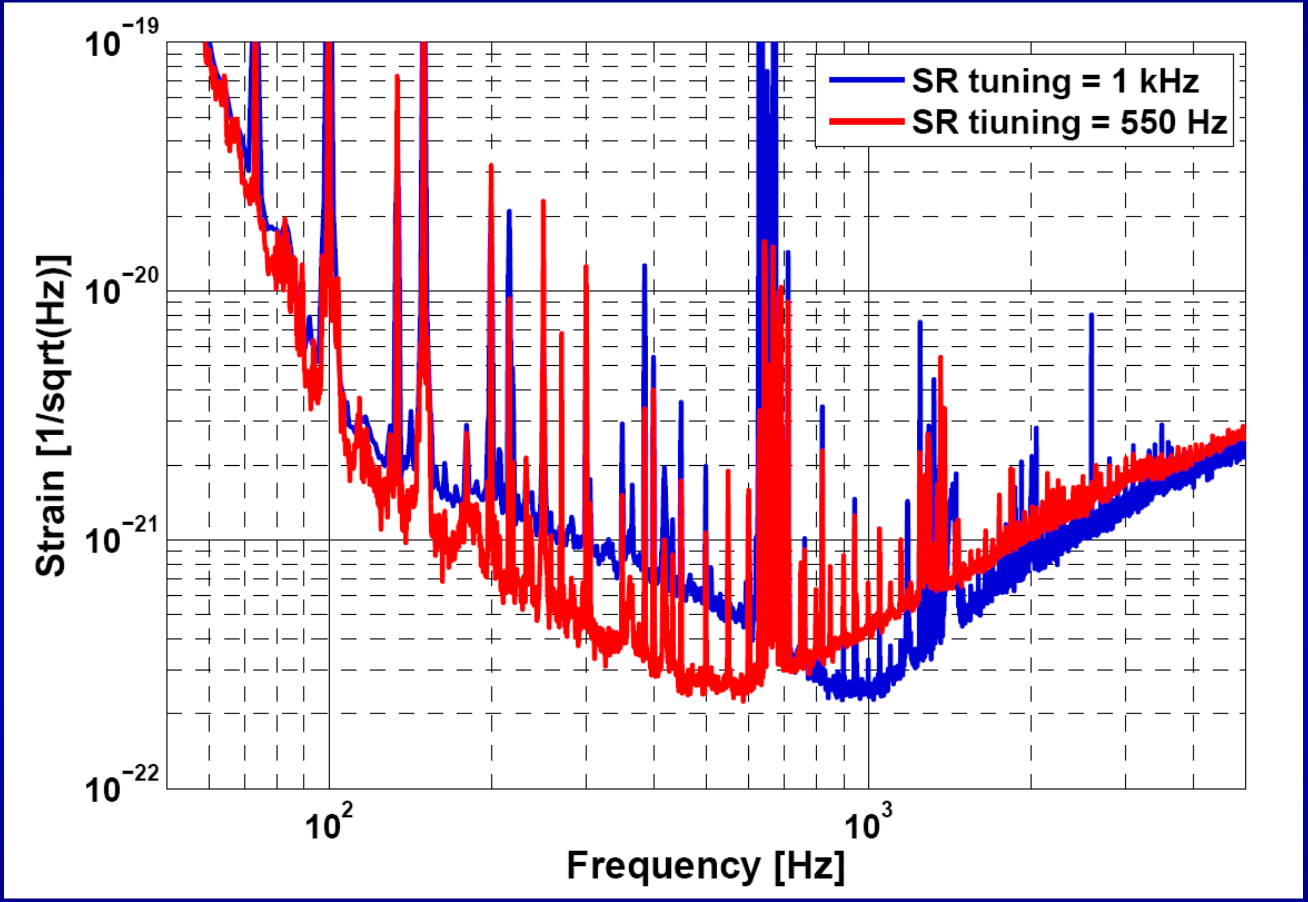
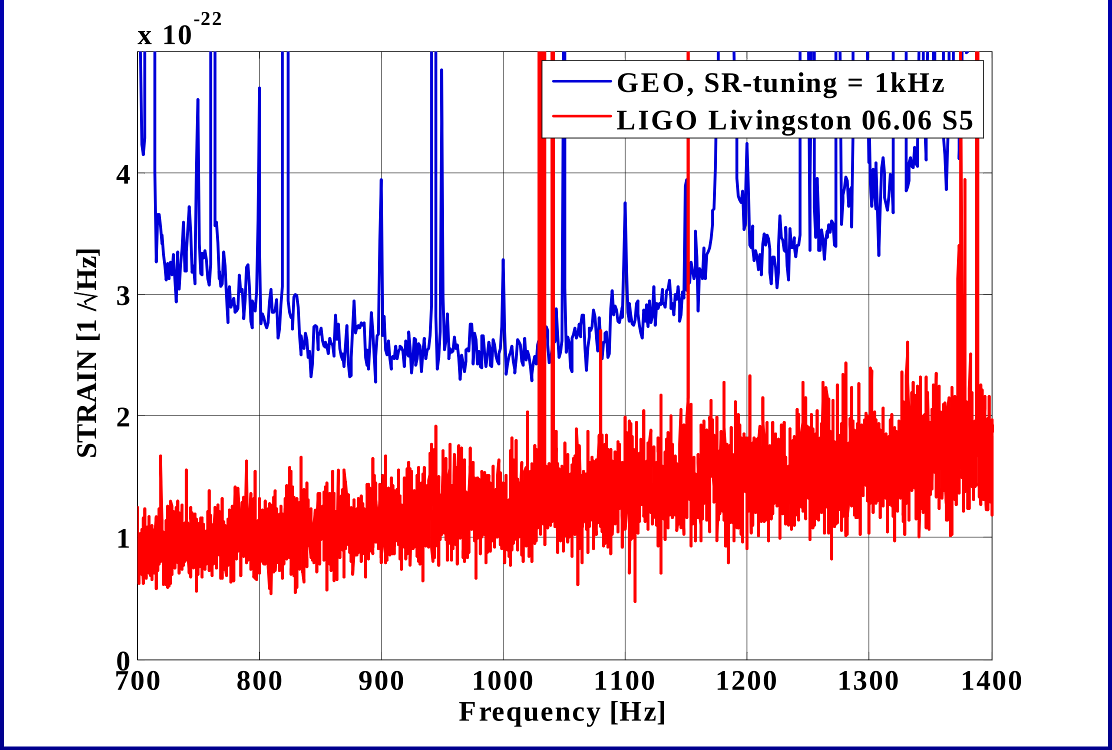
Different SR-tunings



Peak sensitivity better than 3e-22/sqrt(Hz) for both tunings.

SR tuning of 1kHz

Around 1kHz GEO**600** is about a factor **2** worse than the LIGO **4**km Instruments.



Consider to use this tuning in the near term in order to improve the science impact of GEO600.

DC-readout without OMC

IDEA:

- Turning down the RF-modulation *(factor 10 is possible)*
- Using an offset from dark fringe *(of the order of 50pm)*

⇒ Dark port dominated by carrier light

Nominal heterodyne

Heterodyne with only 10% modulation

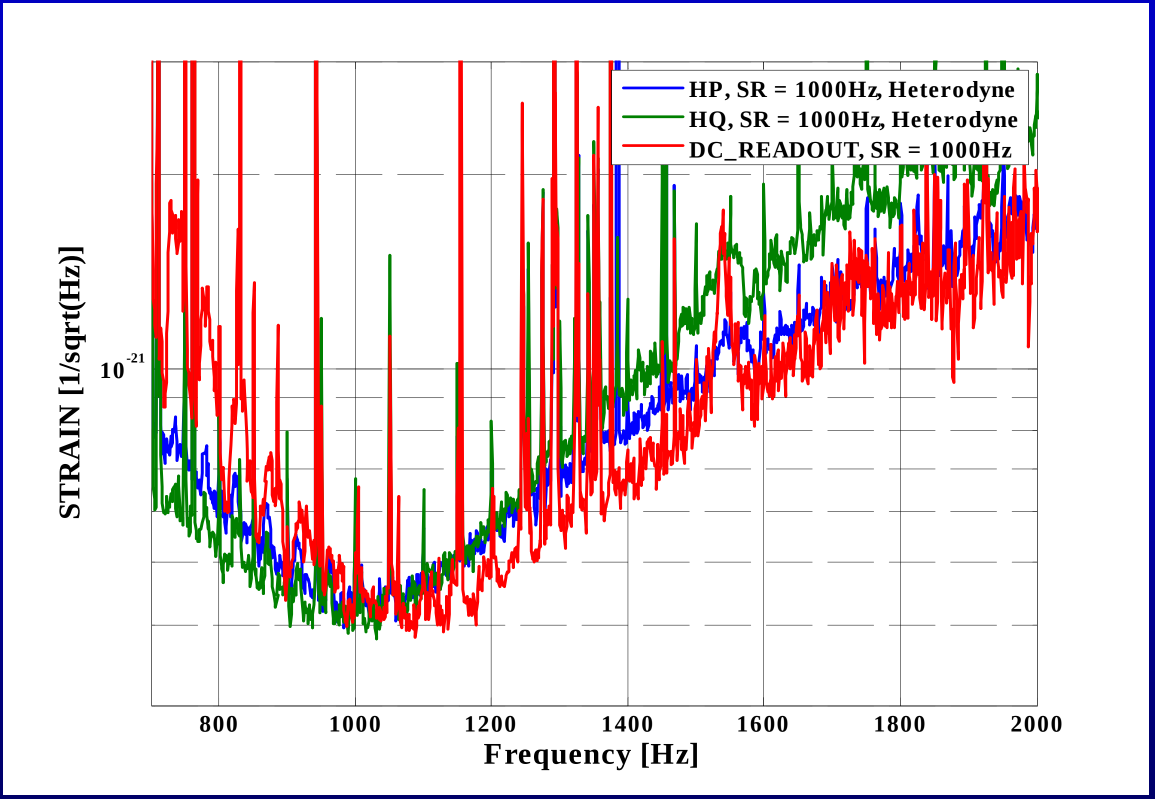
Offset to dark fringe (~ 50pm)

Results from first Experiments with DC-readout

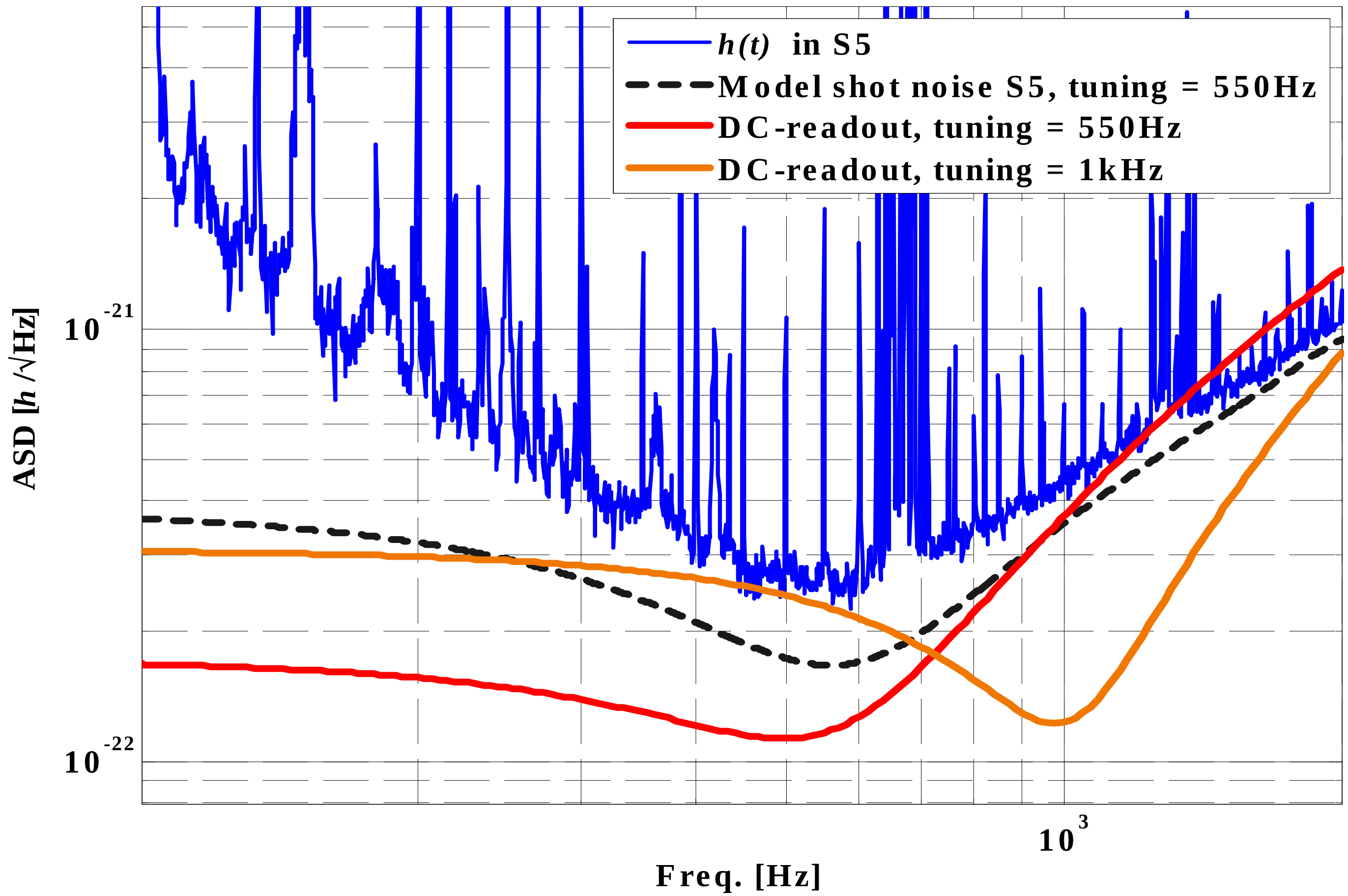
- Stable interferometer with reduced modulation and dark fringe offset:
  - Locking with heterodyne signal, readout with DC signal
  - Locking with DC (homodyne) signal, readout with DC signal

- Above 1kHz a sensitivity competitive to heterodyne readout is achieved

- So far no optimisation or noise hunting took place



What might be gained from DC-readout



Options and Plans for the near future

- **Improving sensitivity & detector stability:**
  - Implement ESD-Autoalignment
  - Reduce scattered light (larger viewports in endstations)
  - Increase circulating light power
  - Tuning flexibility
  - DC-readout scheme

- **Datataking in 2008 to cover the period when LIGO and Virgo are going to upgrade.**

Combination of tuned SR and squeezed – An option for GEO HF?

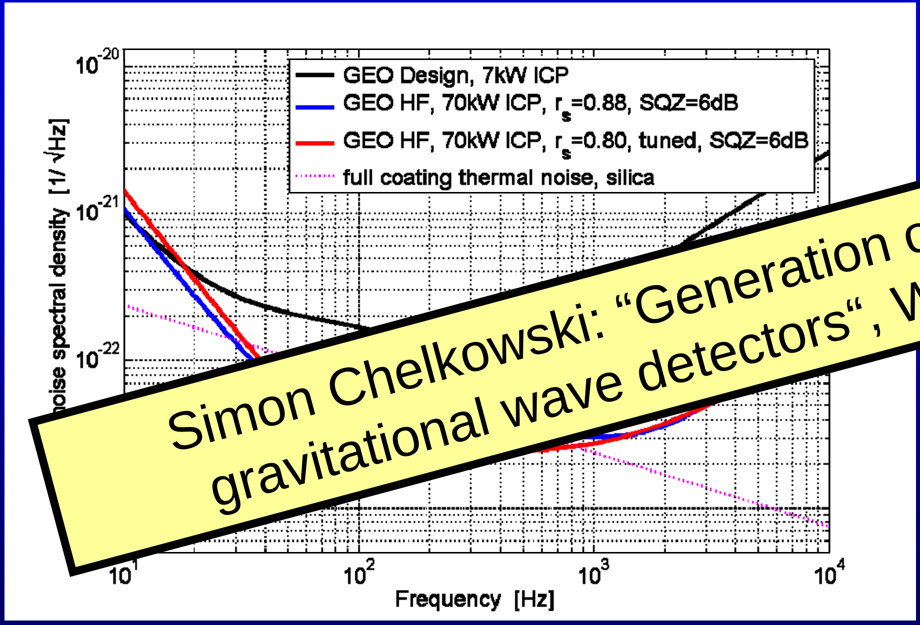
- Squeezed light is available for injection

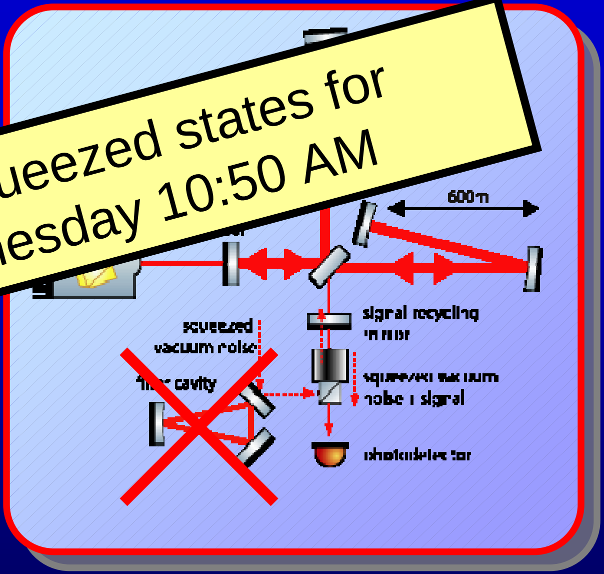
"Coherent Control of Vacuum Squeezing in the Gravitational-Wave Detection Band", Vahlbruch et al, PRL 97, 011101 (2006)

- Tuned Signal-Recycling operation was demonstrated

„Demonstration and comparison of tuned and detuned Signal-Recycling in a large scale gravitational wave detector" , S Hild et al, CQG. ***24*** *No 6, 1513-1523.*

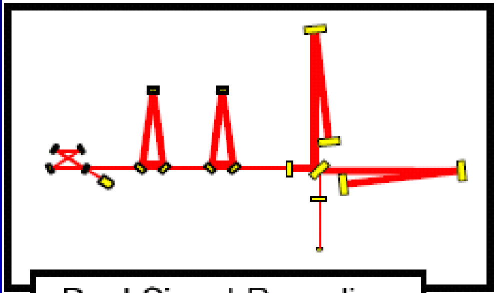
⇒ No need for long filter cavity !

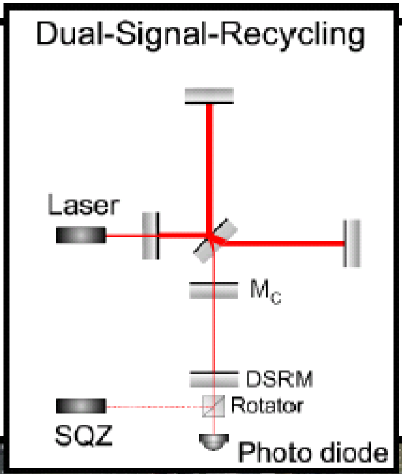




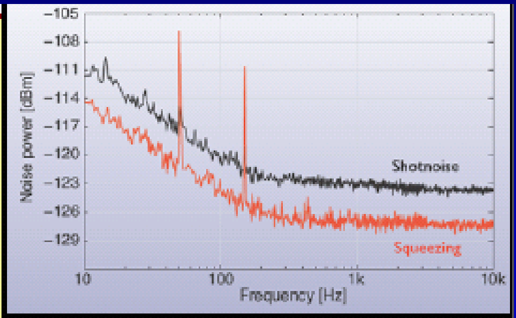
Simon Chelkowski: "Generation of squeezed states for gravitational wave detectors", Wednesday 10:50 AM

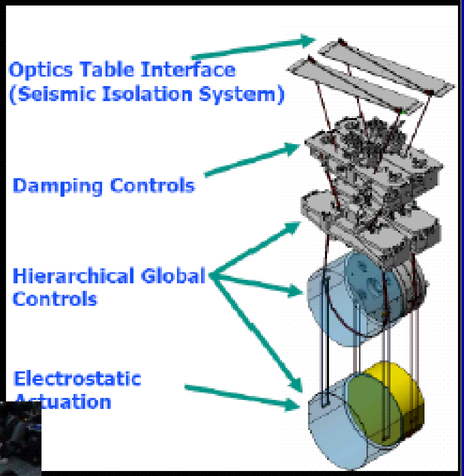
Plans of the GEO collaboration

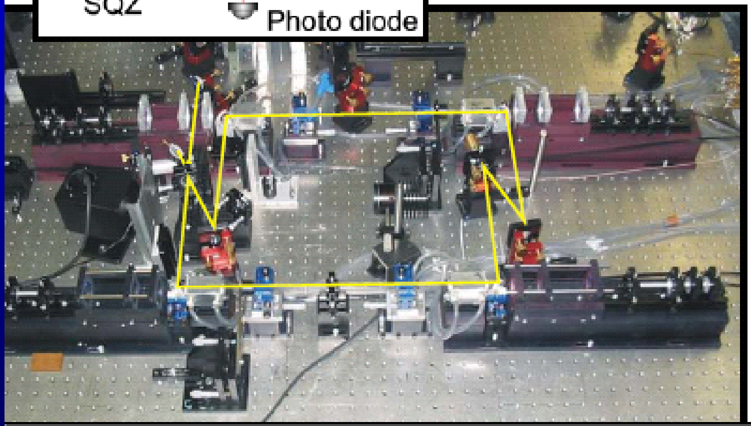


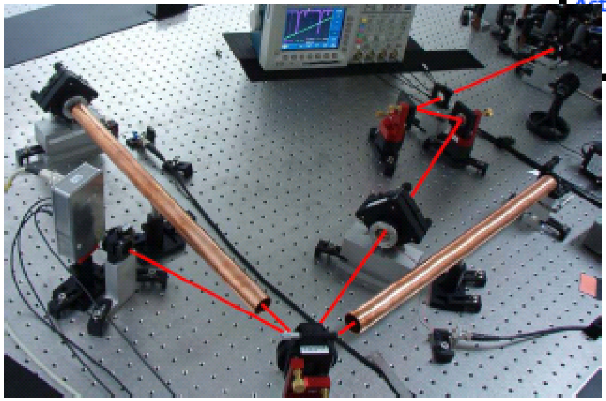


- operate GEO600 / GEO-HF as LSC detector
- LSC data analysis
- laser and suspensions for AdvLIGO (laser for Enh. LIGO)
- contribute to AdvVIRGO design
- R&D and design towards third generation detectors









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