GEO600: Mystery Noise, Owls, Astrowatch, and More

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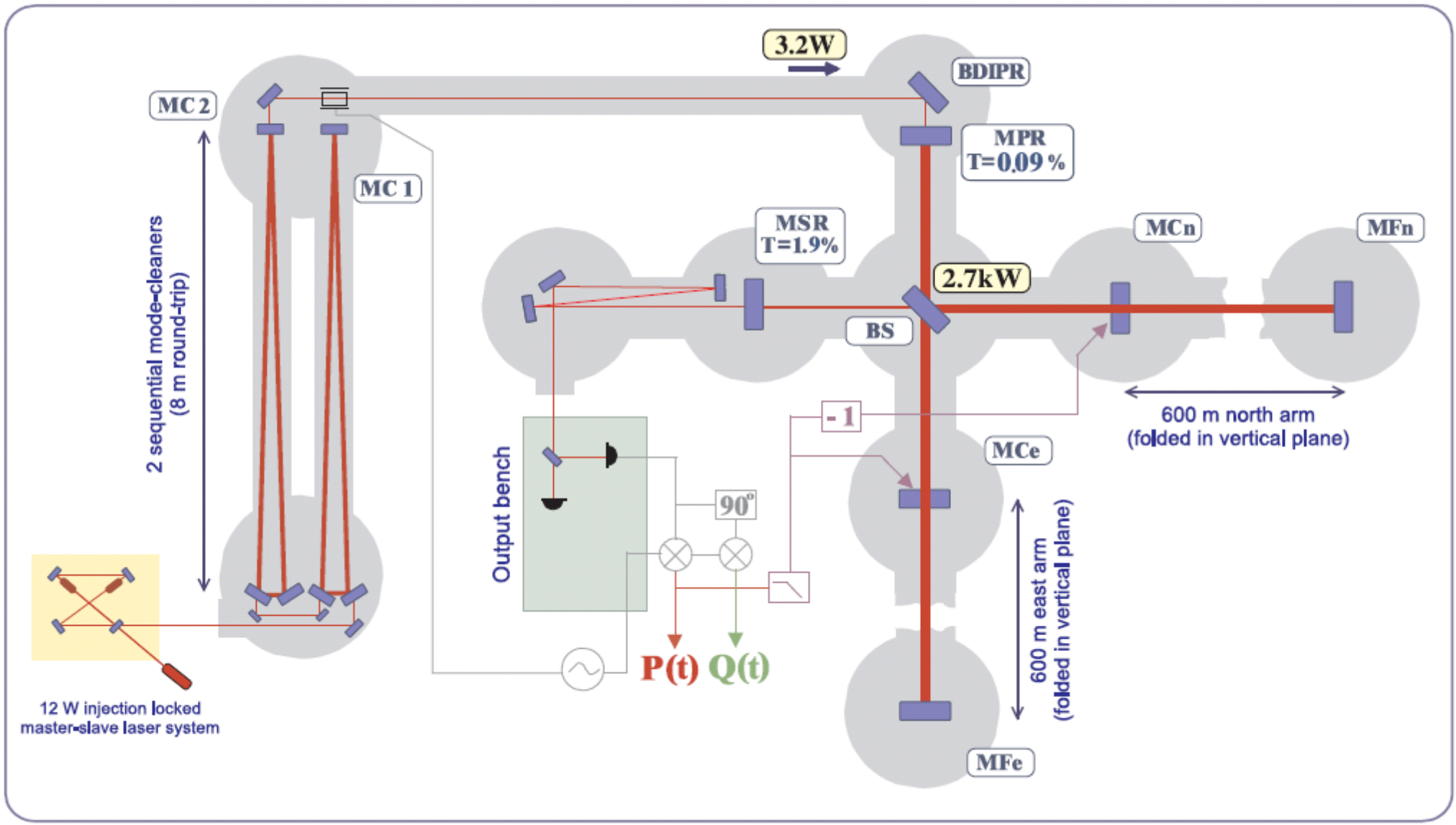
Tokyo University, 1. Feb. 2008

Content

- What is GEO600?
- Something about noise hunting over the last year(s)
  - Mystery noise
  - Owls
- The s5 and *Astrowatch* data taking programs
- Some extra topics:
  - DC readout in GEO
  - A very large acousto-optic modulator
  - A cable sermon
- Plans

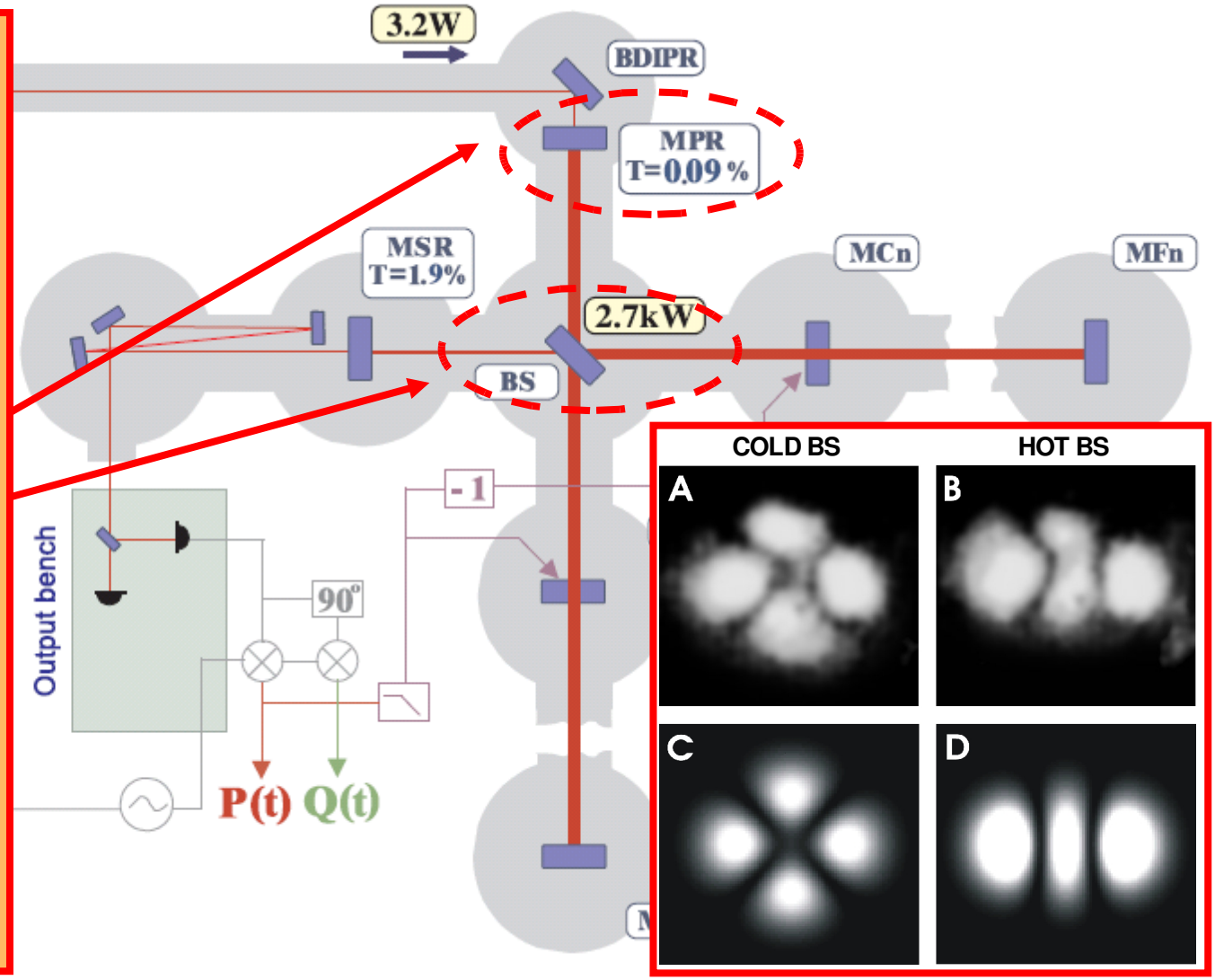
The GEO600 Interferometer



The GEO600 Interferometer

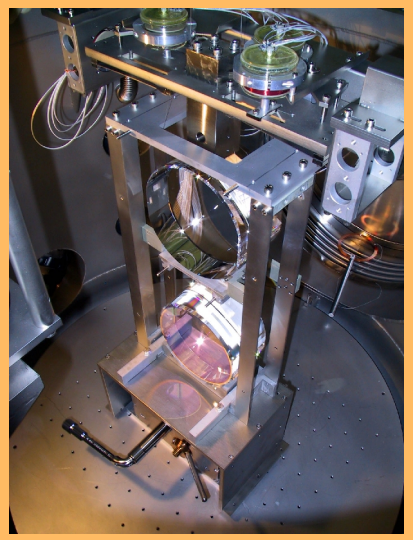
No arm cavities, but folded arms:

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

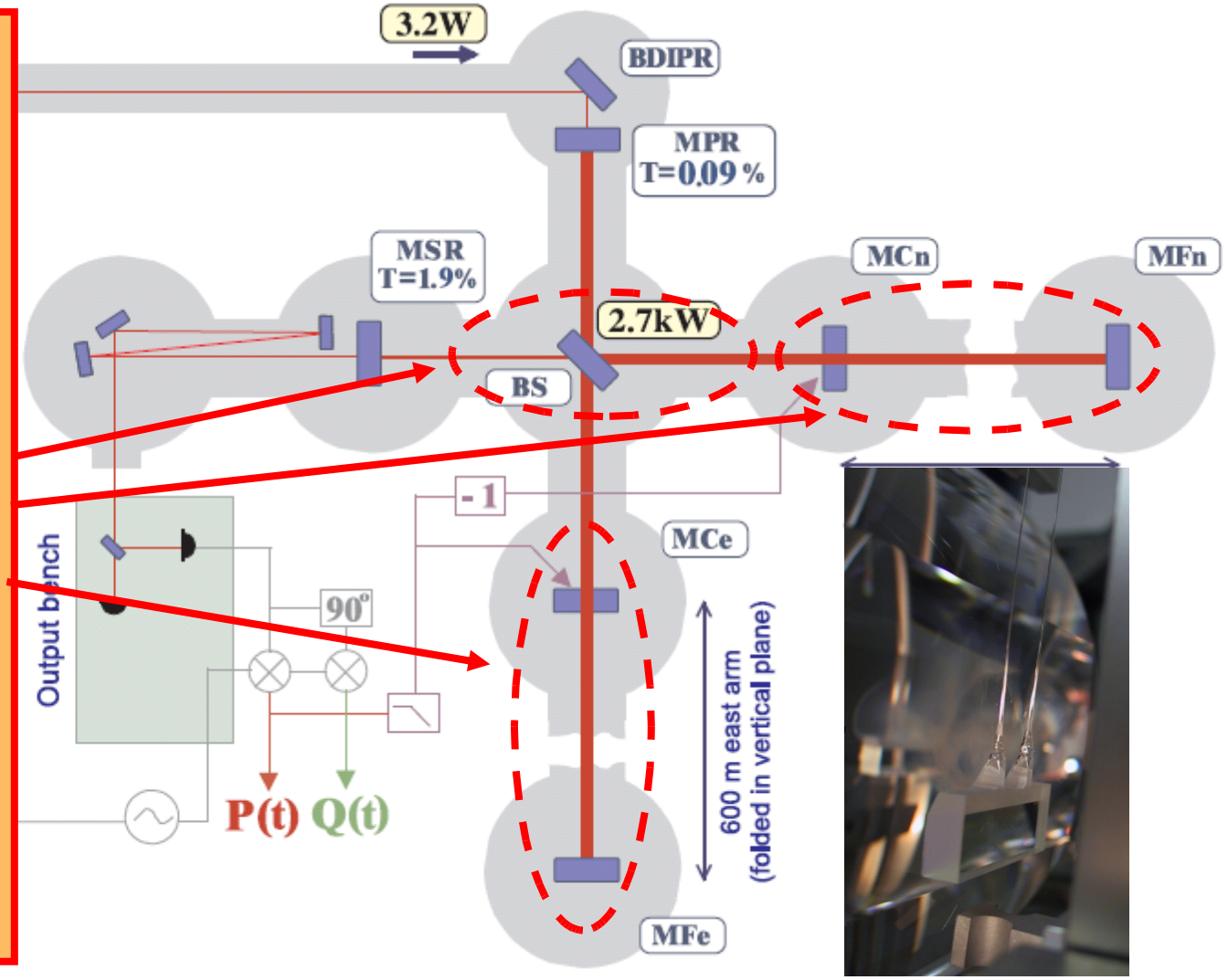


The GEO600 Interferometer

Triple suspensions:



Split-feedback (3-stage hierarchical control: longitudinal + alignment)

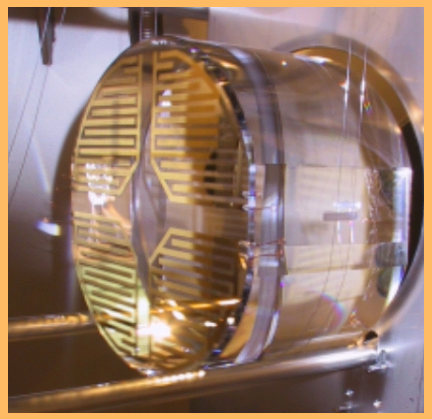


Monolithic stages: ~100 fibre years on running IFO with ~5 partial ventings

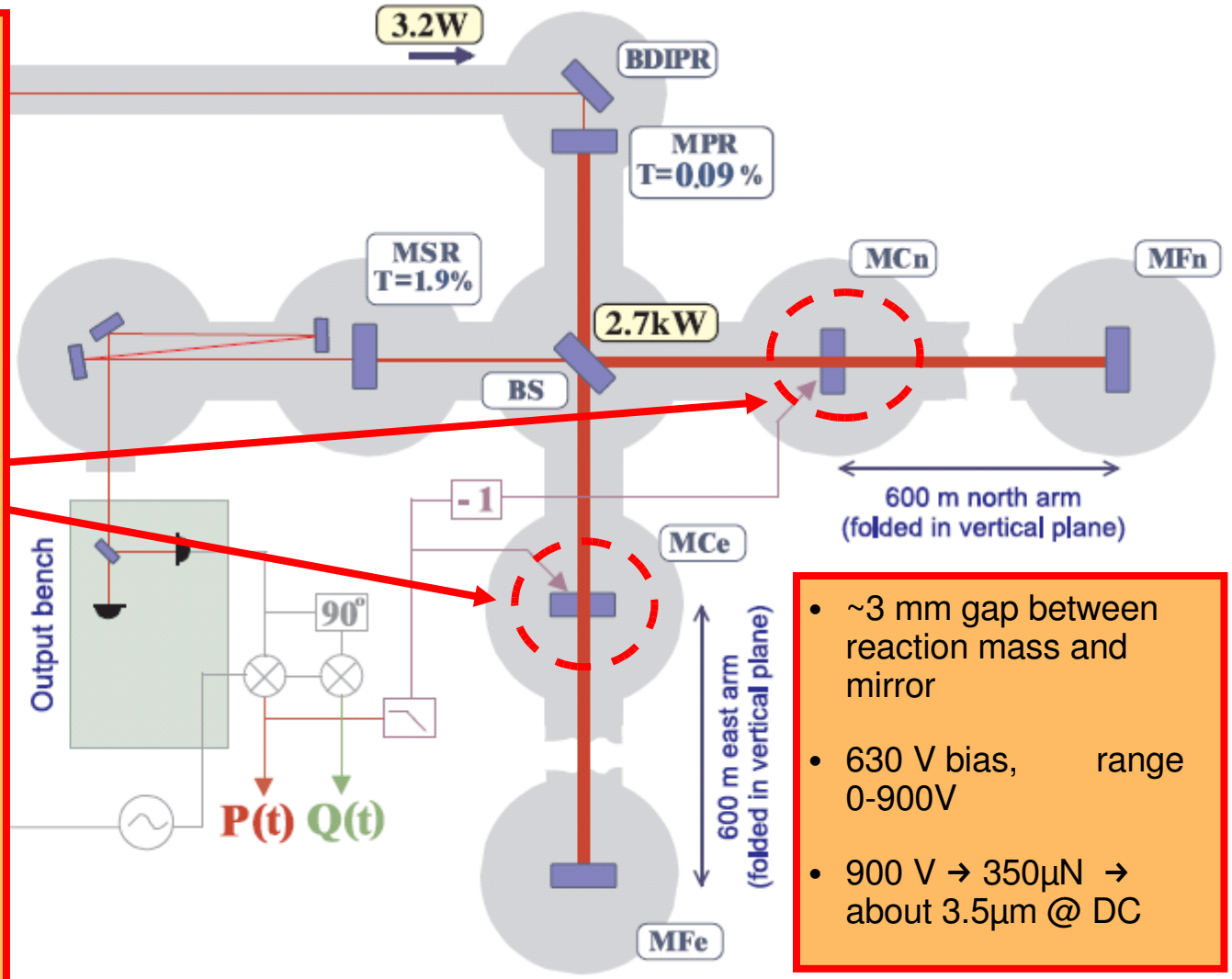
The GEO600 Interferometer

Electro-Static Drives:

- **Used for fast control of diff. arm length**



- **Also used for fast autoalignment (quadrants).**

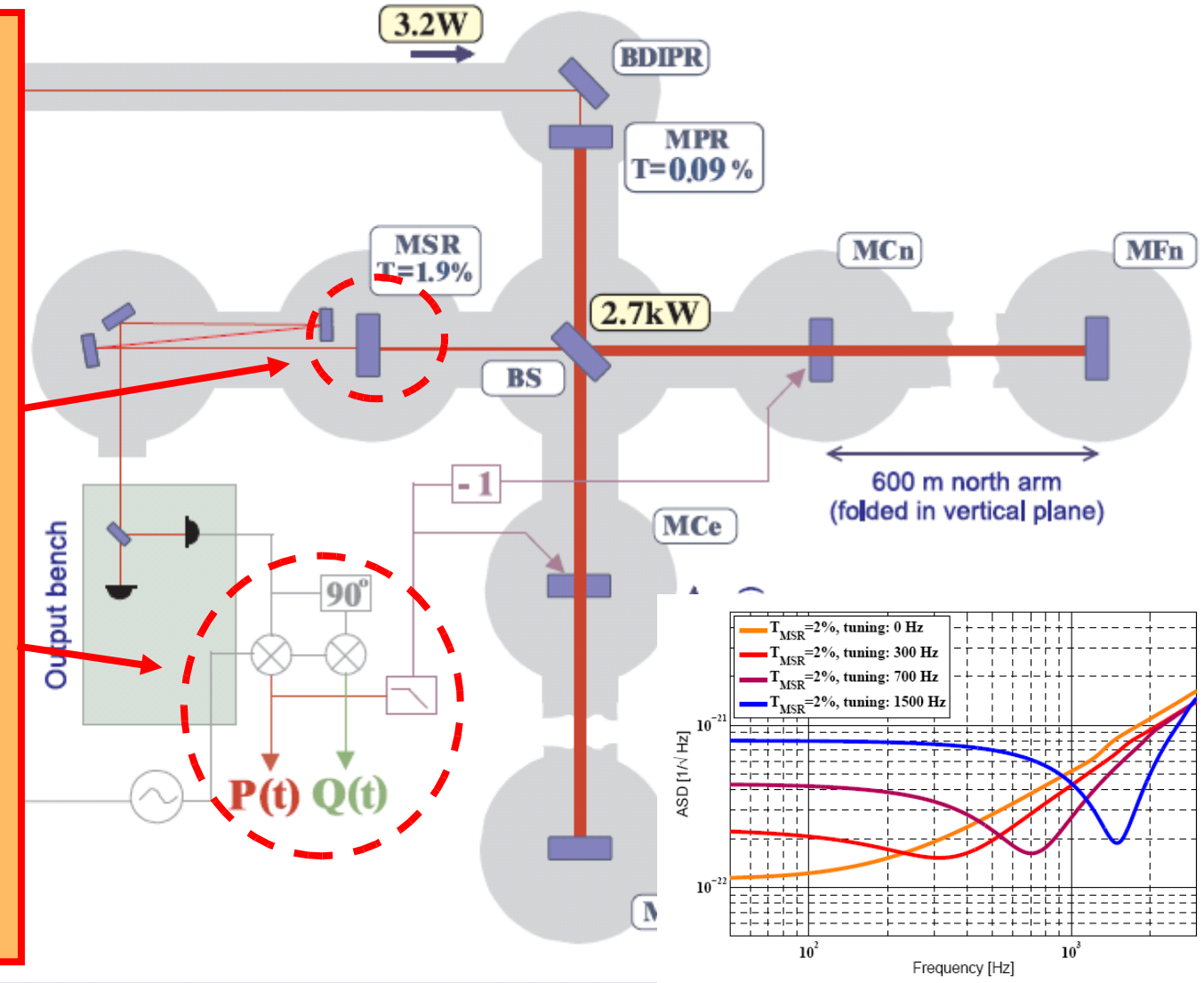


- ~3 mm gap between reaction mass and mirror
- 630 V bias, range 0-900V
- 900 V → 350µN → about 3.5µm @ DC

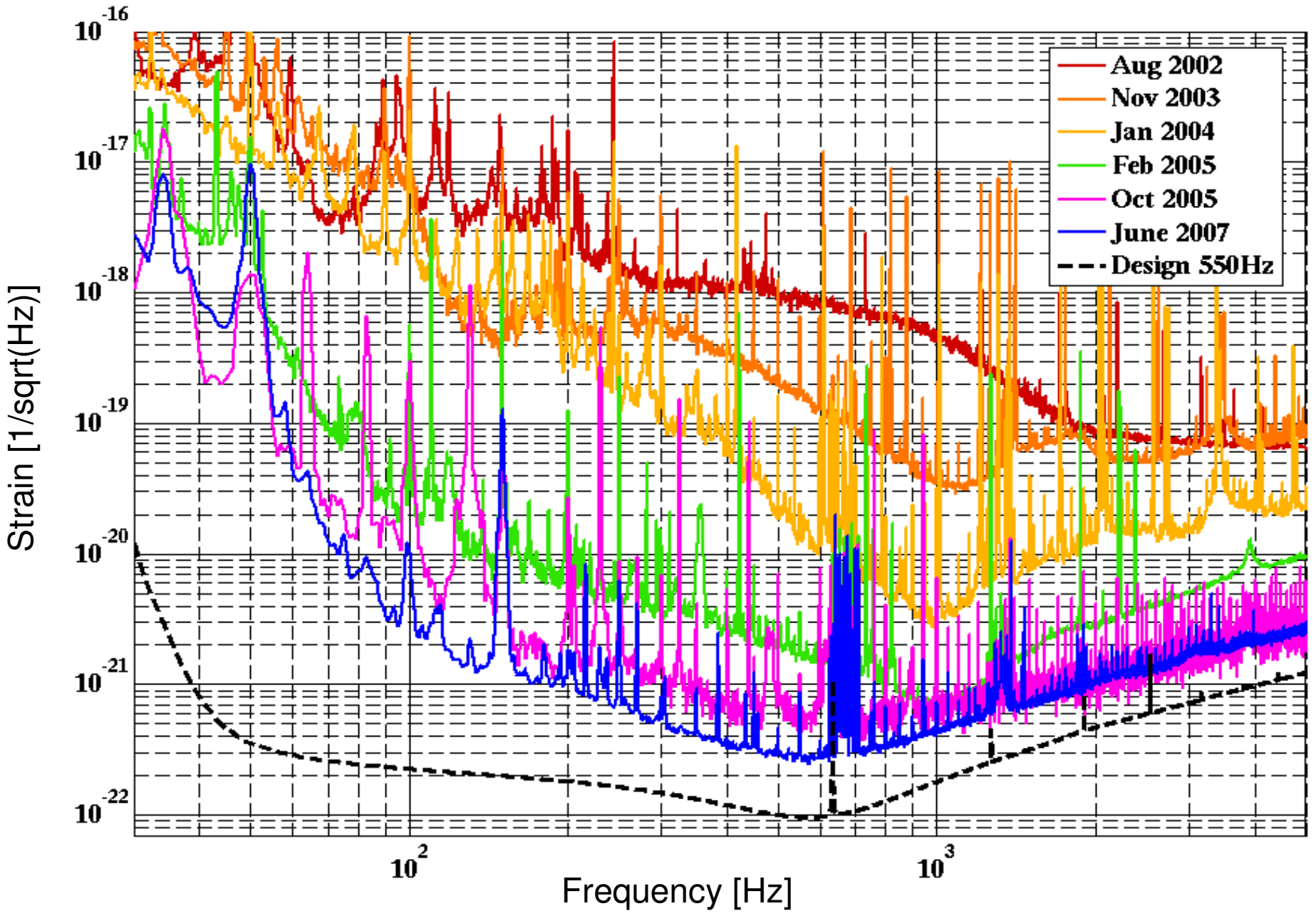
The GEO600 Interferometer

Signal-Recycling:

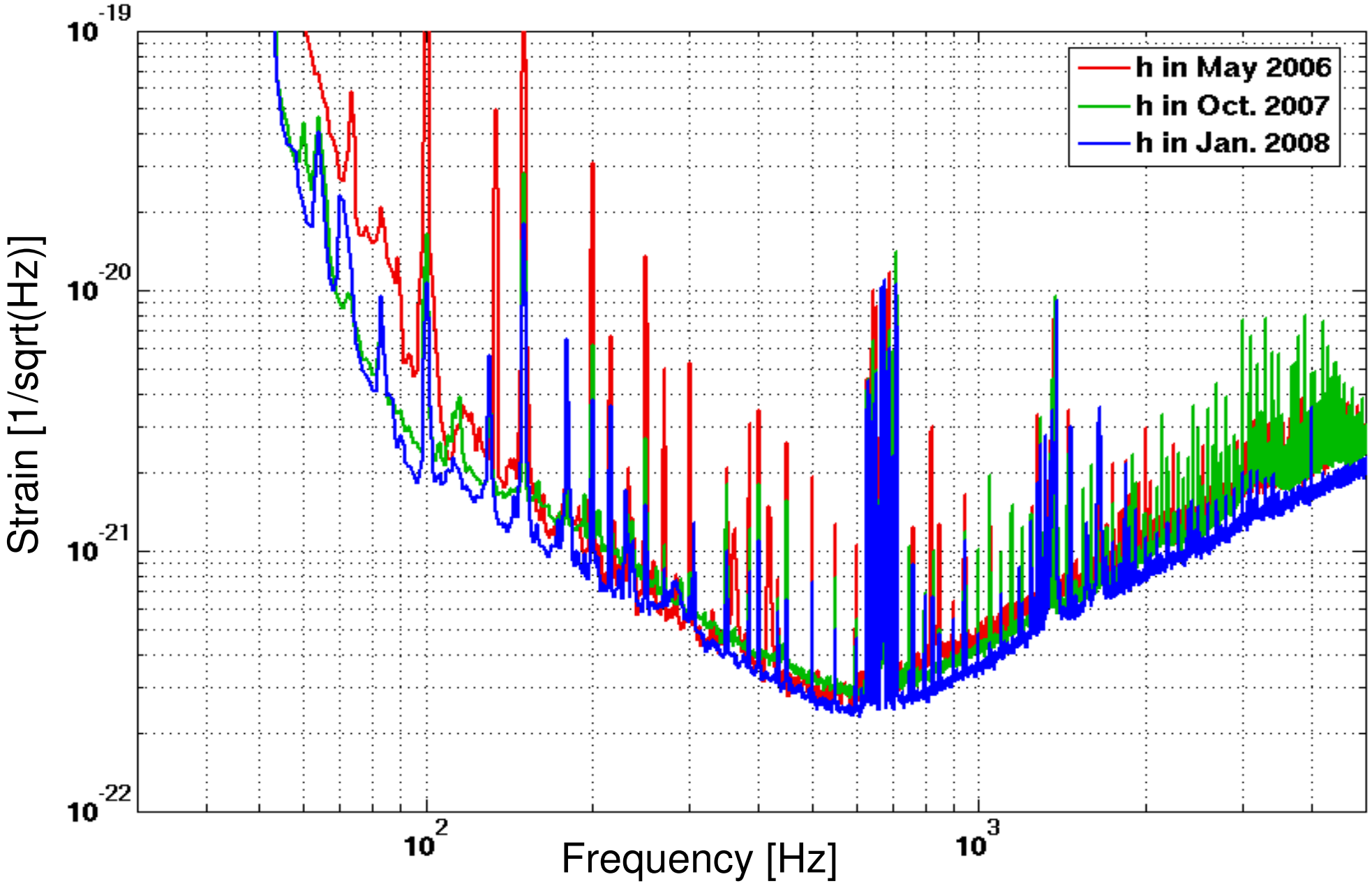
- **Shaping detector response**
- **Complex detector (resonance conditions with detuned SR)**
- **GW signal is spread over both quadratures *P* and *Q*.**



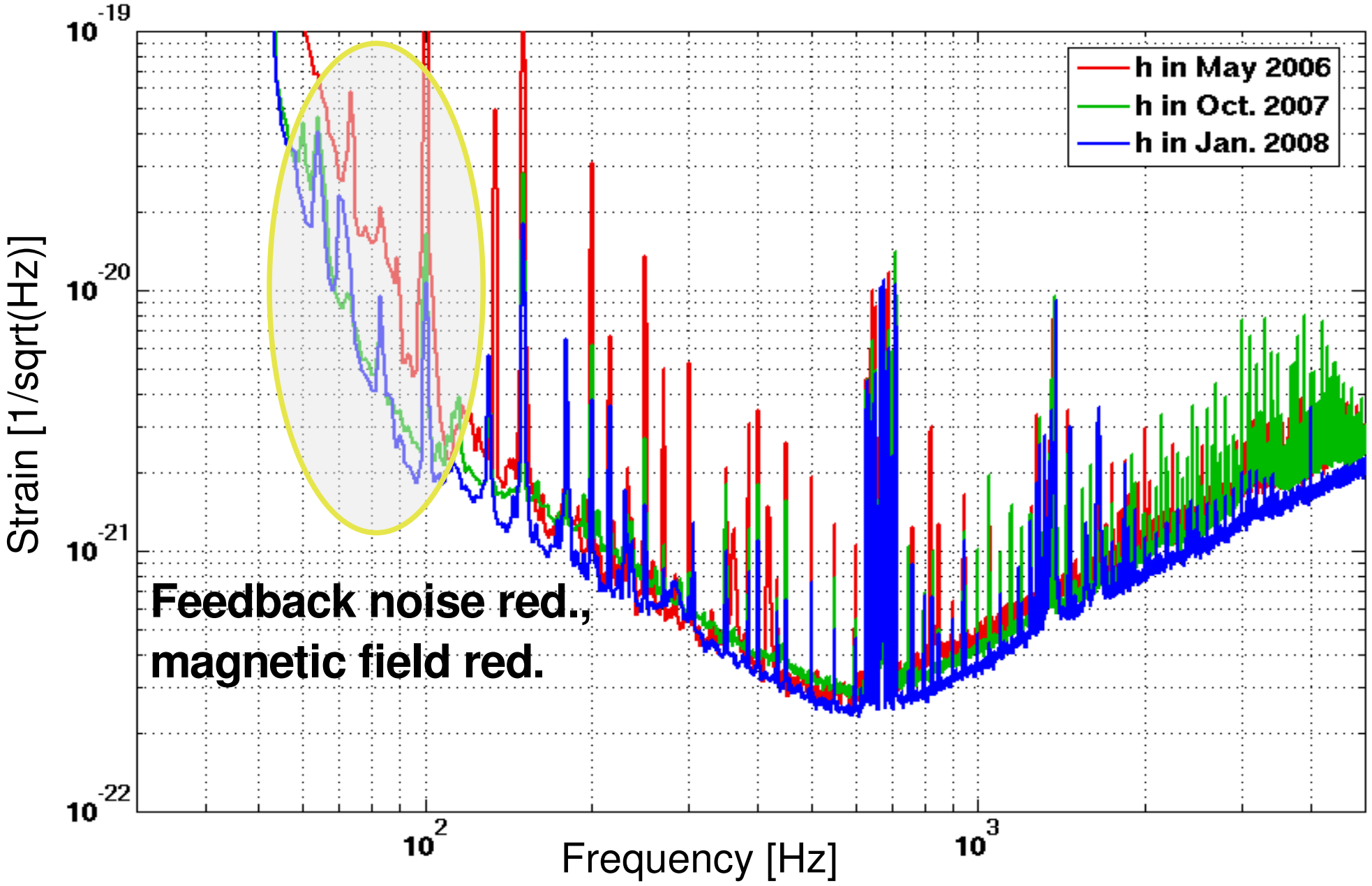
GEO Sensitivities



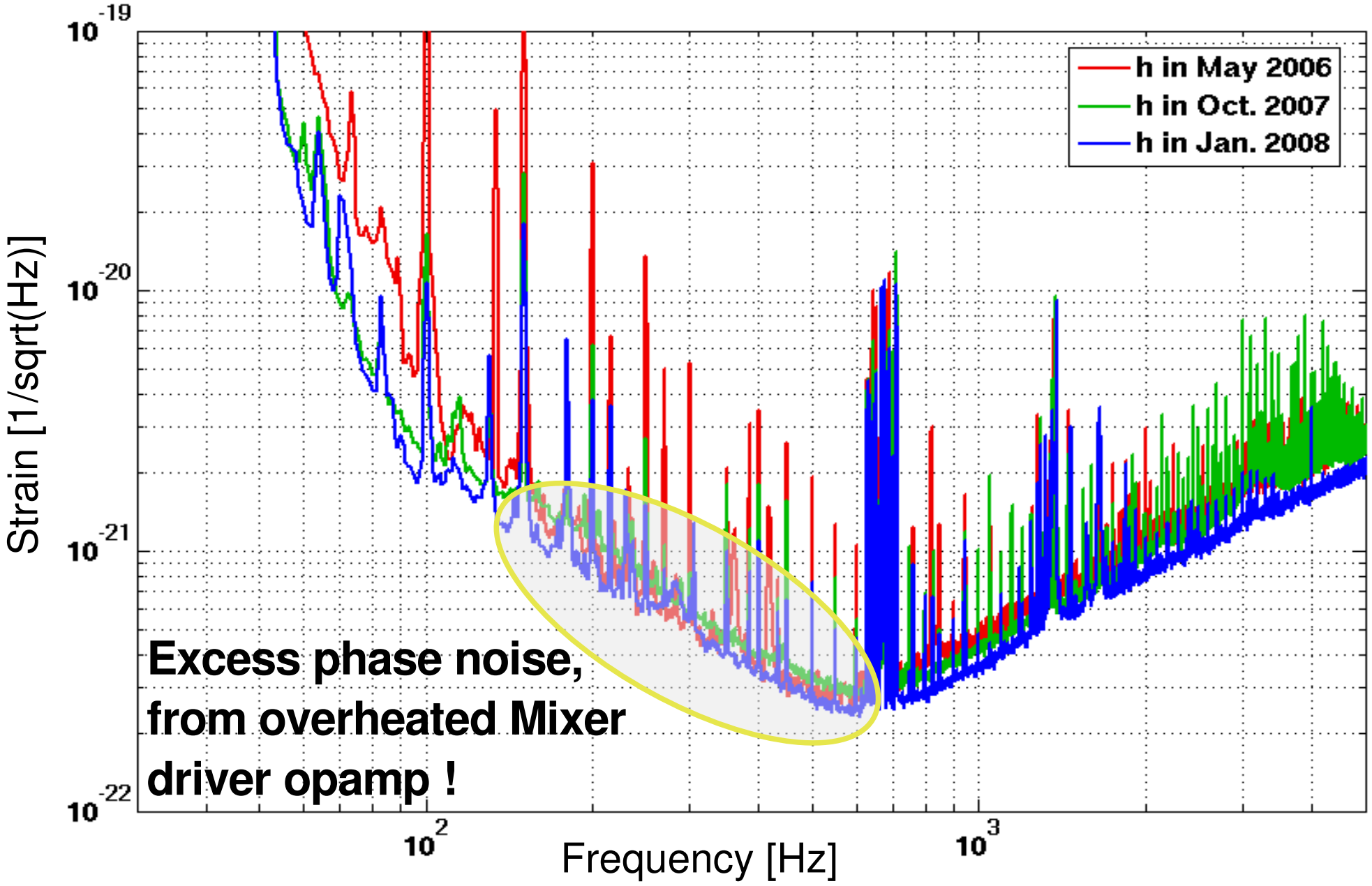
H in the last two years



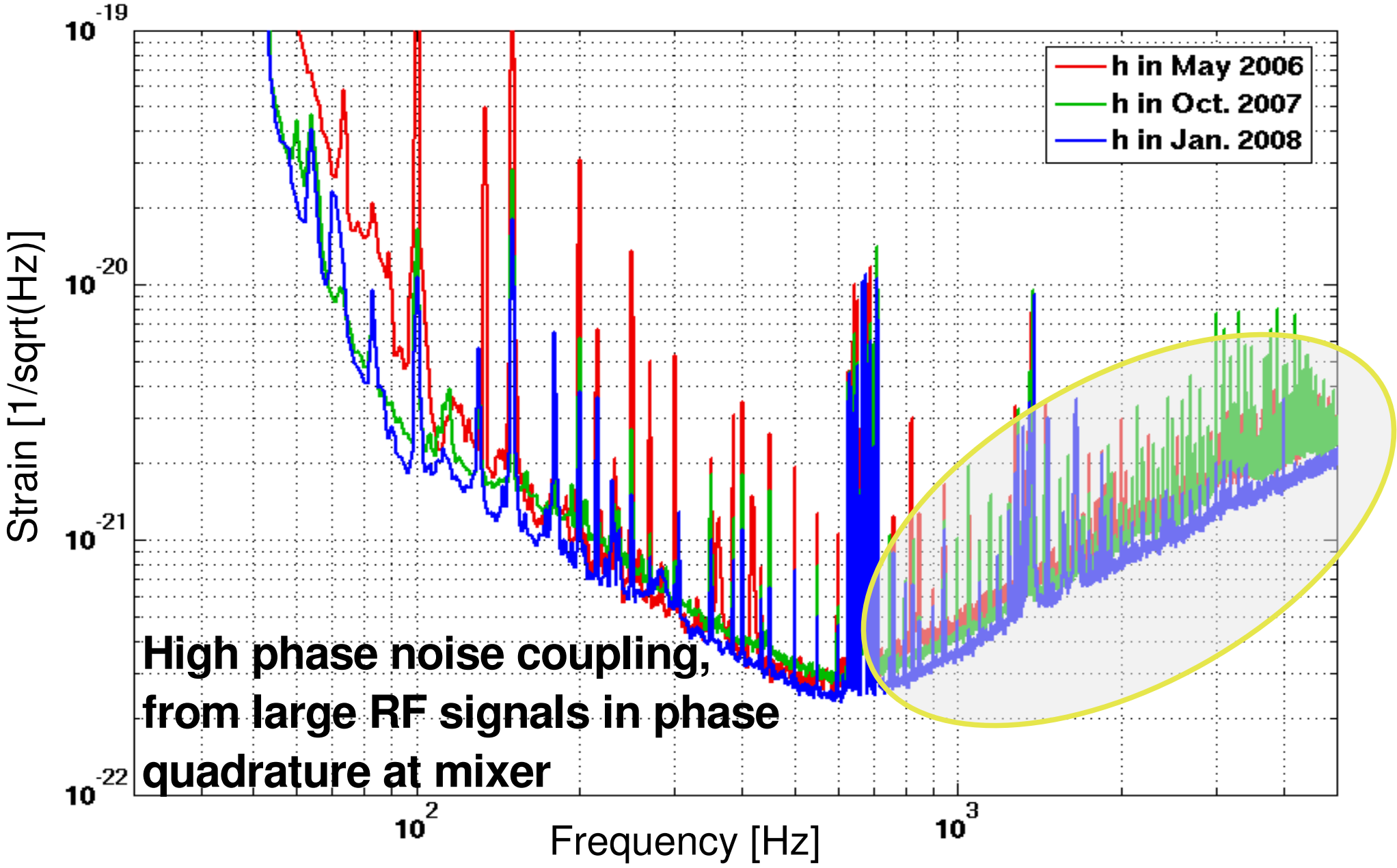
H in the last two years



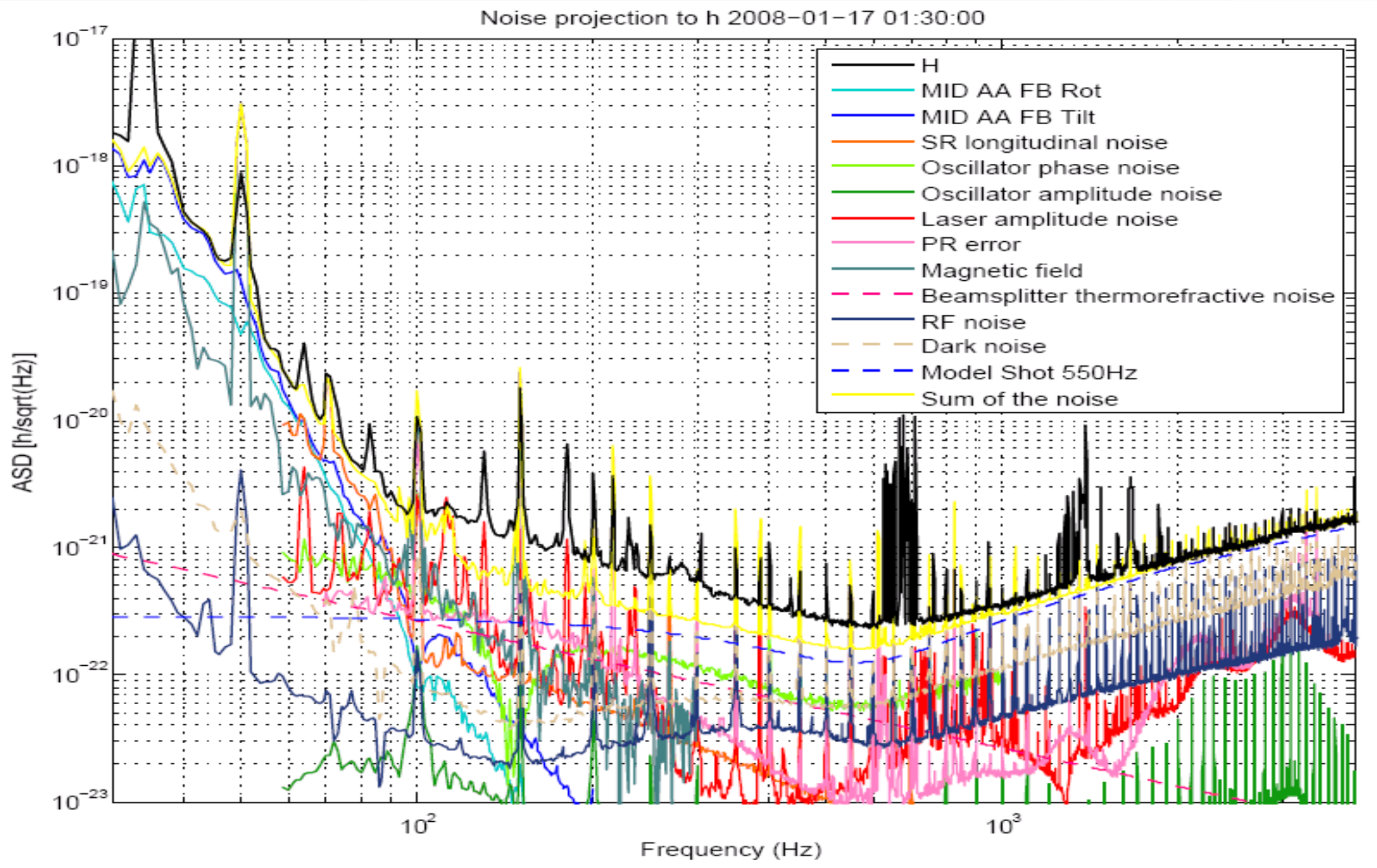
H in the last two years



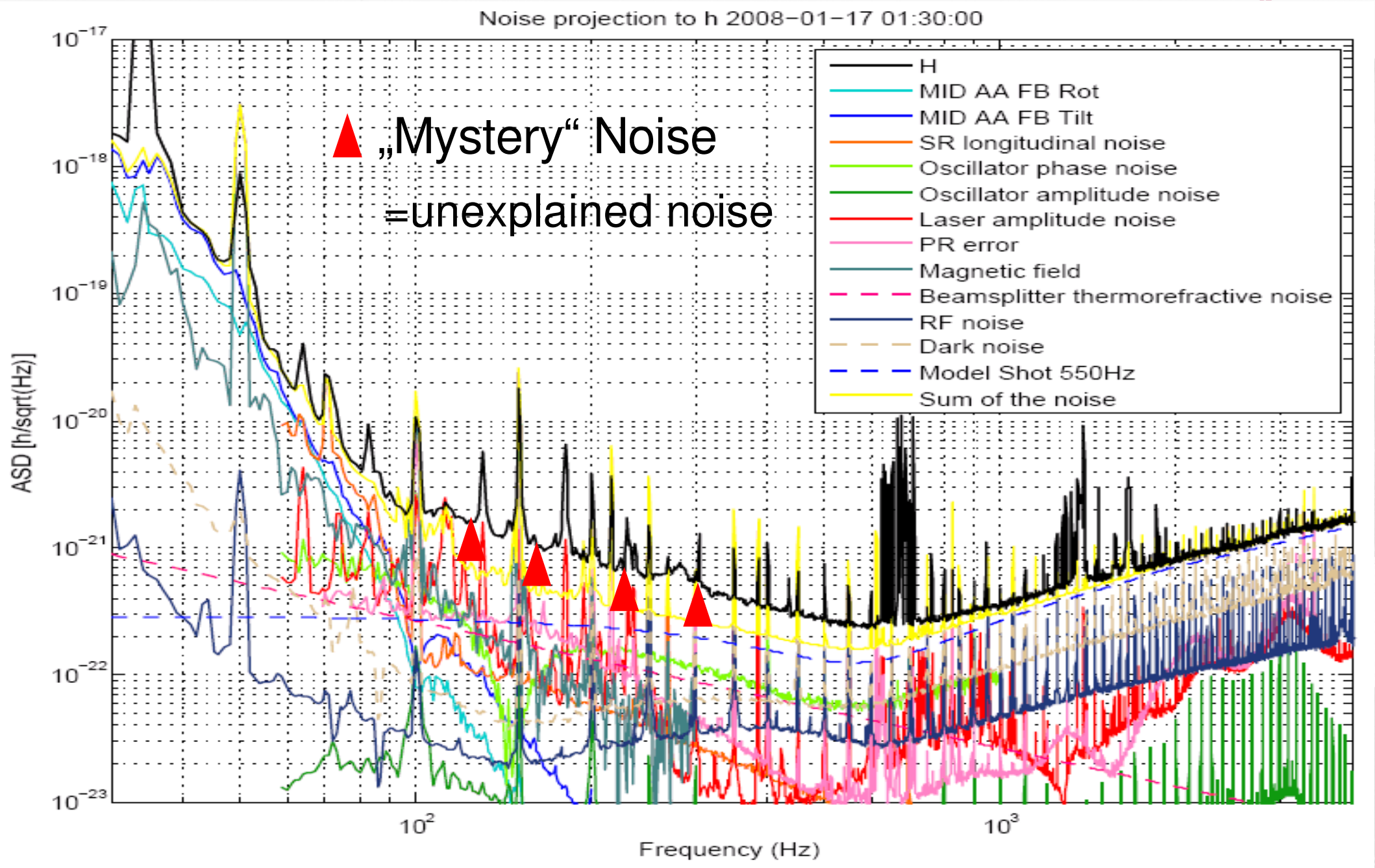
H in the last two years



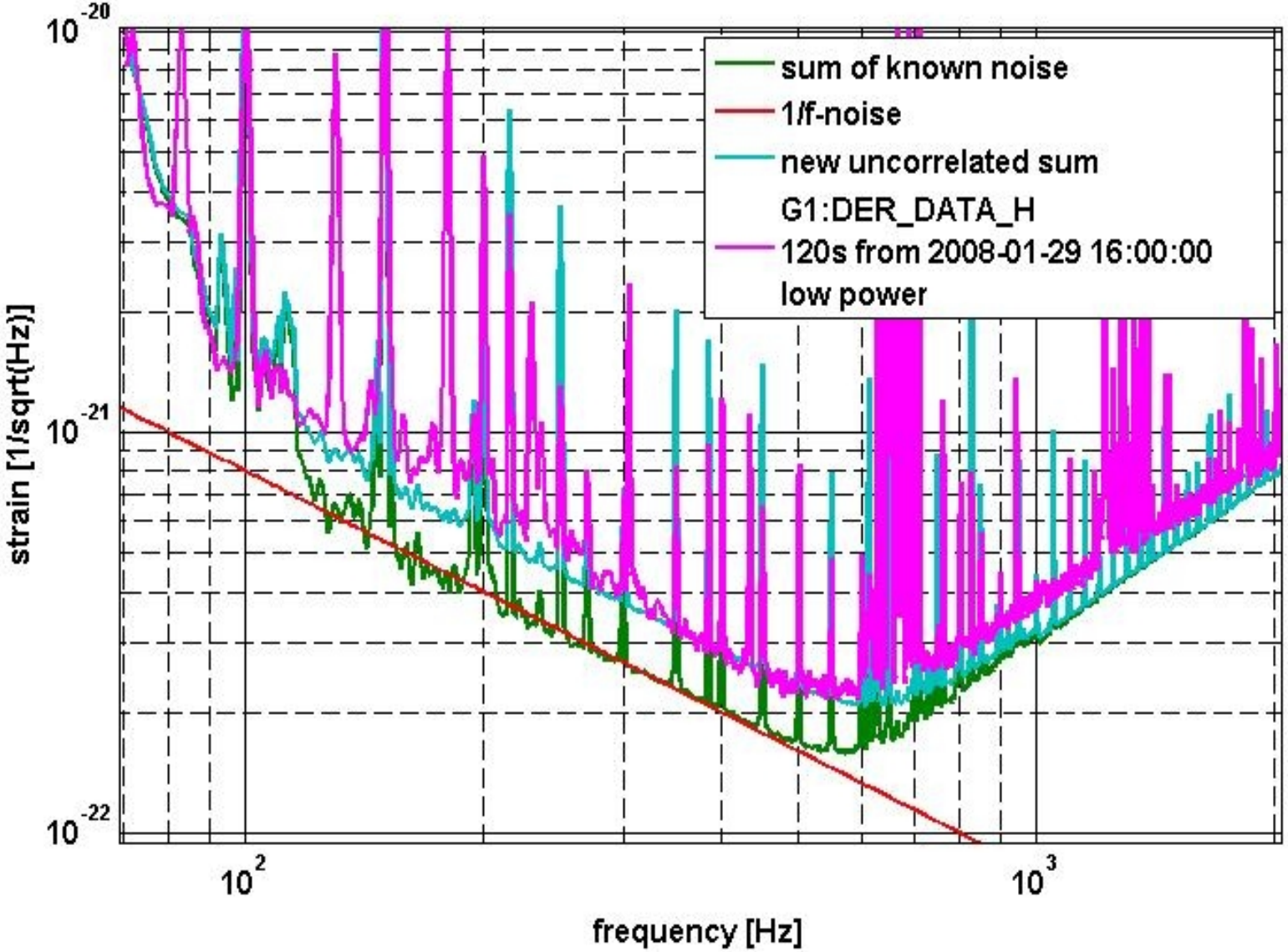
Noise Projections



Noise Projections



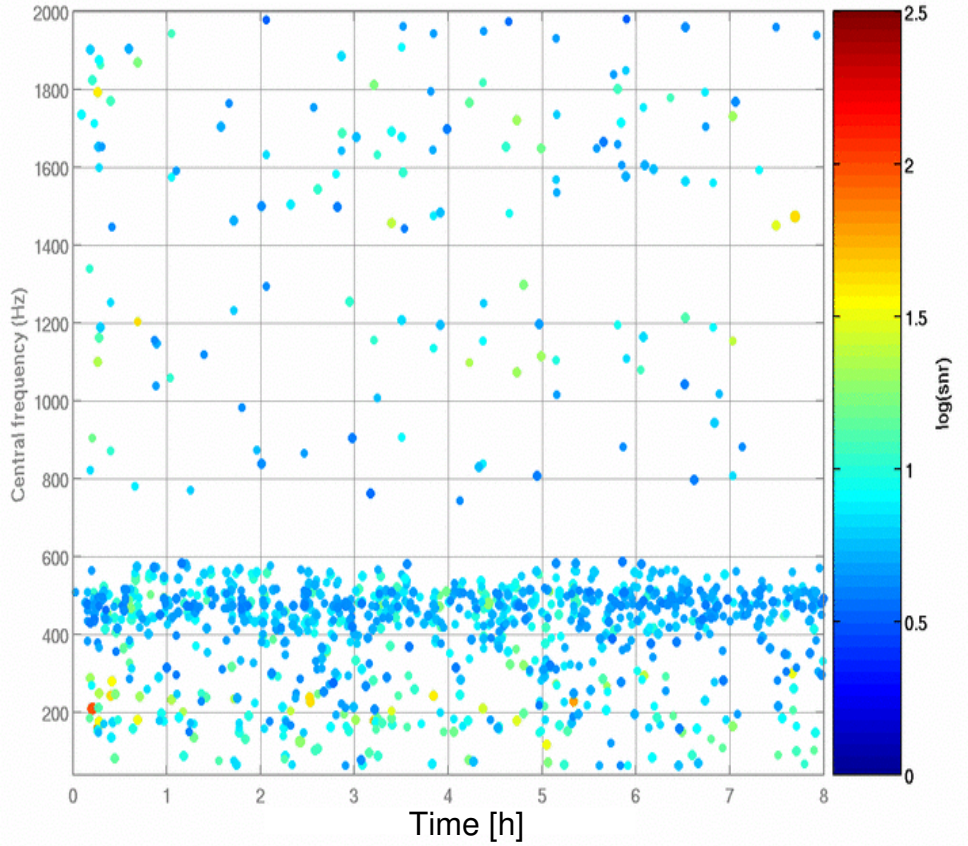
1/f ?


sum of known noise
1/f-noise
new uncorrelated sum
G1:DER_DATA_H
120s from 2008-01-29 16:00:00
low power
strain [1/sqrt(Hz)]
10^-20
10^-21
10^-22
10^2
10^3
frequency [Hz]

Reduction of Glitches

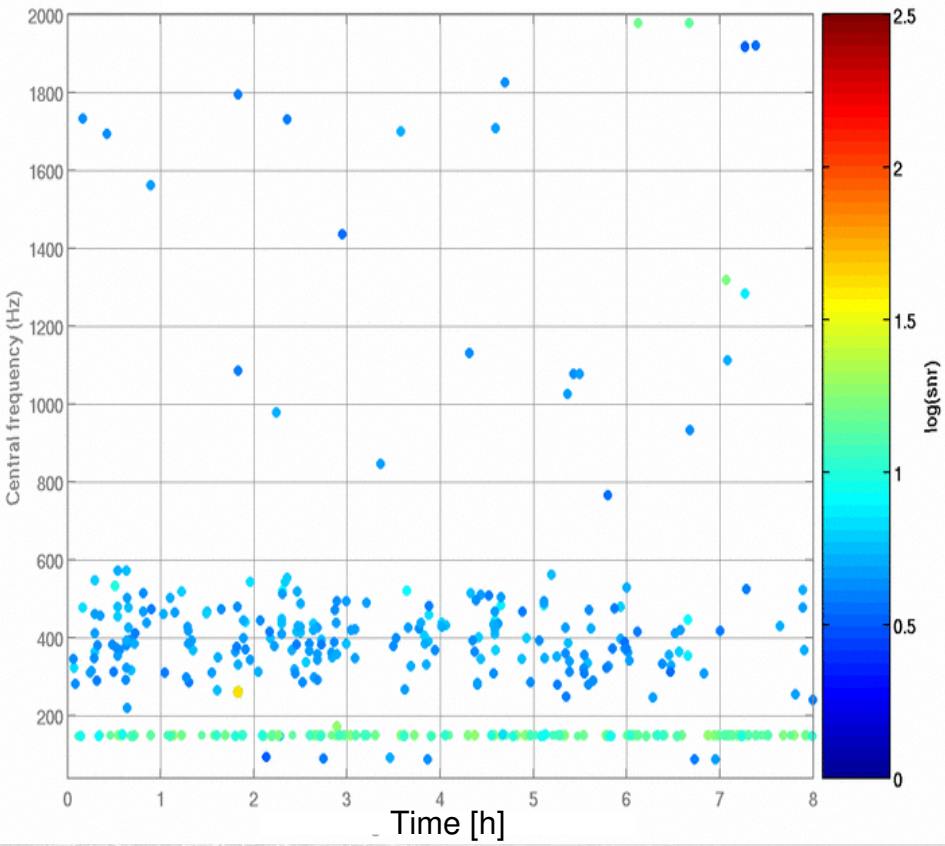
Different measures lead to the reduction of glitches: New cables + connectors, improvement of control loops, and unknown.

H triggers in HACR mon: n=1067



Typical s5 in 2006

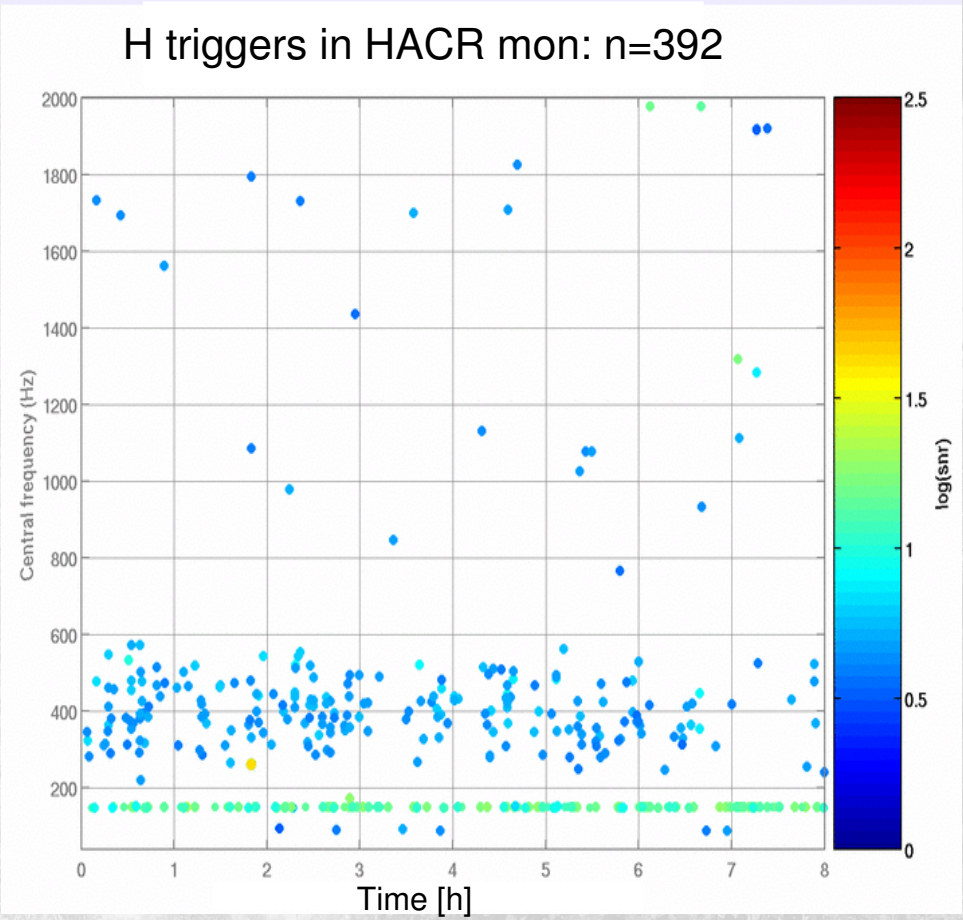
H triggers in HACR mon: n=392



End of June 2007

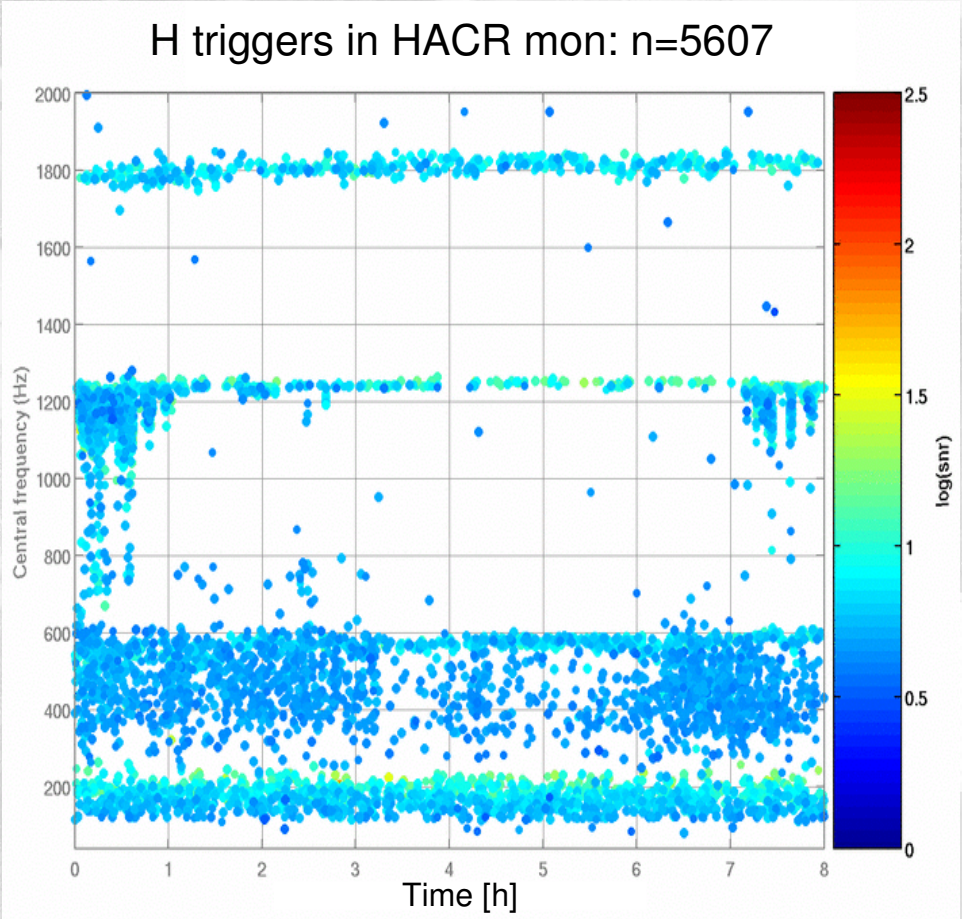
Increasing of Glitches

:-)



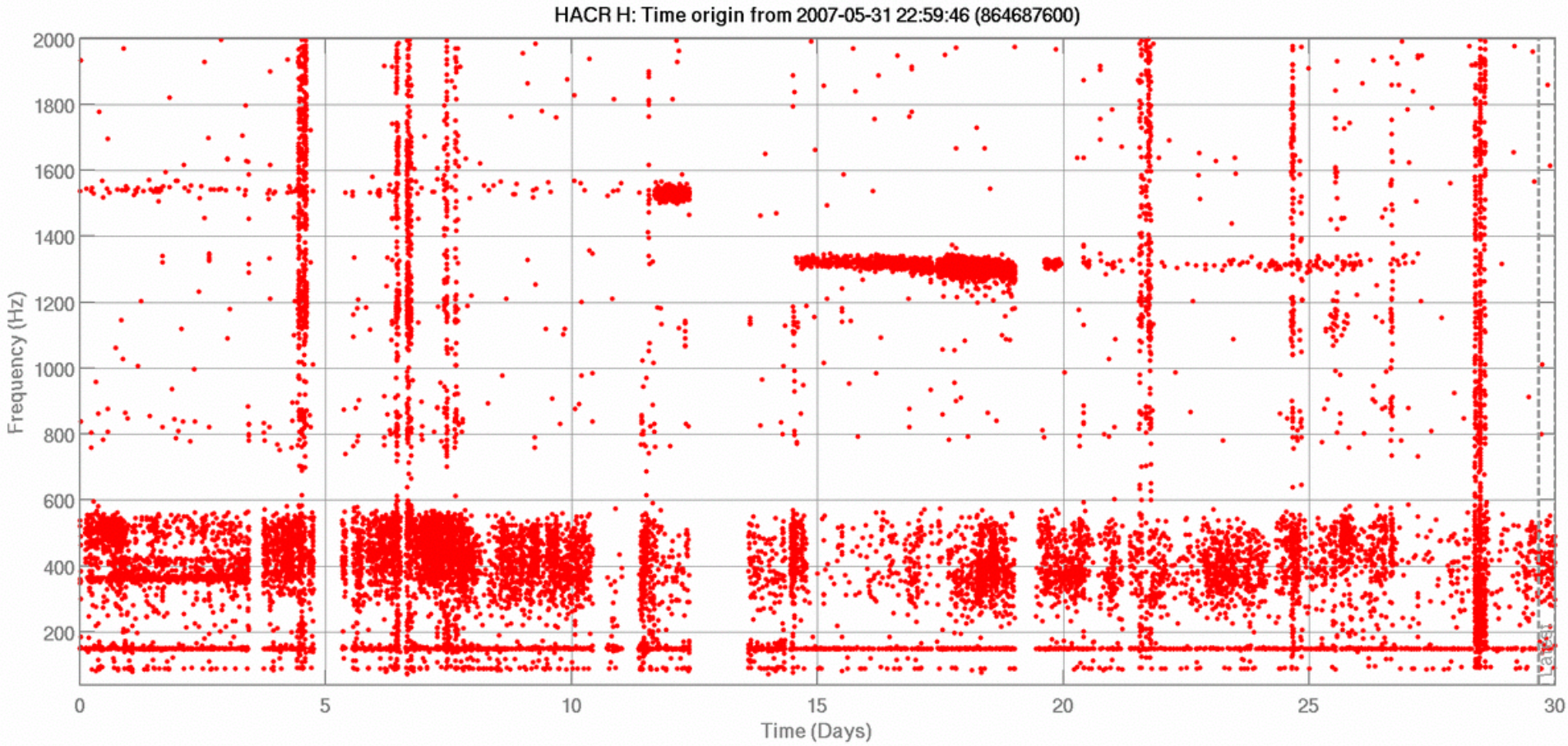
End of June 2007

:-(

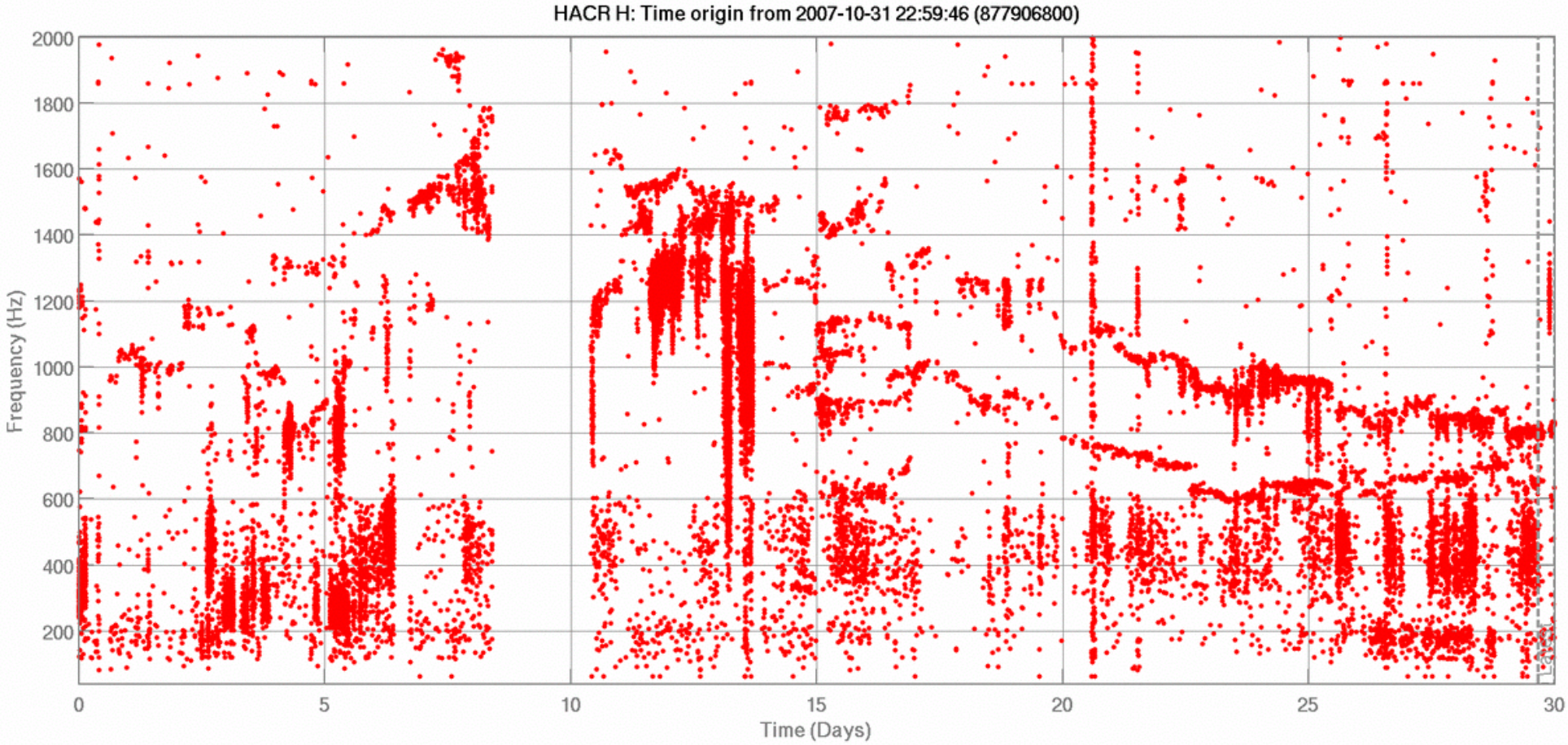


A time in Jan 2008

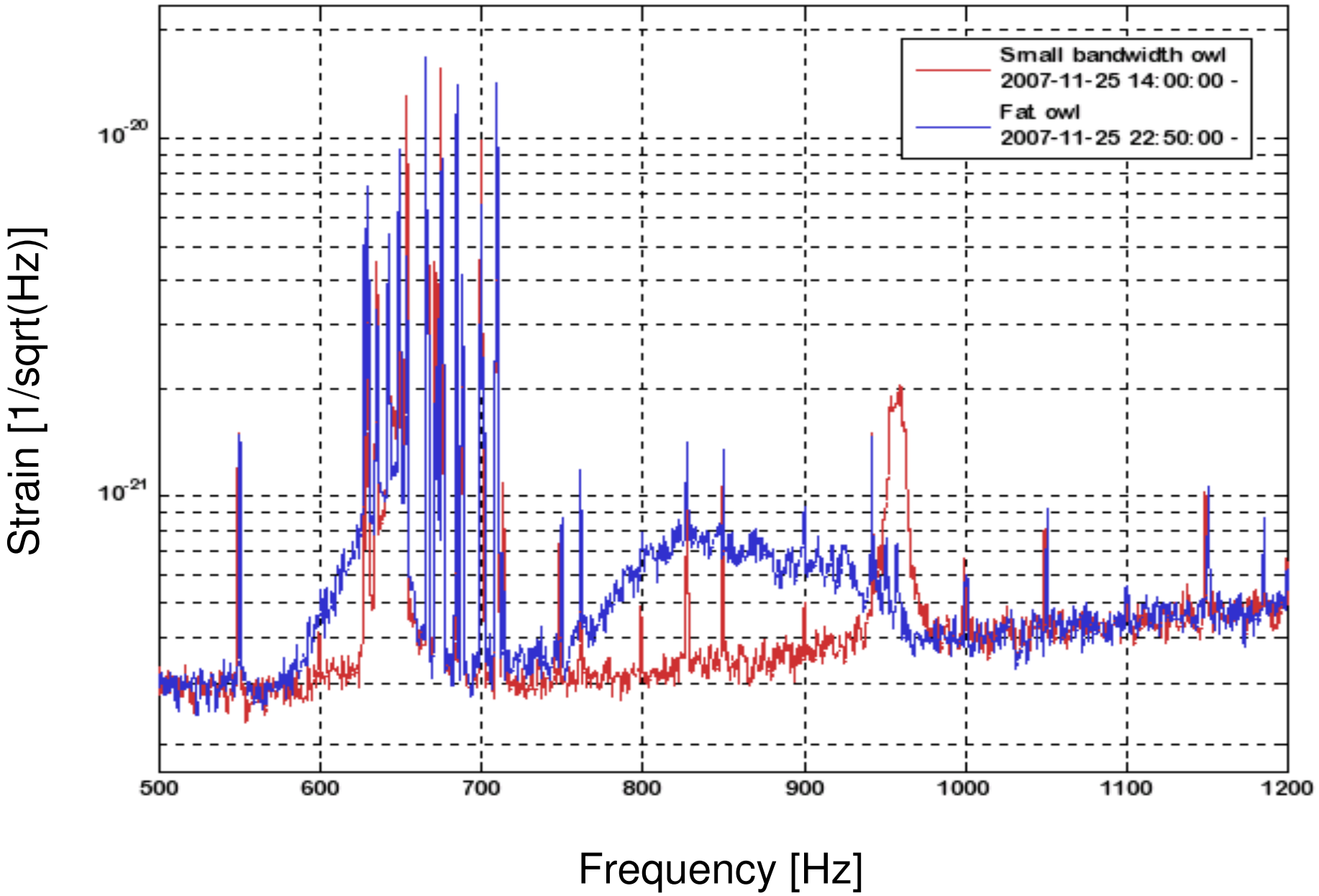
Monthly HACR plot: June 2007



Monthly HACR plot: Nov. 2007



Moving line(s) sounding like an owl...



So we have an OWL problem

100.000000 円

for hints leading to the capture of the OWL

Owl hunting done so far...

RF world:

3154 Measurement of enviromental RF in the controlroom (SR, MI, PR)
3333 Exchanged Wenzel oscillator
3338 Checked in MI RF forward power
3344 Injecting RF to Q compensation to check dark noise
3393 MU3 rotation
3442 looking at reflected RF

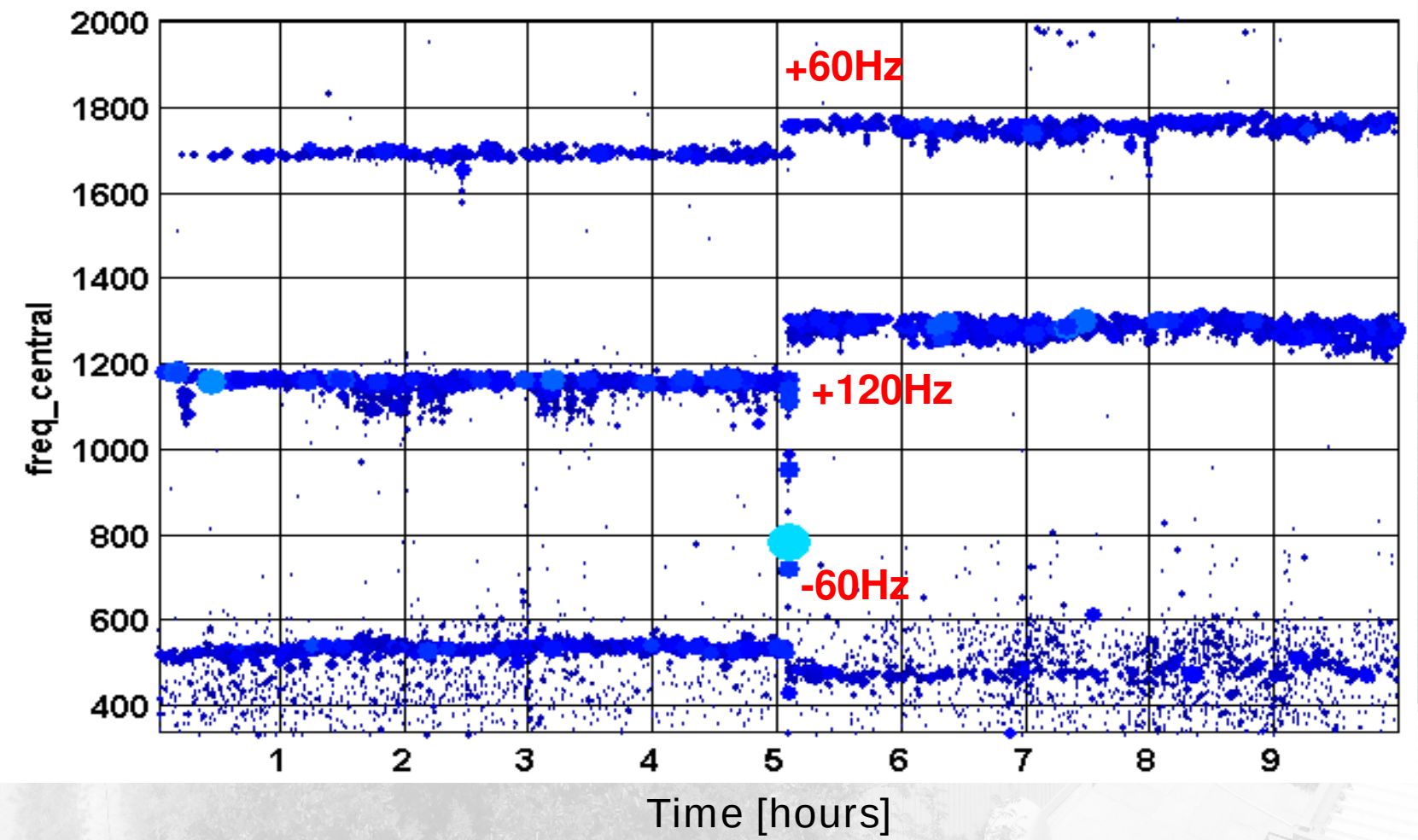
PR loop:

3338 Changing PR RF modulation by 500 Hz
3349 Changed master laser pump current
3417 Changed long gain of PR, MC1 and MC2
3417 Switching off PR scanners
3434 Blocked PR AA path.

Other observations:

3341 Owl sometimes changes frequency with a period of 0.558 Hz
3346 Observation of 2nd and 3rd order owl
3350 Sawtooth
3353 MPR misalignment influences the strength
3389 Shifting spot on bdipr seems not have influence
3359 Owl doesn't see optical transfer function (owl not h like)
3421 Owl is h like
3391 heater experiment to check for higher order modes
3393 SR tuning 100 Hz up
3396 Owl sometimes jumps
3415 MI scanner off
3415 Pstab loops off
3419 change alignment of MFE, MFN, BS and BDO1
3419 SQRT circuits in/out
3477 lowering bias for ESD, switching press. sensors off in central bldg.
3570 switching of pressure sensors in the middle of the tubes.
3570 owl was excited by doing a single MCE handy click in rotation
3571 owl changes frequency and amplitude with various alignments
3575 Owl's frequency depends on MPR alignment, but not on alignment on MCE, MCN, MFN, MFE or the output beam.
3578 Blocked PR_AA path and disconnected both PR scanners. no influence.
3580 Owl's frequency depends on MPR alignment but not on BDIPR alignment.
3590 Change PRC gain. no influence.
3590 Owl's frequency depends on MPR rot alignment, but not on tilt.
3593 Spot position on BDIPR changes owl's frequency.
3602 Turning fibre attenuator.
3602 Tried to excite owl by driving the fibre attenuator with 800 Hz no influence.
3602 Turned lambdaplate and increased input power, no influence.
3591, 3596, 3597, 3612 locking for owl at higher frequency. No clear influence.
3719 OWL stuff
3768 Owl flying low
3955 Owl again?
4566 Owl vetoed by nullstream?
4568 some (owlish) thoughts
4894 owl is h-like

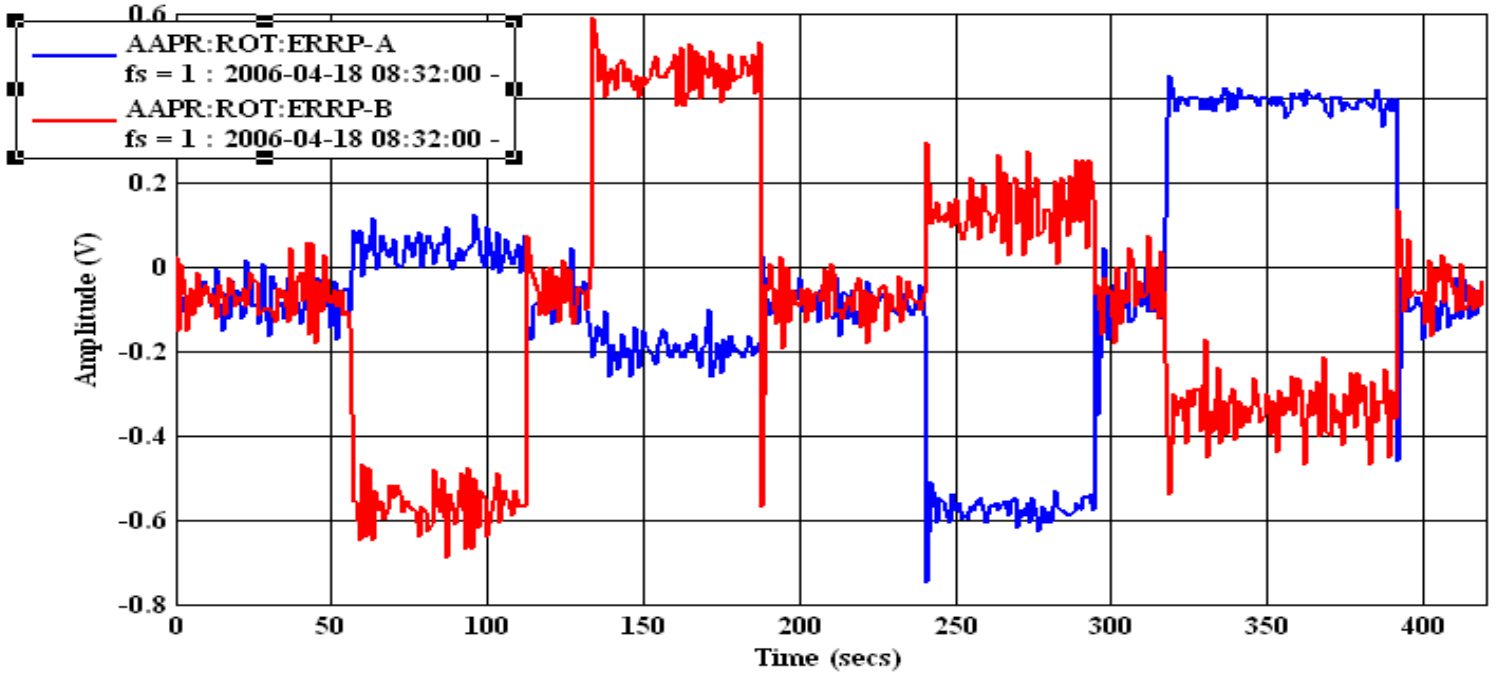
Owl may jump in frequency

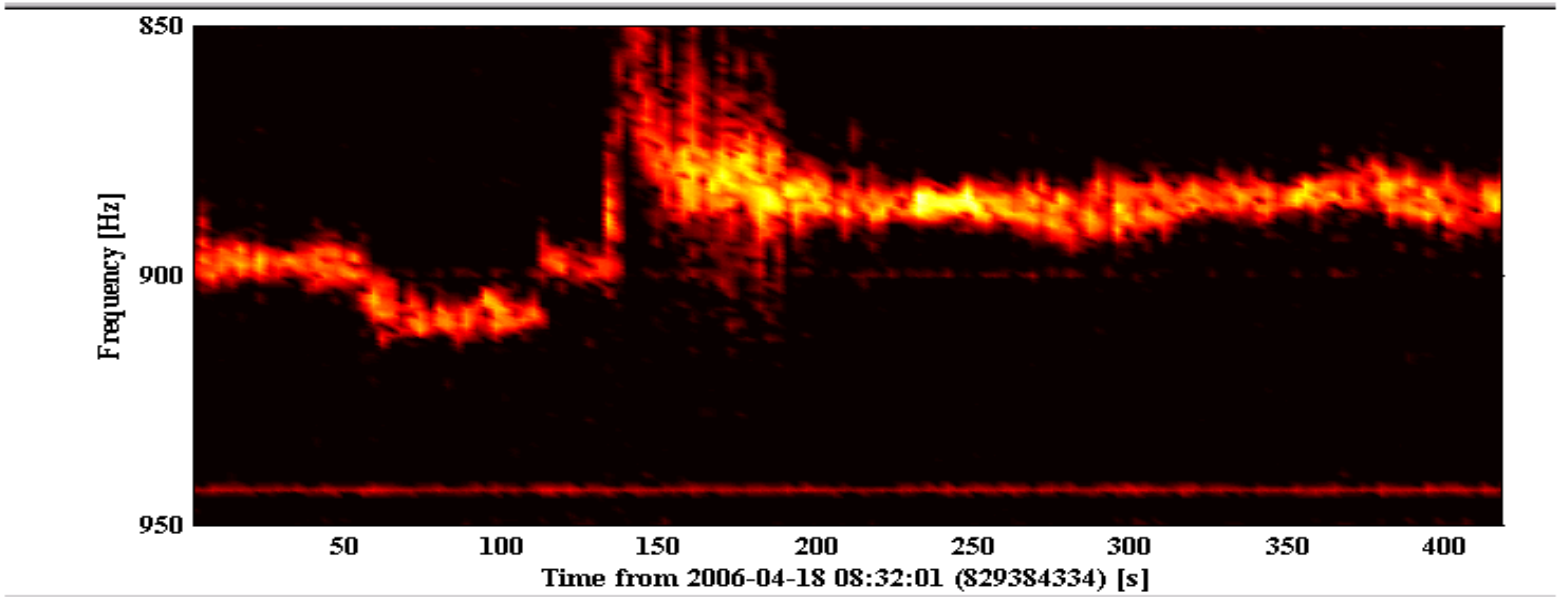


Next step is to check hour trend data...

- looked at all (47) signals that contain the 'offset' and 'rot'. Nothing suspicious at the corresponding time.
- looked at all signals containing 'offset' and 'tilt'. => no result
- looked at all signals containing 'offset' and 'long'. => no result
- looked at all PEM channels (seismic, acoustic, magnetic, temperature). => nothing suspicious
- looked at trend data of all fast channels => nothing
- looked at all flag data (138 channels)

Only known influence on owl yet:

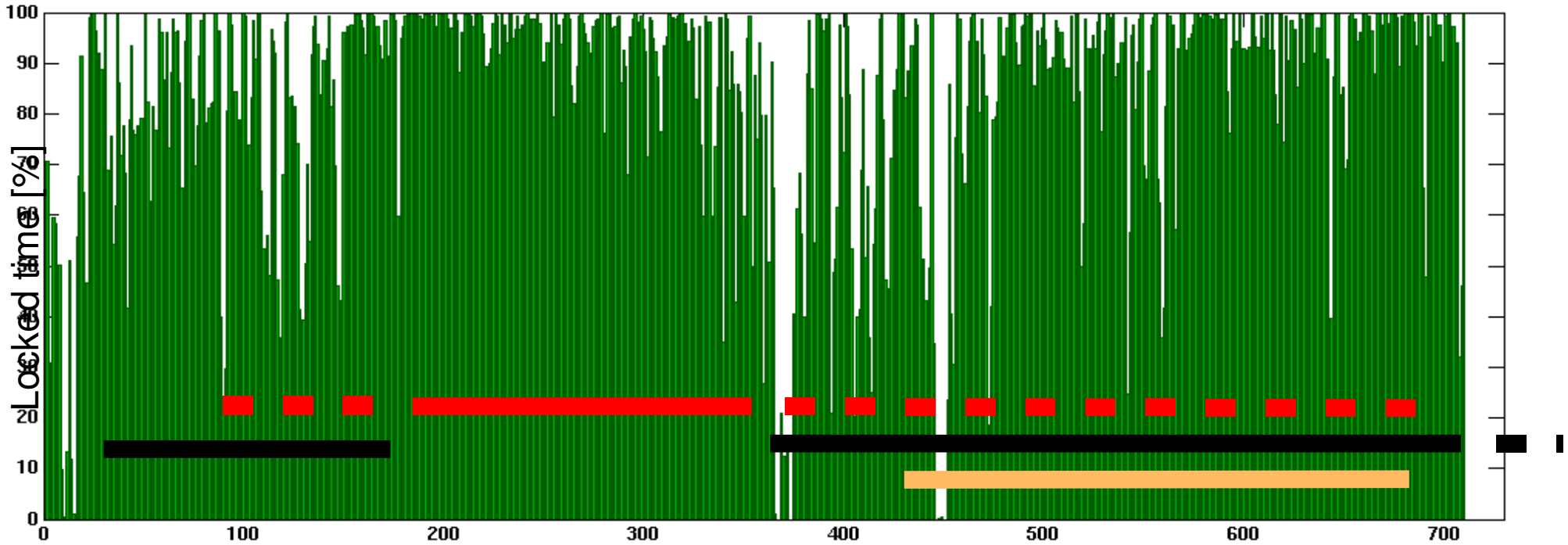




Beam position
in central cluster

The Last Two Years

Locked state and main activities at GEO600



Time [days] (starting 1. Dec. 2005)

S5 N&W — ~269 days science time [60%]

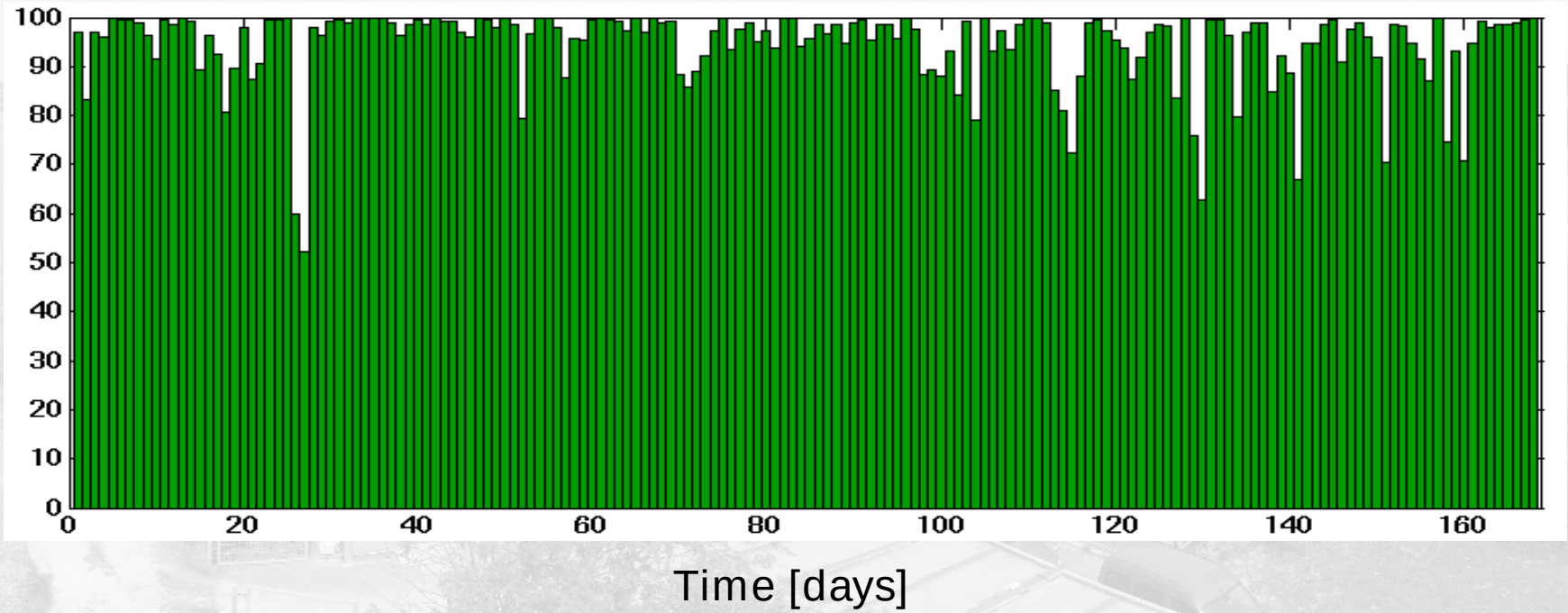
S5 24/7 — ~152 days science time [91%]

421 days

Noise hunting

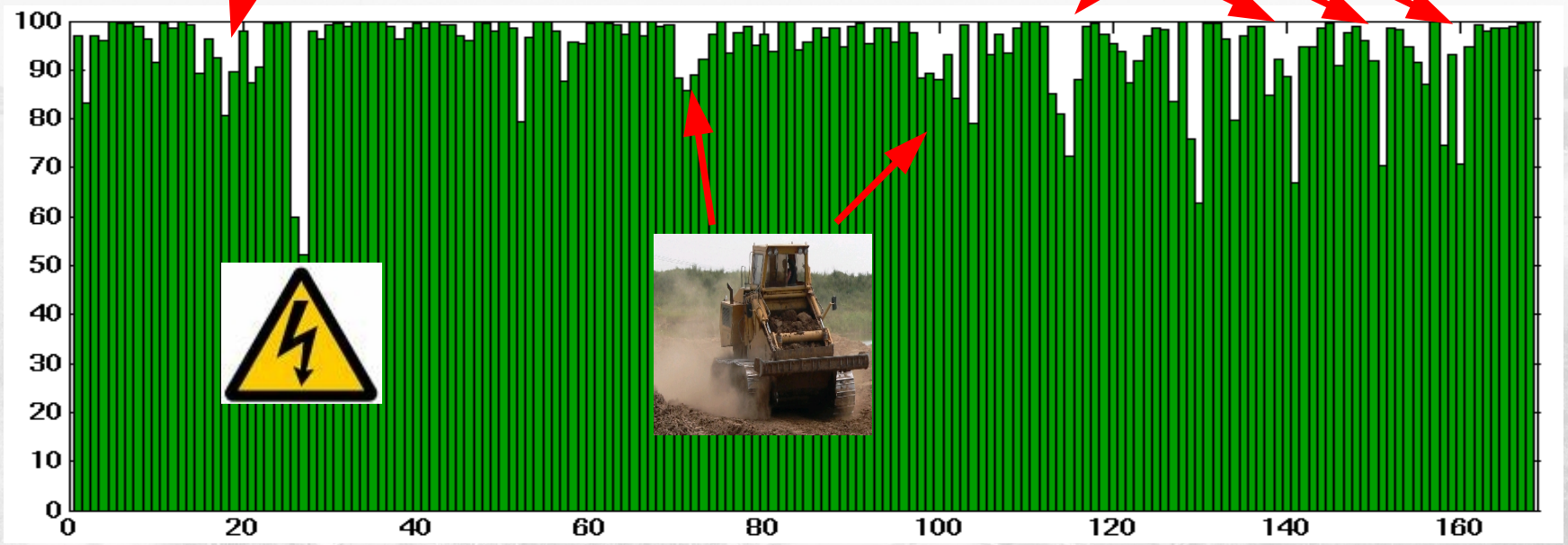
Infrastructure work

S5: 24/7 Mode



- 1. May - 15. October, 168 days
  - Instrumental duty cycle: 94.3%
  - Science time duty cycle: 91 %
- Longest lock: 102 hours

S5: 24/7 Mode



- 1. May - 15. October, 168 days
  - Instrumental duty cycle: 94.3%
  - Science time duty cycle: 91 %
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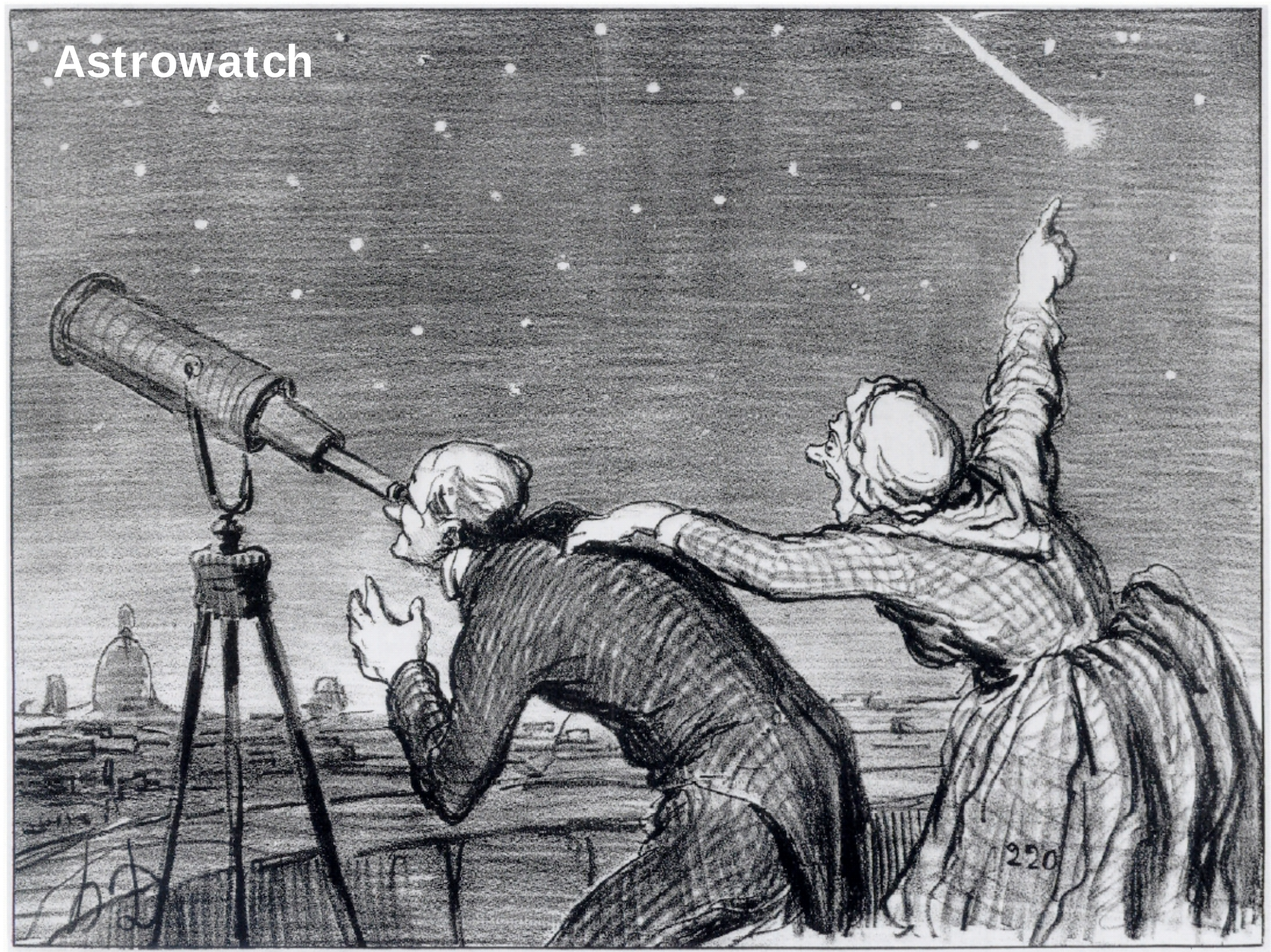
Astrowatch



Astrowatch

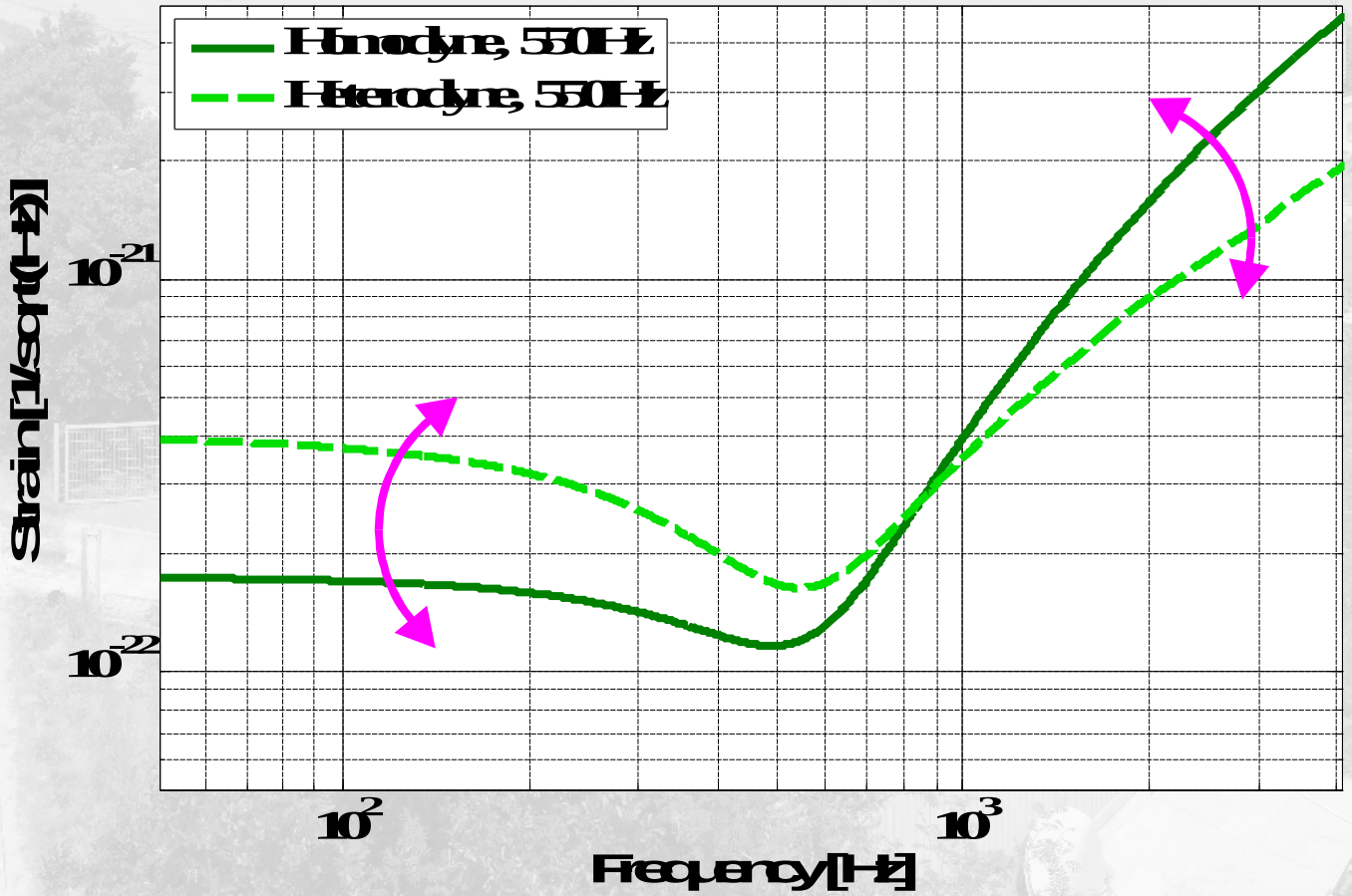
- Astrowatch is the name for the idea to run some IFOs (GEO, LIGO-H2), while others (LIGO 4ks, Virgo) are upgrading their instruments
- We are in Astrowatch since November 2007
- We still allow for investigations and commissioning at the detector, but keep risks low and aim for at least 80% up-time.
- Searches with this data will be mainly for triggered events. E.g. X-ray flare/faint GRB observed at 2008-01-09 13:32:49 UTC (SN 1c ? ~26Mpsec?)

DC Readout: A New World

- From heterodyne (AC) to homodyne (DC) readout:
  The term 'DC readout' refers to local oscillator generation from a dedicated dark fringe offset

- Anticipated advantages:
  - Reduced modulation noise coupling
    (in particular important for detuned signal recycling)
  - Better sensitivity (~20 to ~40 %)
- But pay attention to:
  - Larger power noise coupling?: OK, but get optical filter for LO !
  - Output mode-cleaner: Alignment to power coupling, scattering

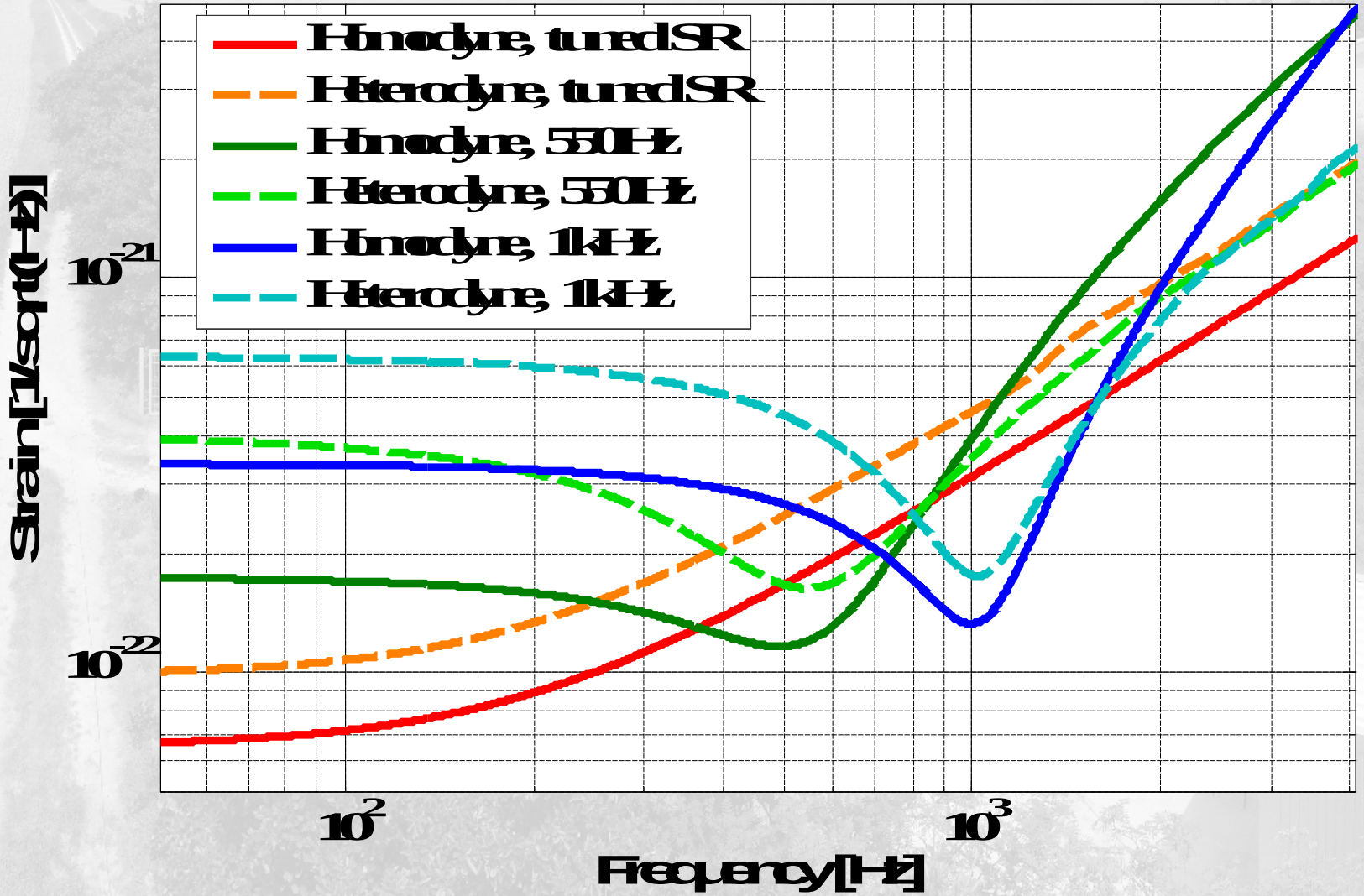
Simulated shot noise: Homodyne vs Heterodyne detection



DC-readout with detuned SR: - better peak sensitvity

- shape is rotated => better at low freqs, worse at high freqs.

Simulated shot noise: Homodyne vs Heterodyne detection



DC-Readout without OMC

IDEA:

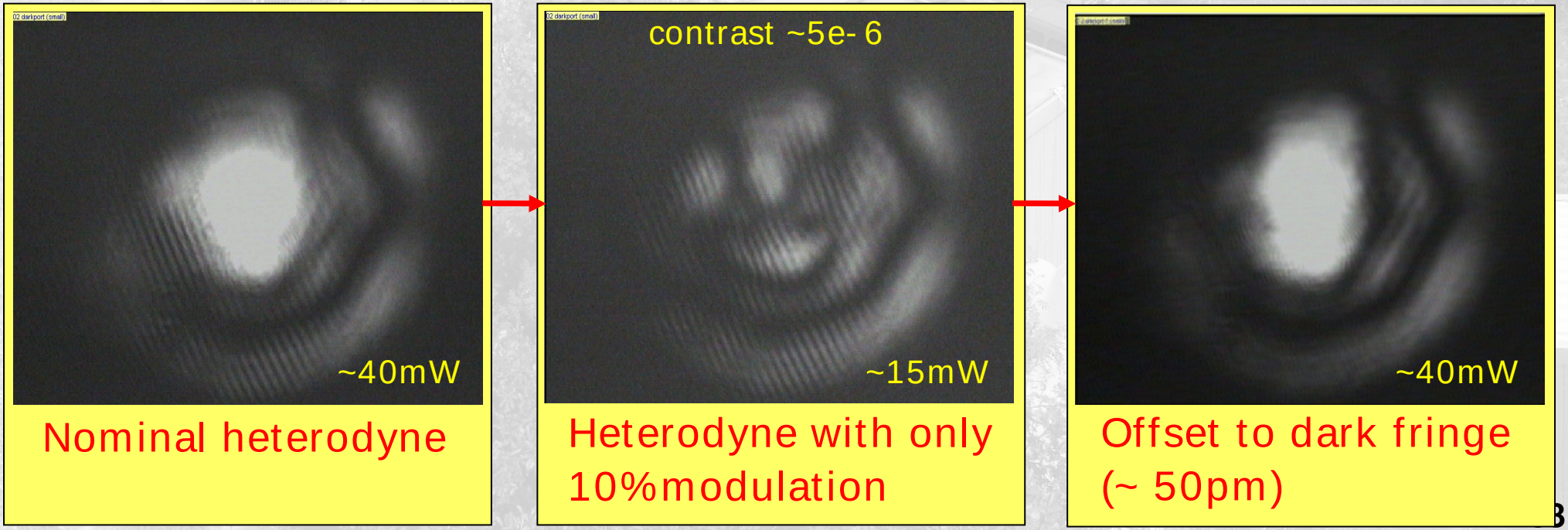
Turning down the RF-modulation *(factor 10 is possible)*

Using an offset from dark fringe *(of the order 50pm)*

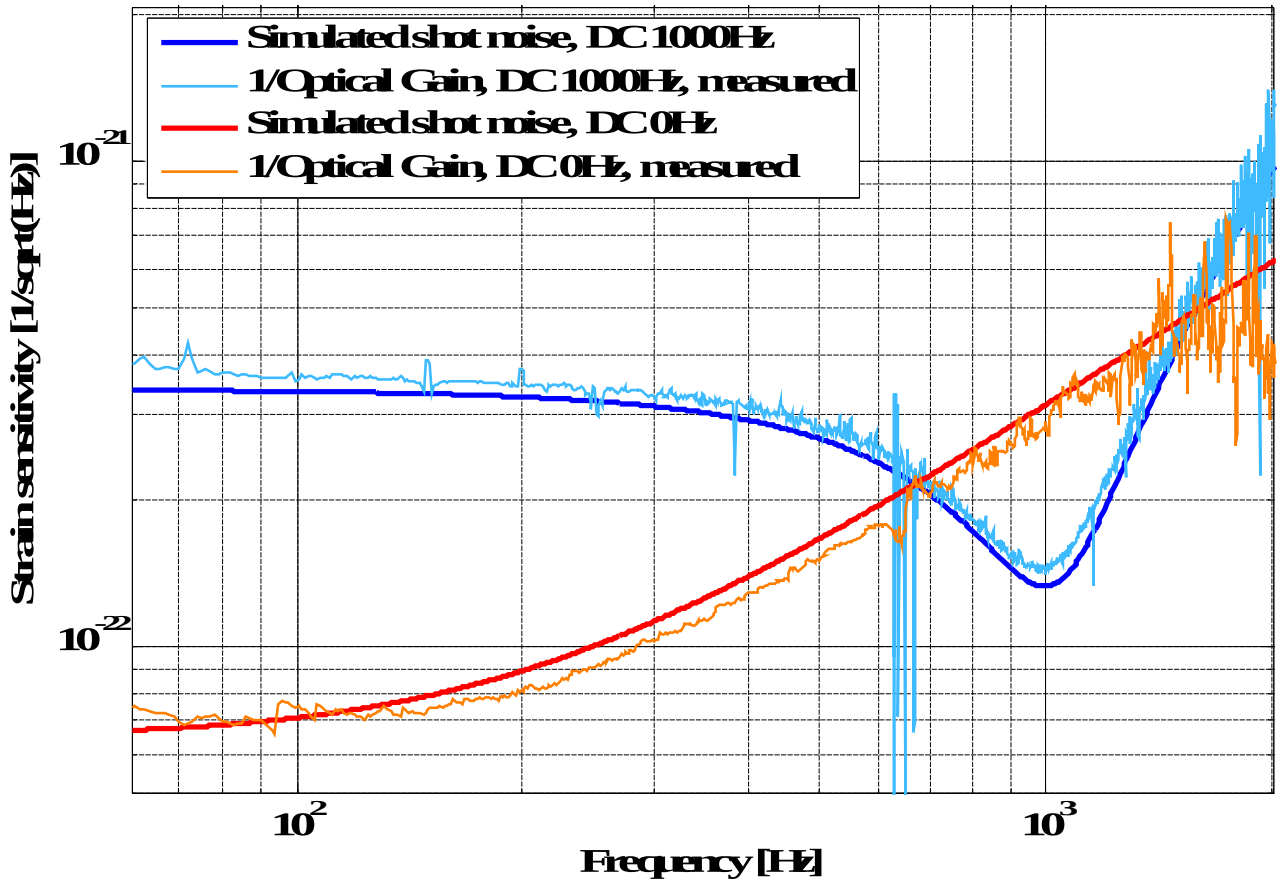
Dark port dominated by carrier light

EXPERIMENT in GEO600:

Locked to dark port power

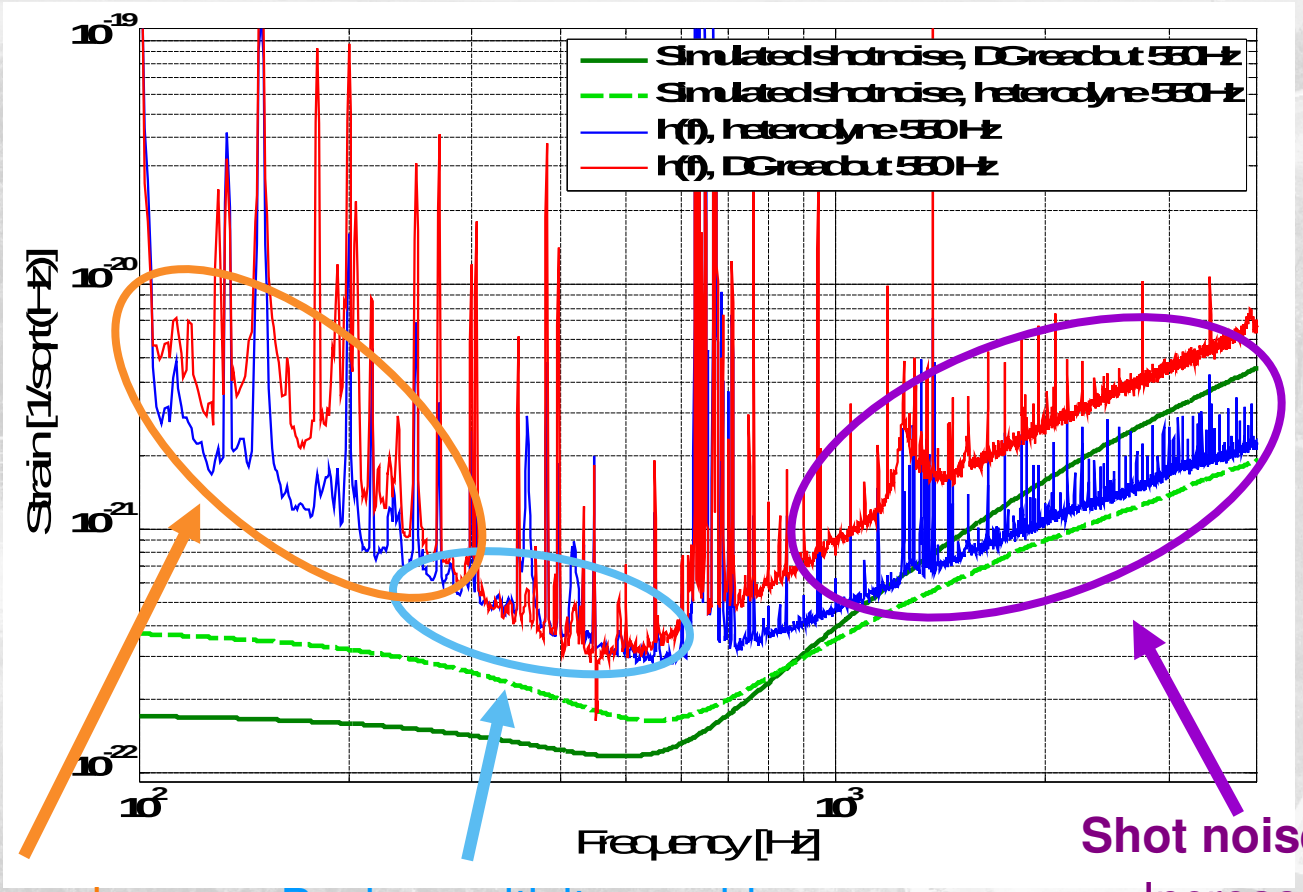


Comparison of measured and simulated optical transfer function for DC-readout



The simulated optical transfer function for tuned and detuned SR wit DC-readout is reproduced by our measurements.

Best sensitivity so far with DC-readout and a SR detuning of 550 Hz



Increased technical noise

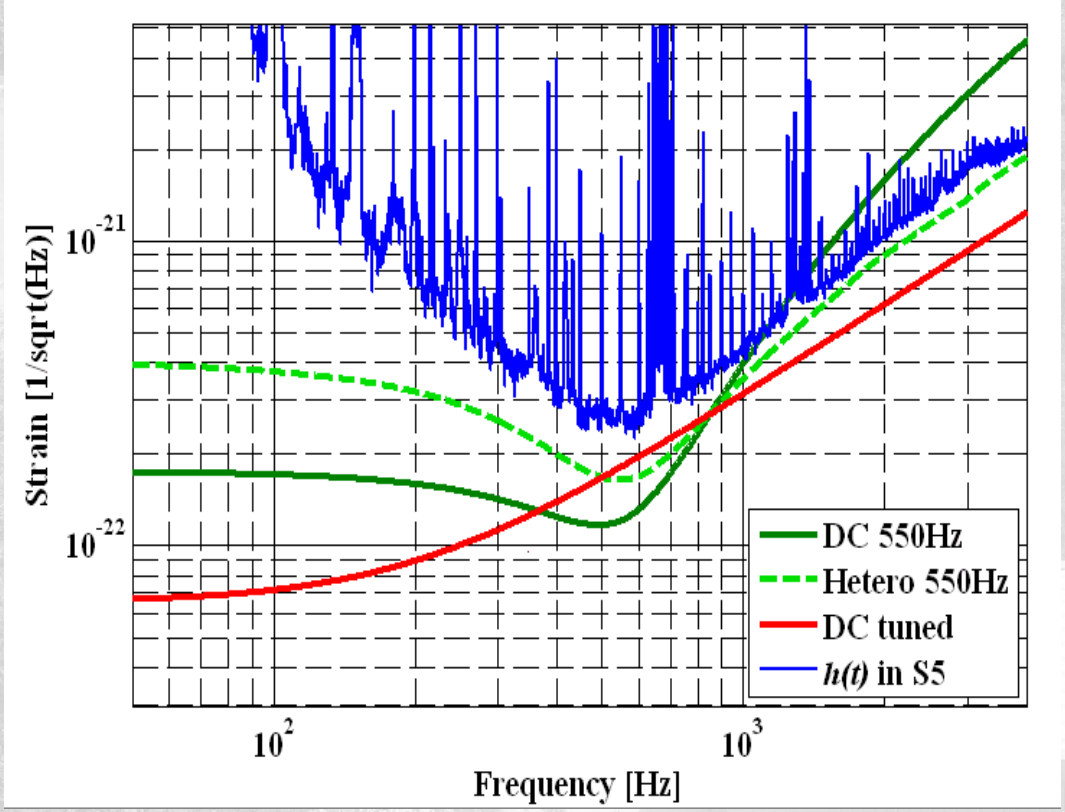
Peak sensitivity roughly same as with heterodyne **(2e-19m/sqrt(Hz))**

Shot noise
⇒ Increased at high freqs in DC-readout (with detuned SR)

Where to go in future ??

DC-readout with tuned Signalrecycling

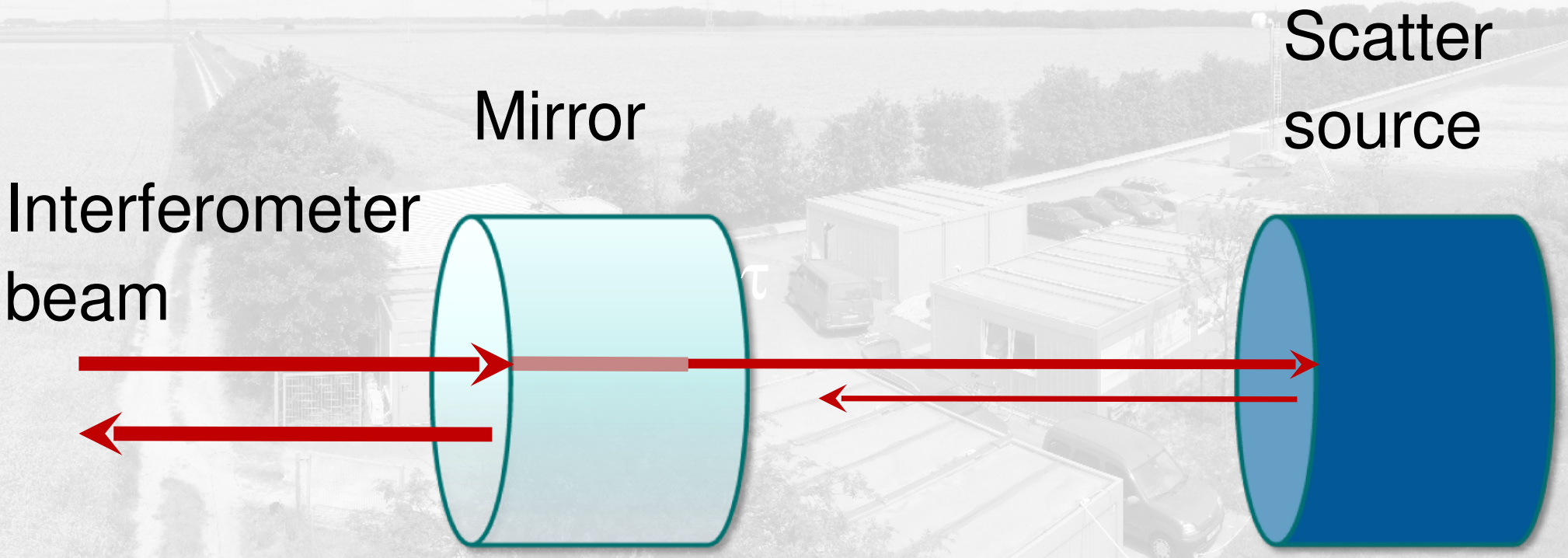
- Best shot noise at low and high frequencies.
- This combination of SR tuning and DC-readout would allow an ‚easy' implementation of squeezed light (no filter cavity necessary to get full benefit)



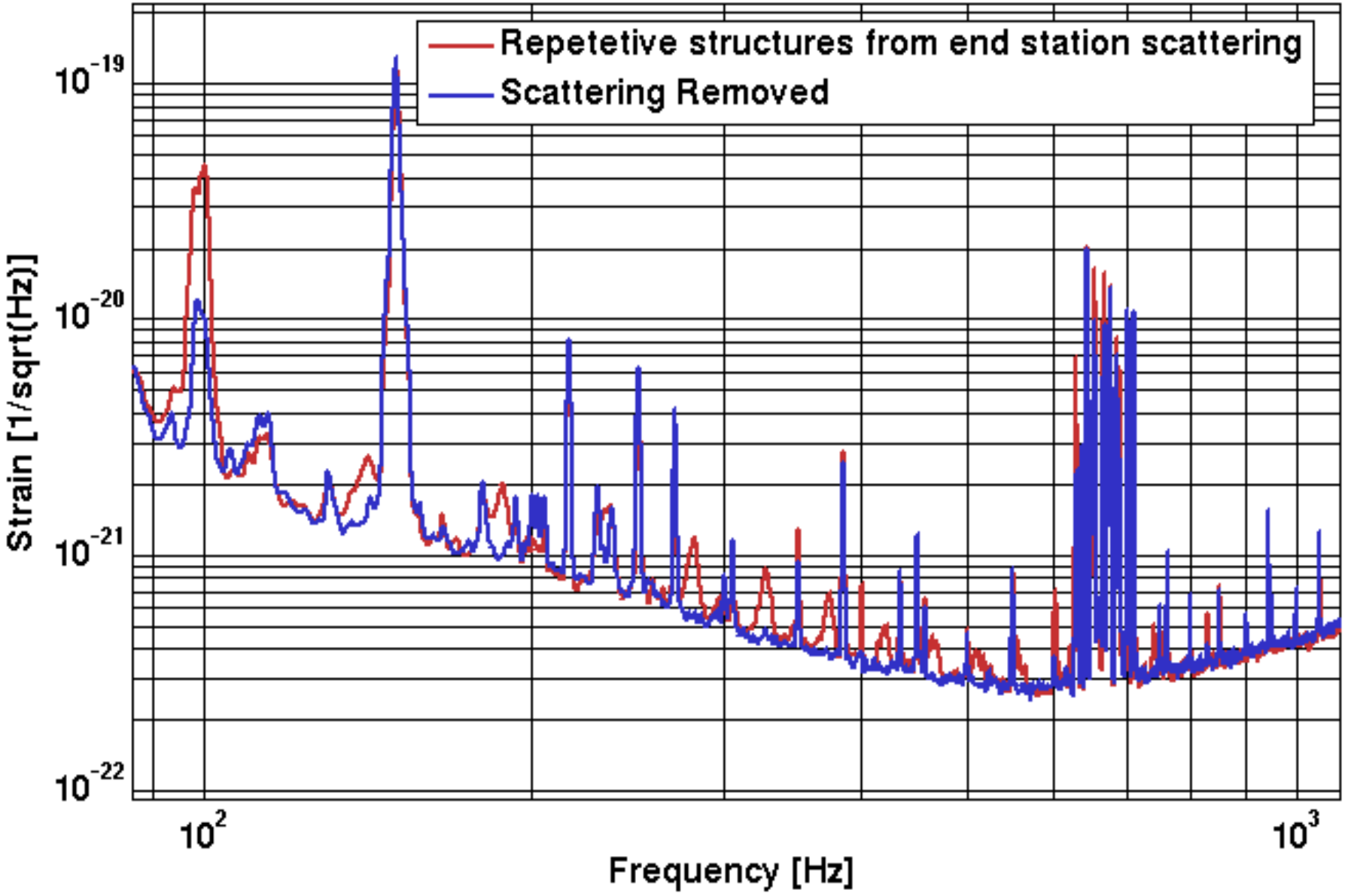
DC readout Summary

- Demonstrated DC-readout with tuned and detuned Signal-Recycling (without OMC)
- Going to DC-readout changes the optical demodulation phase (rotated shape of optical response)
- Optical response measurements and simulations agree pretty well
- Achieved a displacement sensitivity of 2e-19m/sqrt(Hz) (similar to detuned heterodyne around 500Hz
- Laser power noise is not as bad as rumors suggest (due to filtering of PR cavity pole)

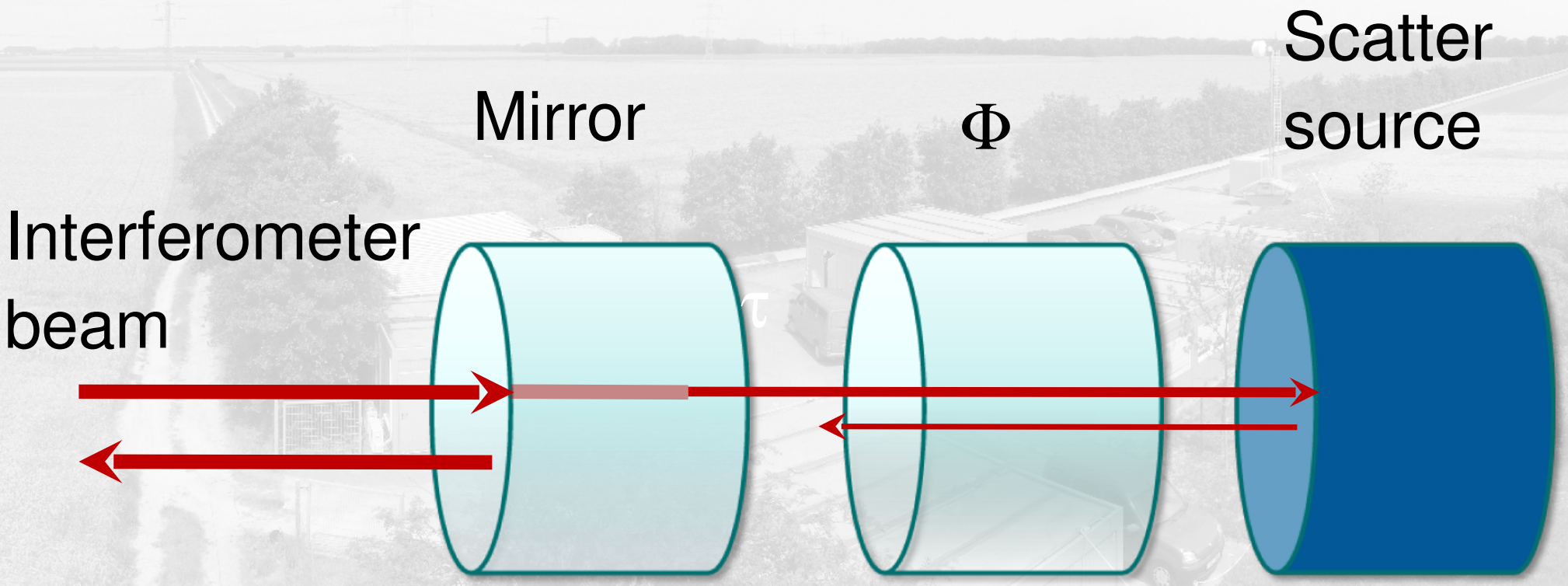
Scattering (example)



Scattering (measured in GEO)

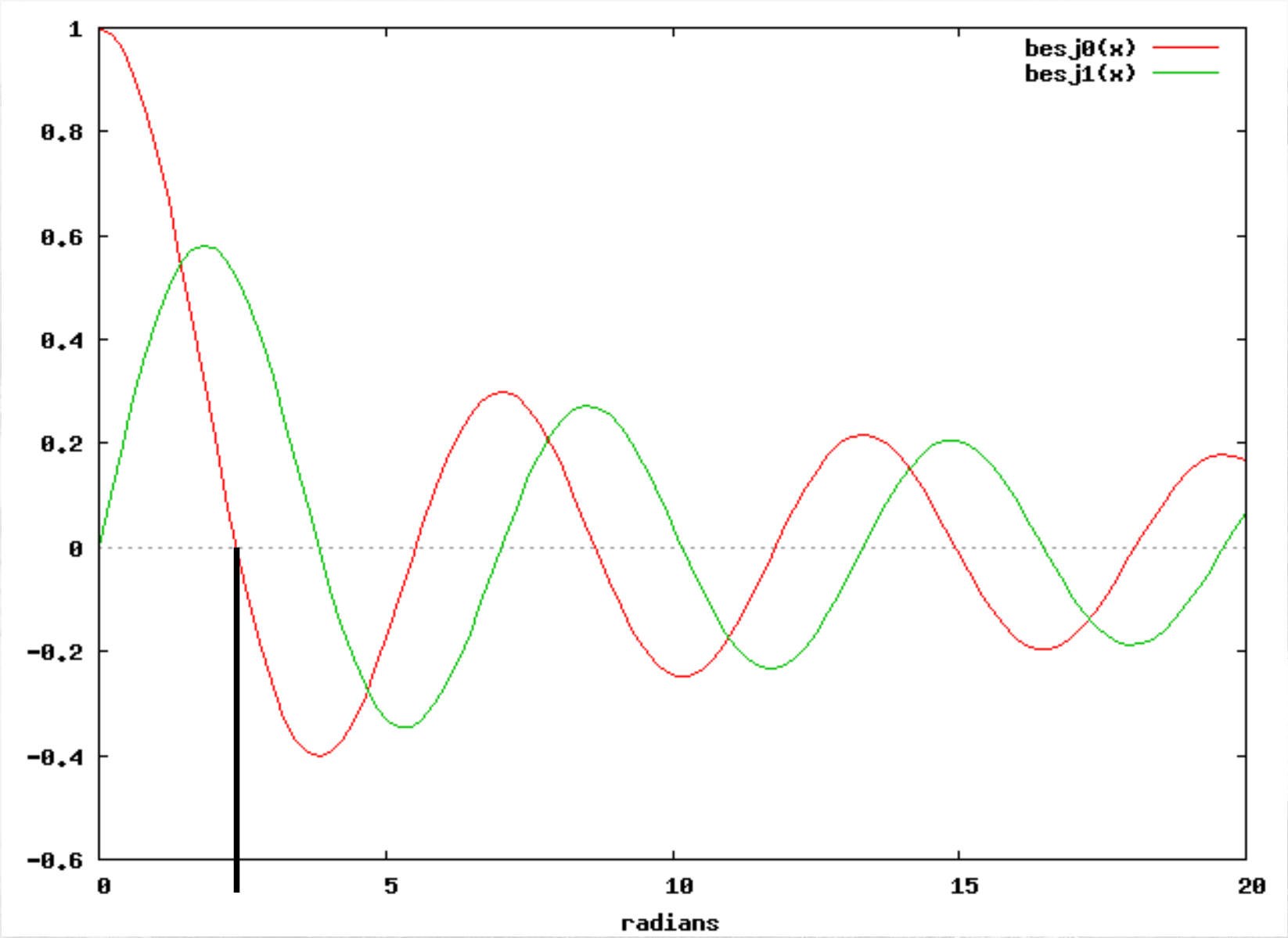


Idea: Shift phase of scattered light

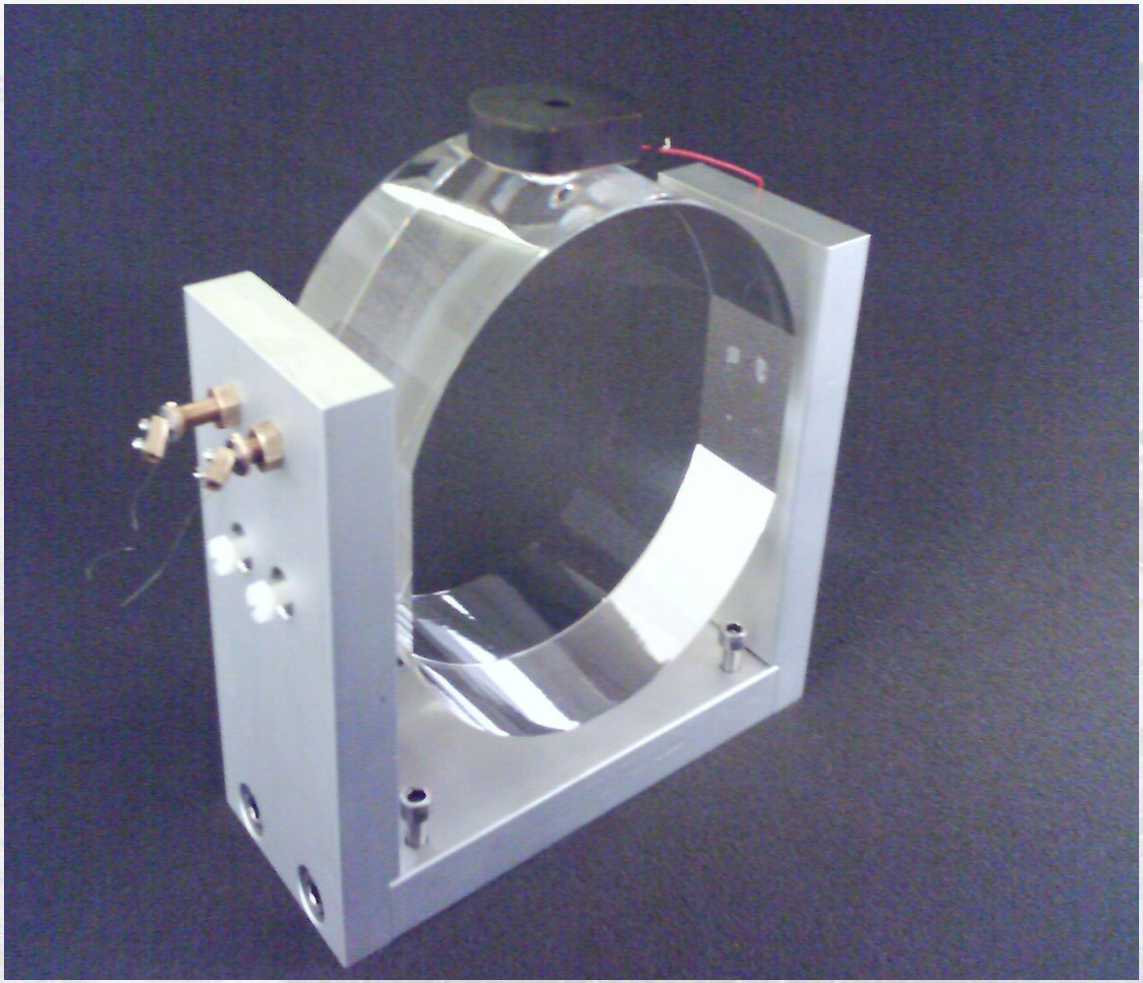


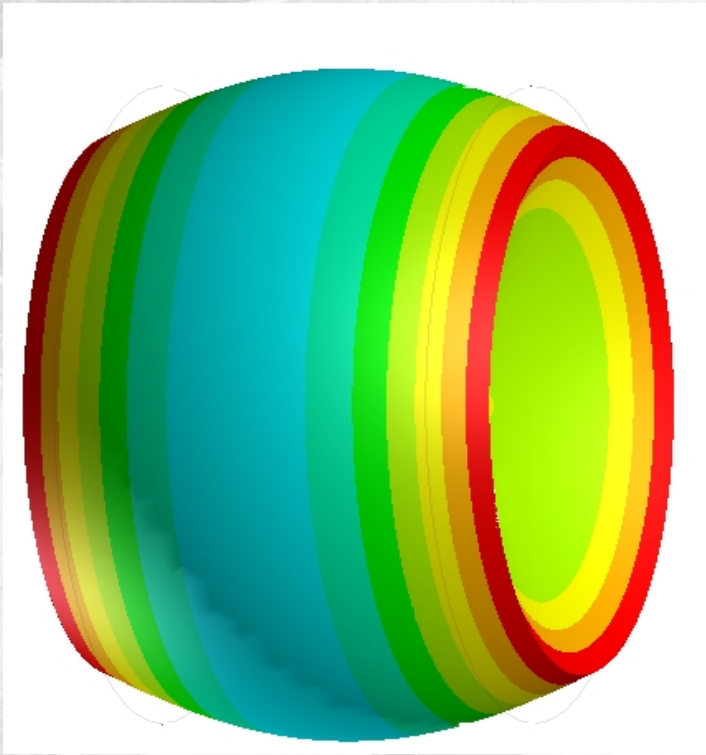
Choose m=1.2 (single pass) to almost eliminate carrier light and its sidebands from the scattering in double pass. J0 has first zero-crossing at m=2.4

Bessel functions J0, J1



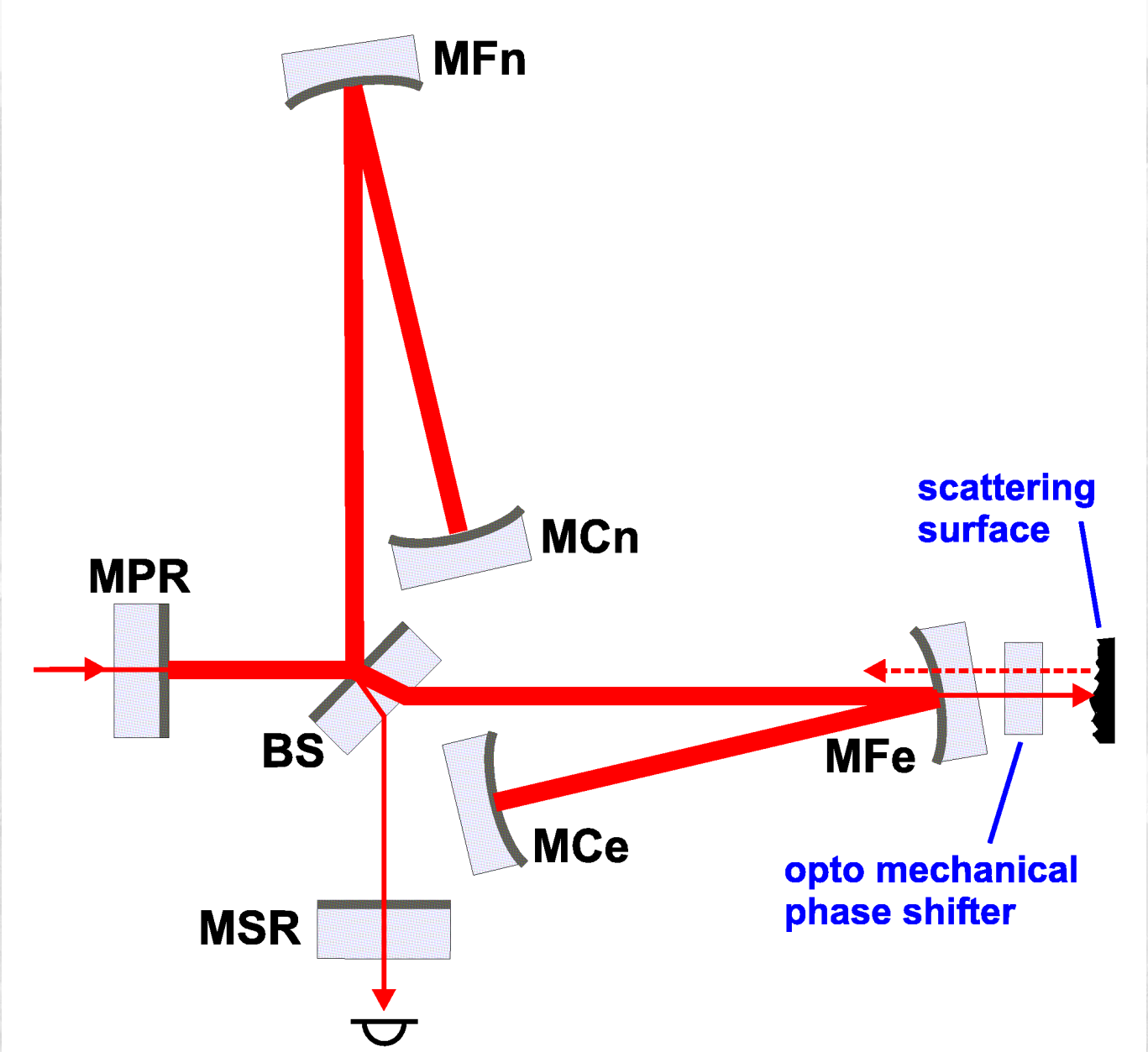
Mirror spare substrate



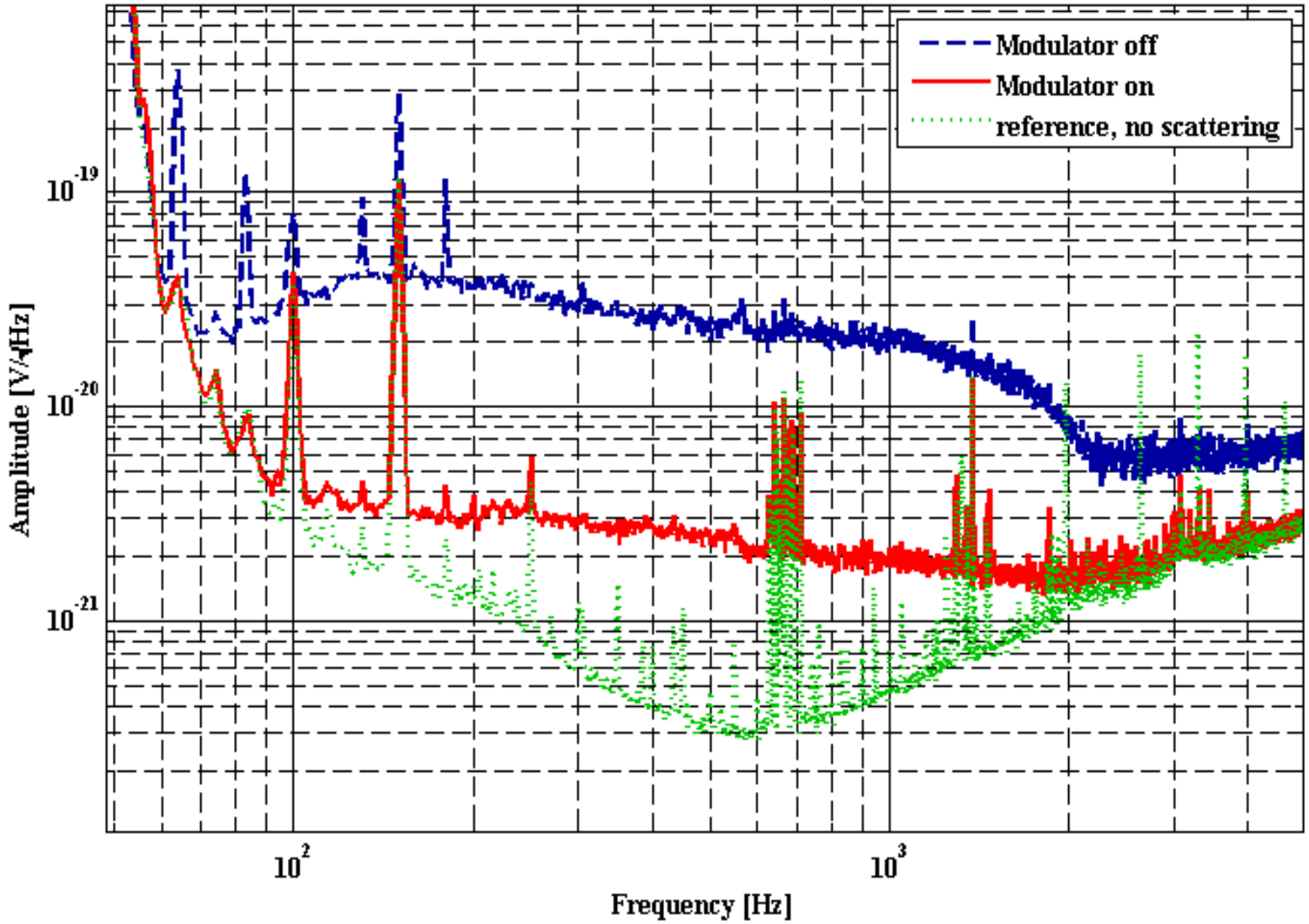


Excite eigenmode at f~24kHz with PZT actuator

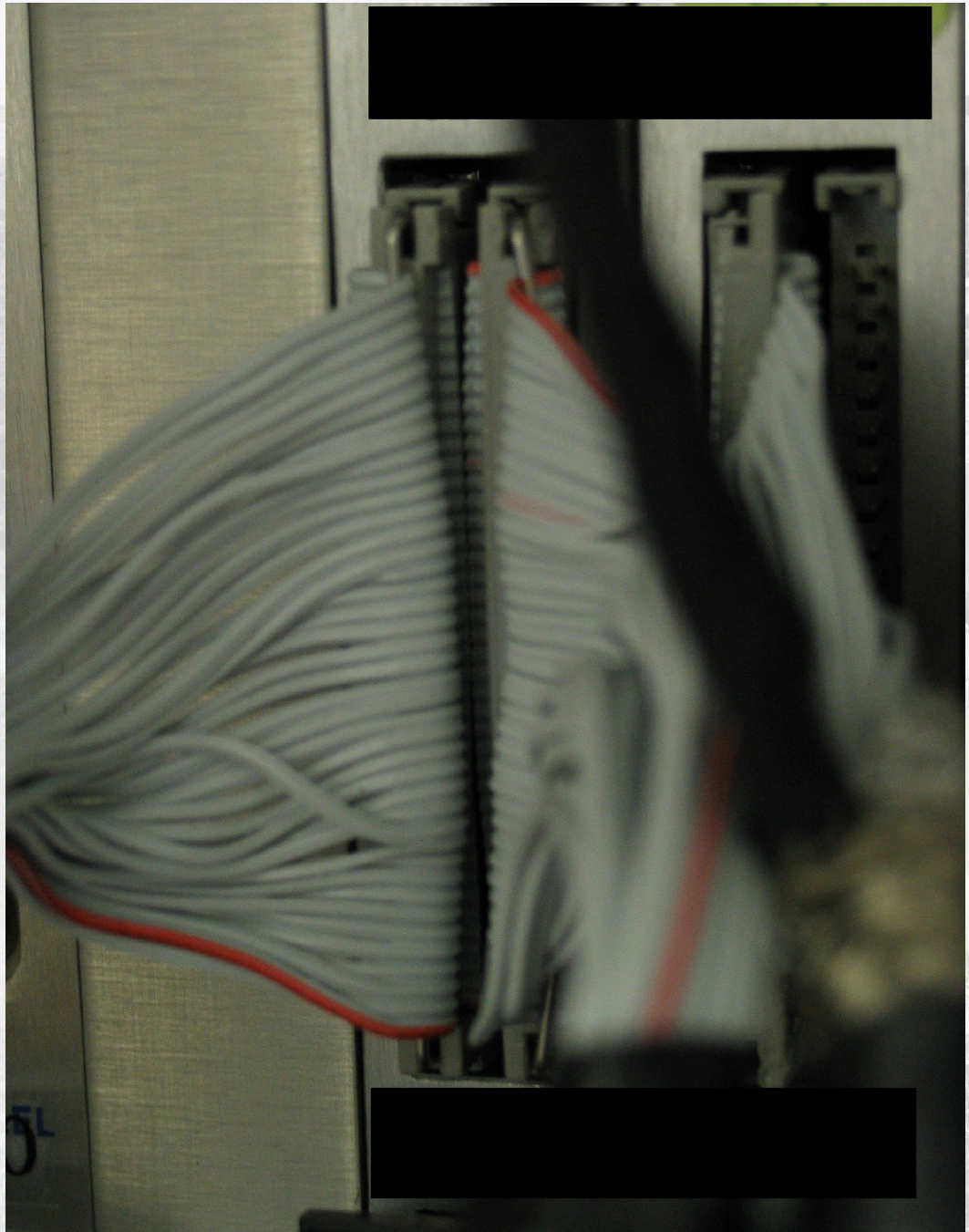
Experimental setup to test the device



Experimental suppression achieved



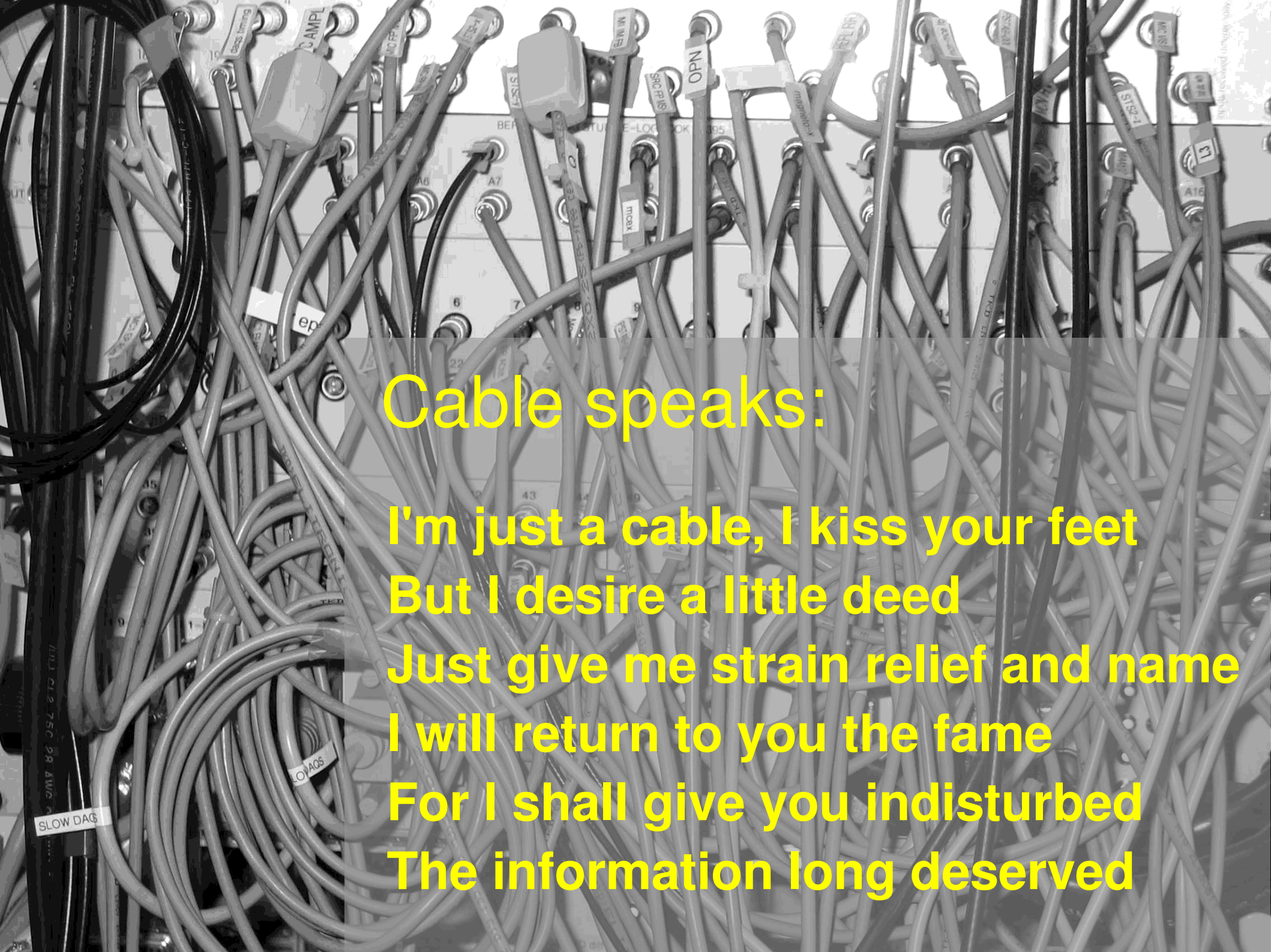
Cables



From an anonymous interferometer.

The Under-Estimated Beings

- **CABLES**
  - Should be treated with more respect
  - A GW detector is different from a lab experiment (we had to learn this...). Cables are permanent installations rather than just connections
  - (Long) cables need design work, regarding impedance, line drivers, line receivers, whitening, shielding, routing, ...
  - ...and they need strain reliefs and labels!
  - Perhaps a site should have a cable manager ?



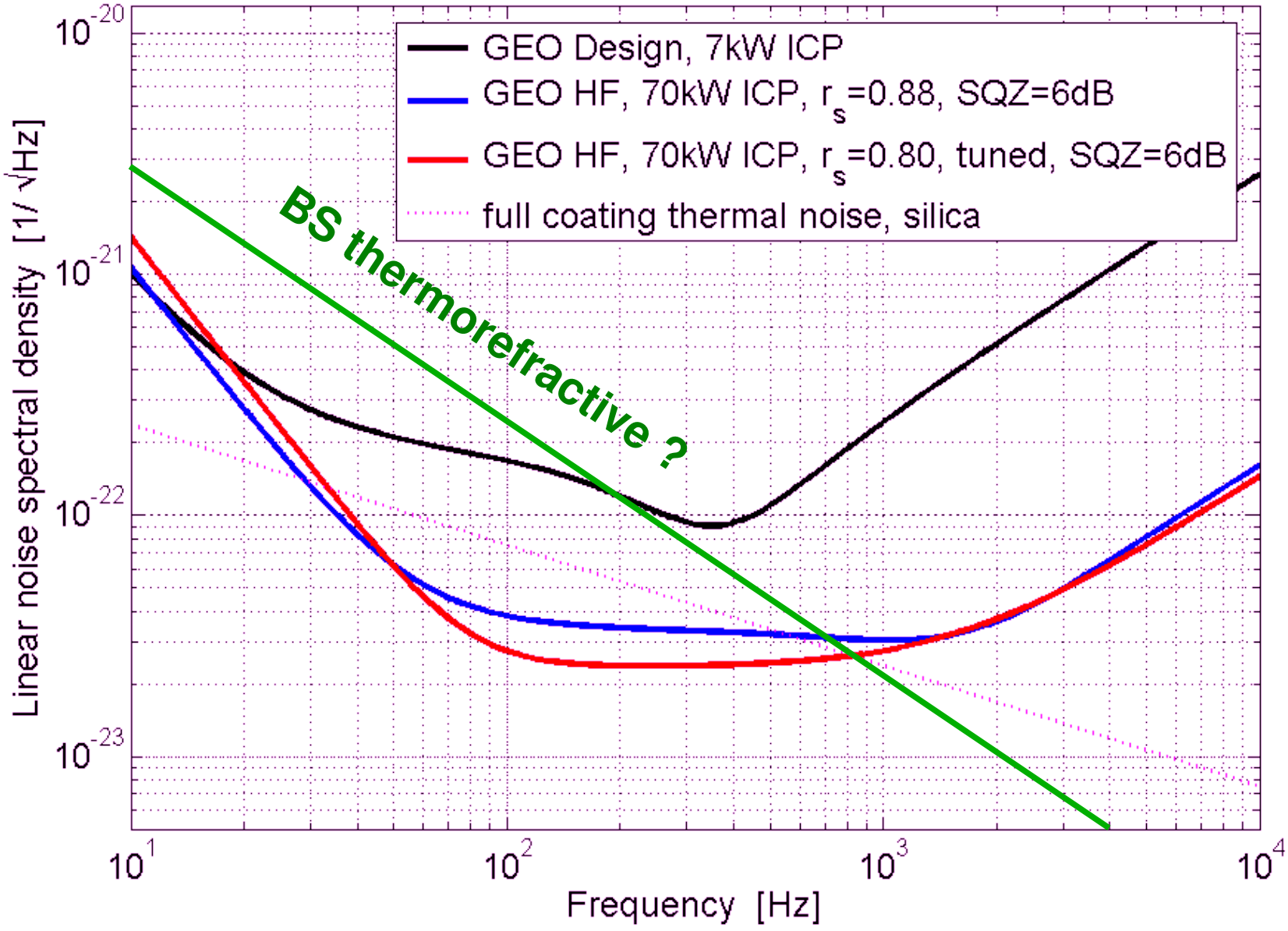
Cable speaks:

I'm just a cable, I kiss your feet
But I desire a little deed
Just give me strain relief and name
I will return to you the fame
For I shall give you indisturbed
The information long deserved

Plans

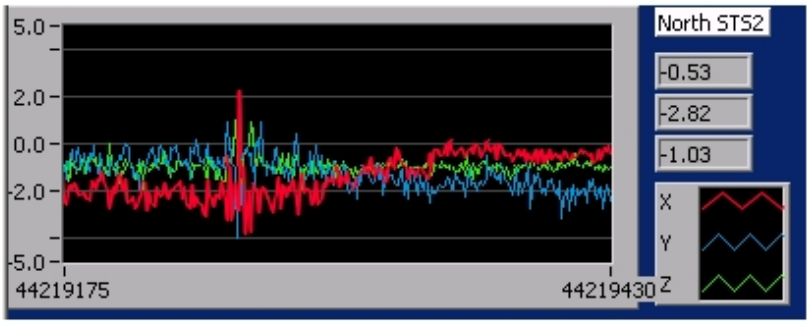
- Astrowatch + low-level commissioning until Enhanced IFOs come online (spring/summer 2009 ?)
- GEO-HF is the frame for sequential upgrades of the GEO600 detector
- Topics: DC readout, squeezing, higher power, more digital controls (Adv. LIGO system), new mirrors/coatings to lower thermal noise ?, ...

A little dream...



Automatic Cameras at GEO...

sheep at the northbuilding

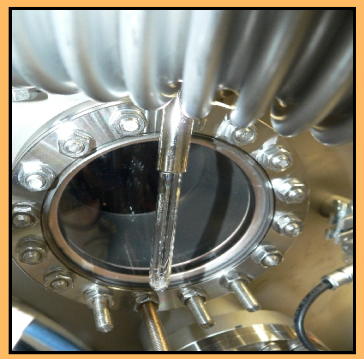


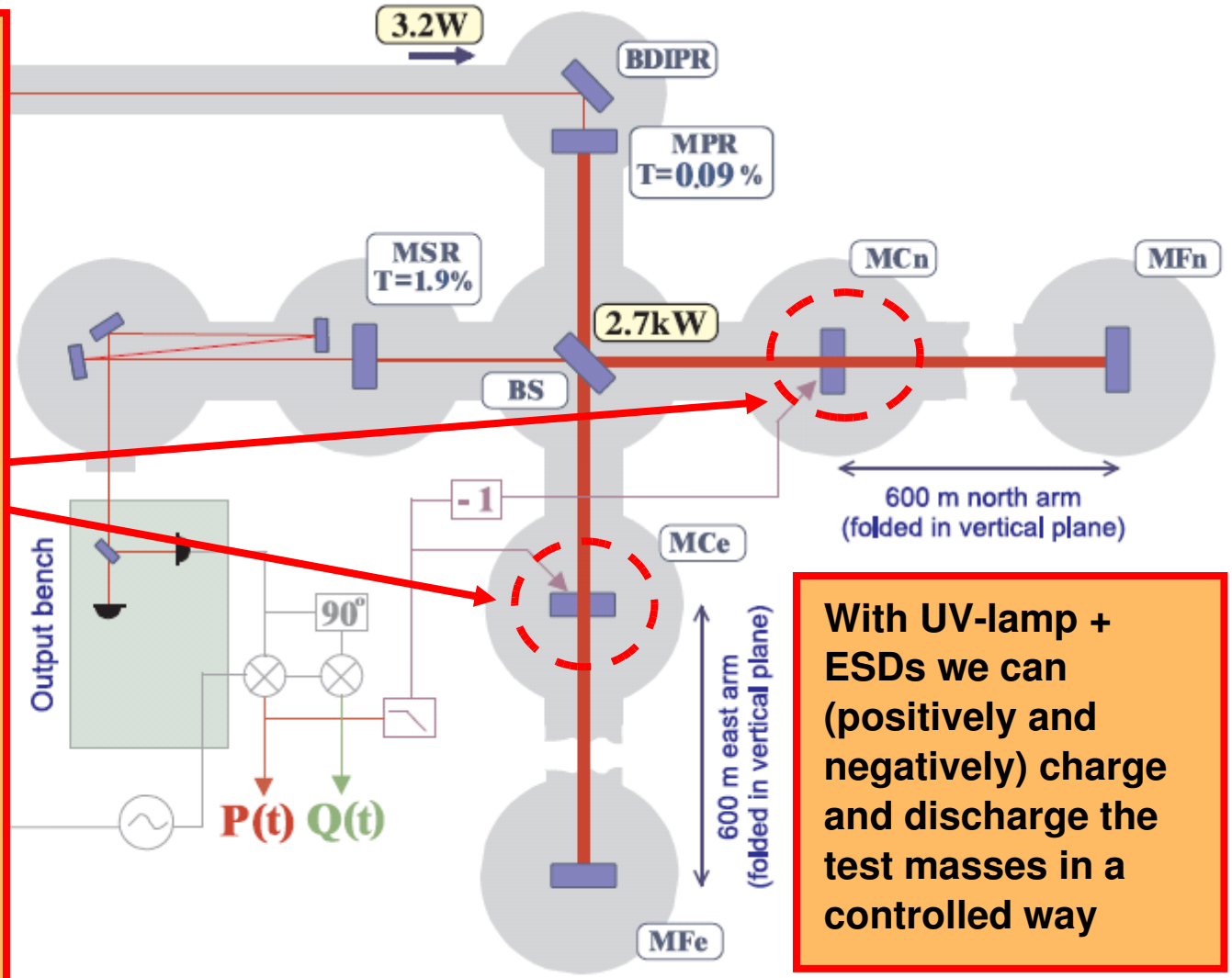
END

The GEO600 Interferometer

Charges on test masses

- **Measured positive charging of testmasses**
- **Discharged by using a UV-lamp**
  (electrons are freed from ESD electrodes)

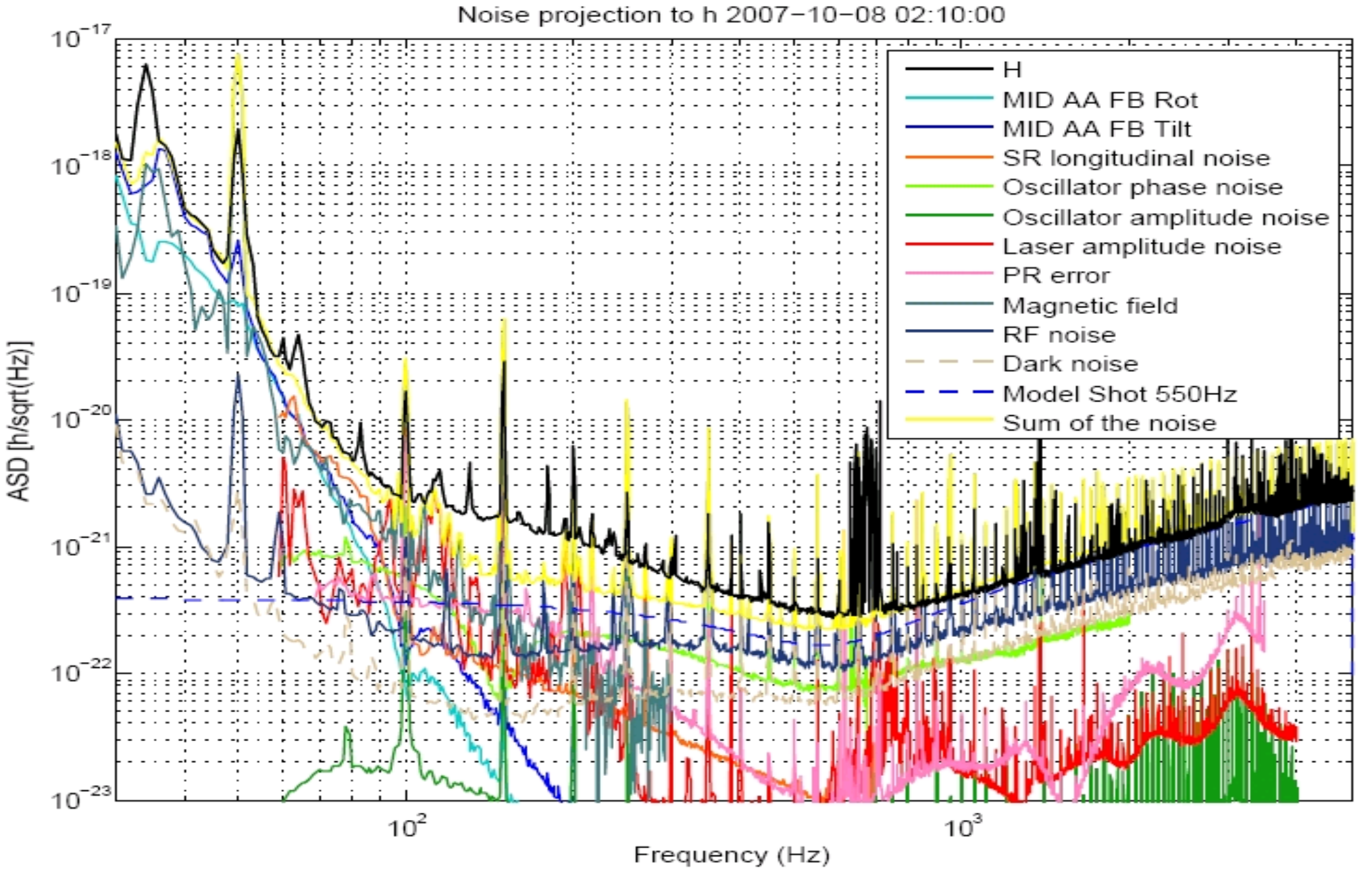




With UV-lamp + ESDs we can (positively and negatively) charge and discharge the test masses in a controlled way

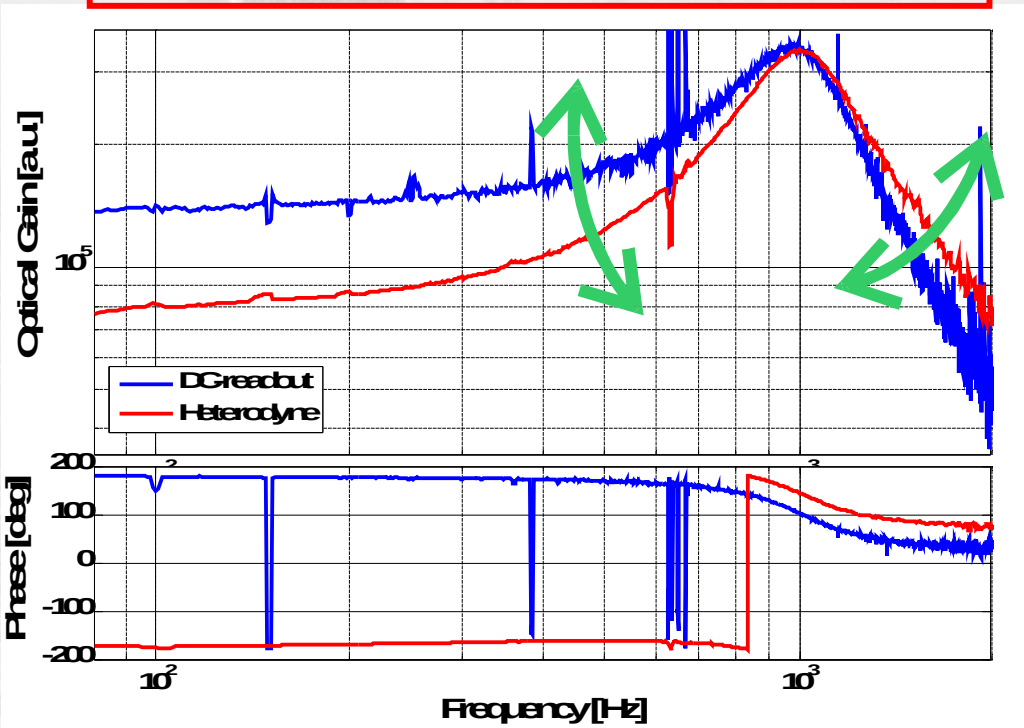
Poster by M. Hewitson: ***Charge mitigation [...] of the GEO600 test-mases***

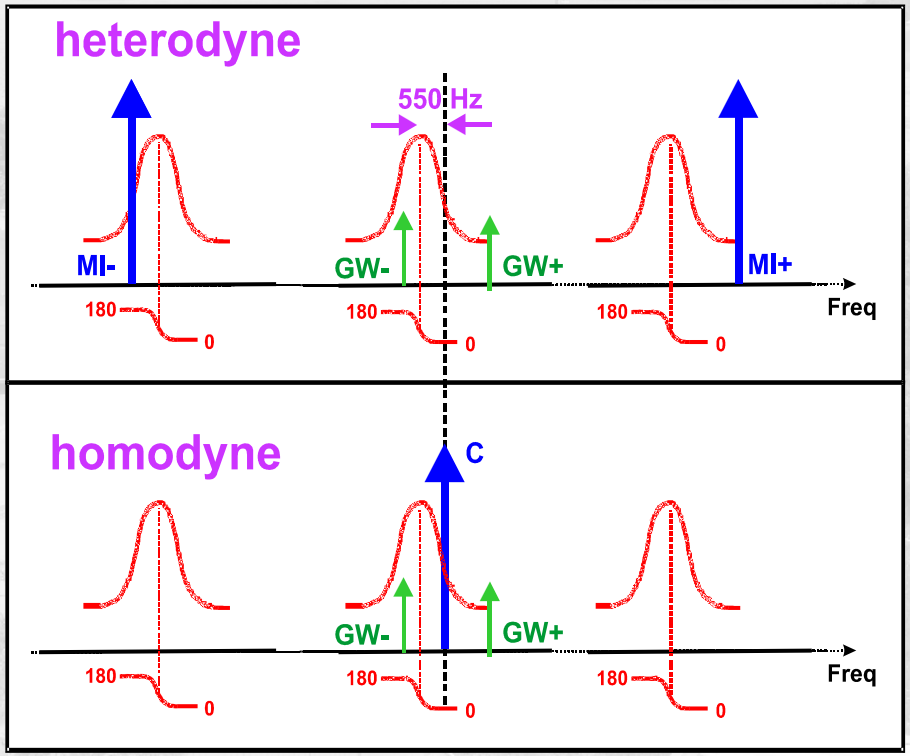
Noise Projections



‚Rotation' of the optical gain

Rotated shape of optical response confirmed by measurement:

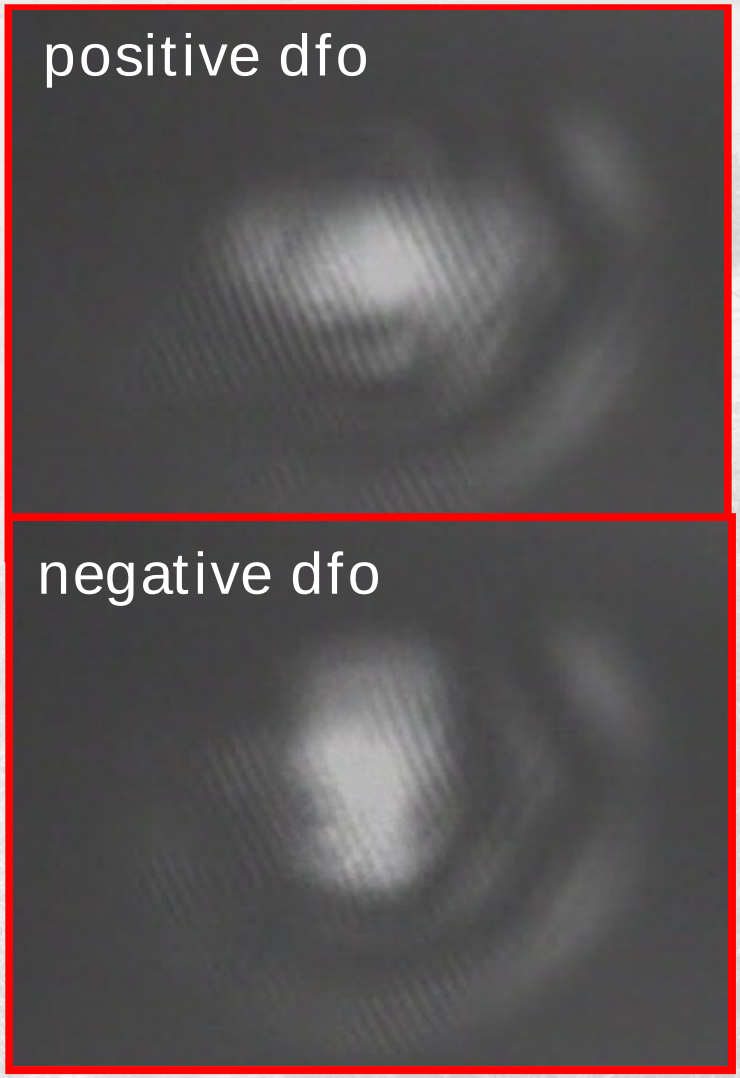


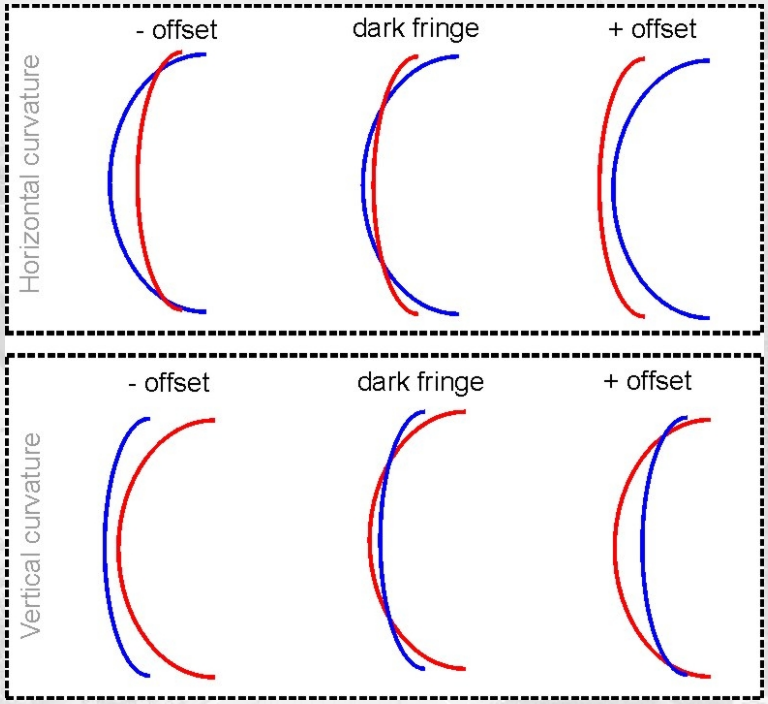


Rotated shape of optical response can be understood by looking at the phases of the contributing light fields. => change of the optical demodulation phase.

	C	GW+	GW-	MI+	MI-
f<< 550 Hz	0	0	0	0	180
f>>550 Hz	0	0	180	0	180

Output mode for positive and negative dark fringe offset (dfo)





Wave front radii of returning beams @ beam splitter:

horizontal: north > east
vertical: north < east

Simulated suppression as function of modulation index