GEO 600 STATUS

Andreas Freise on behalf of
Hartmut Grote for the LSC

Gravitational Waves: New Frontier
Seoul, 16.01.2013 **LIGO-G1300030**


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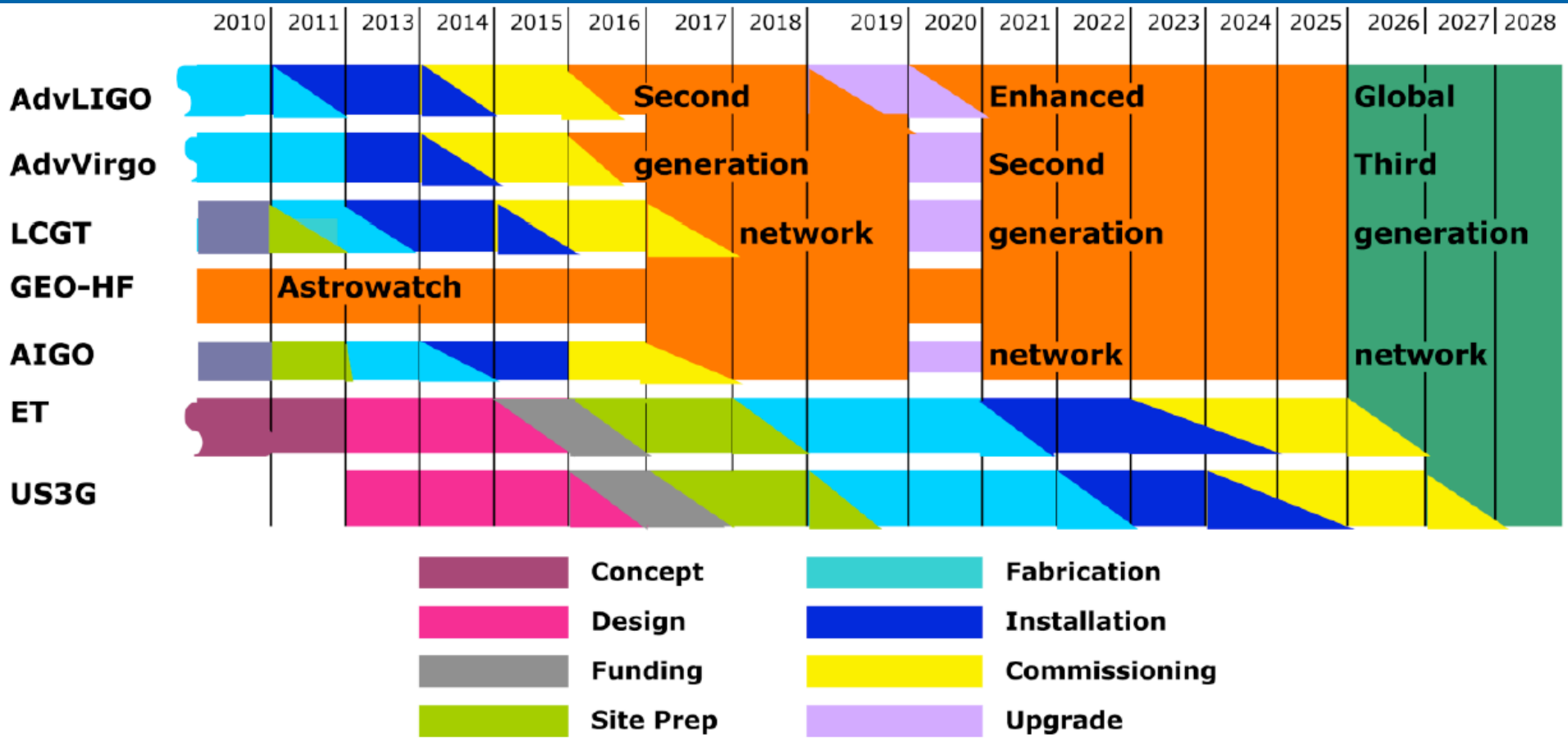
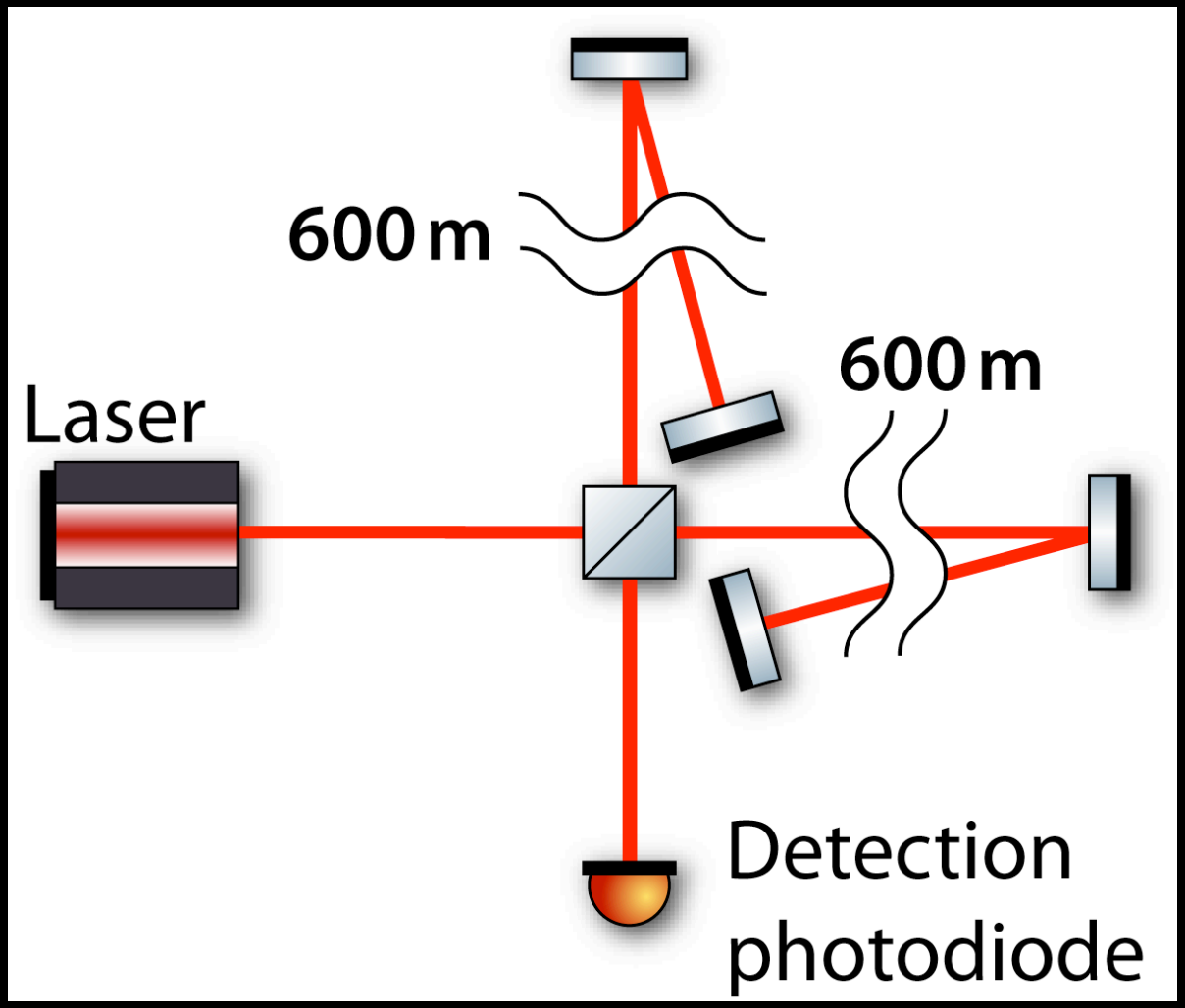
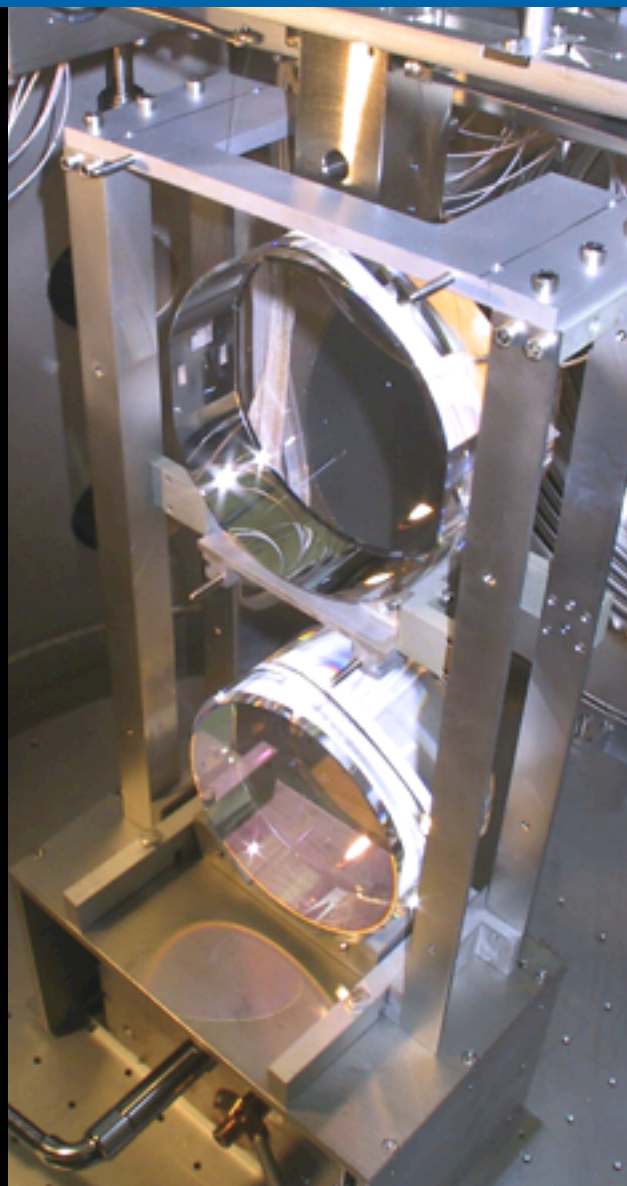
Ground based detector network



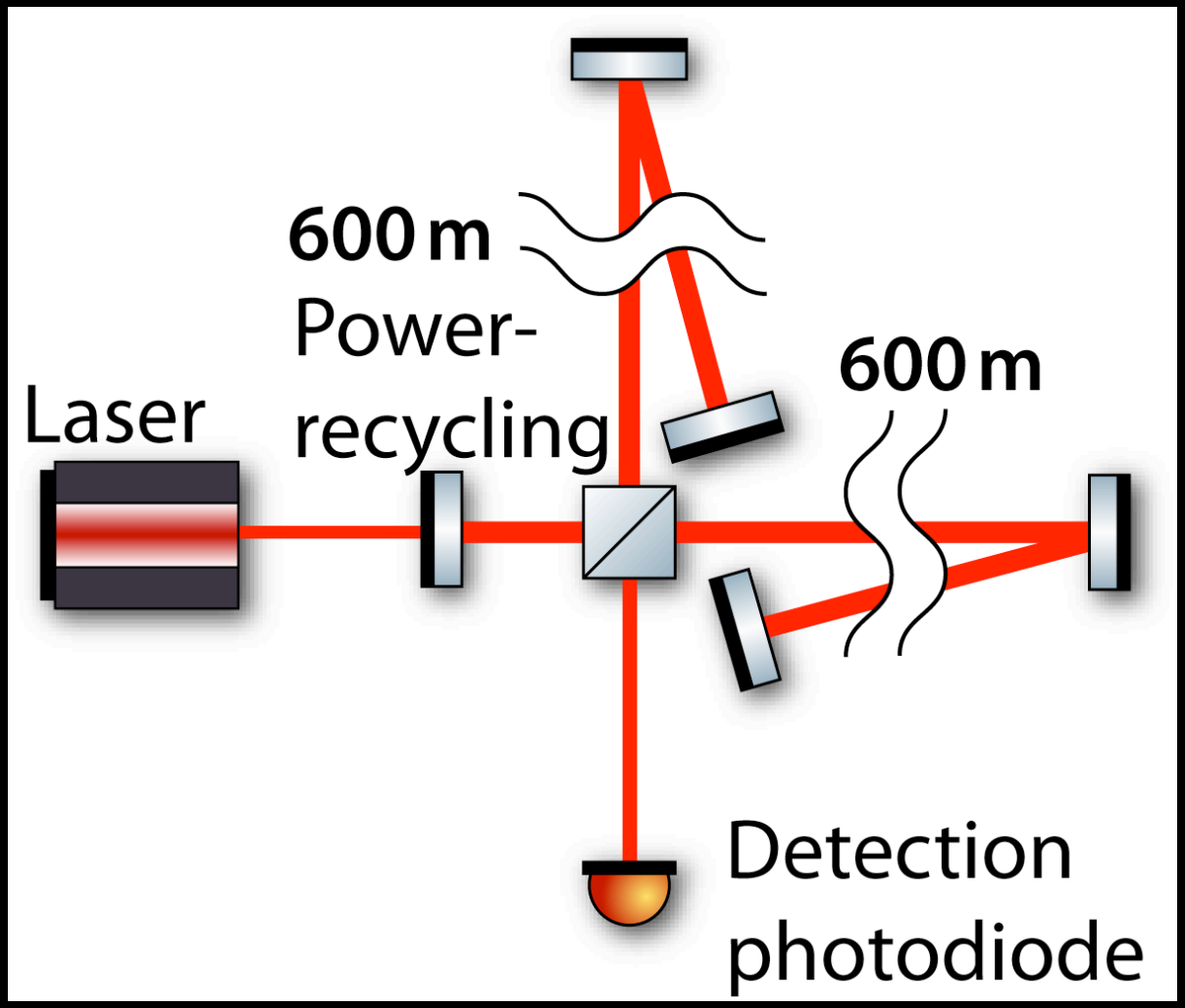
GWIC ‚The future of gravitation wave astronomy‘

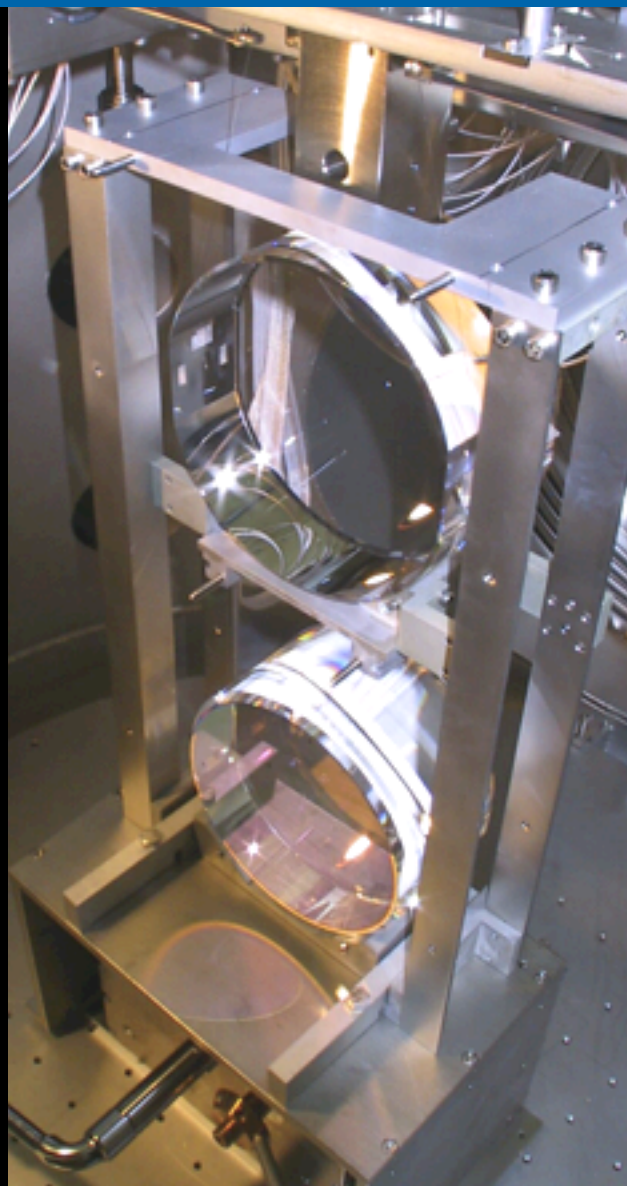
GEO 600 optical design





GEO 600 optical design





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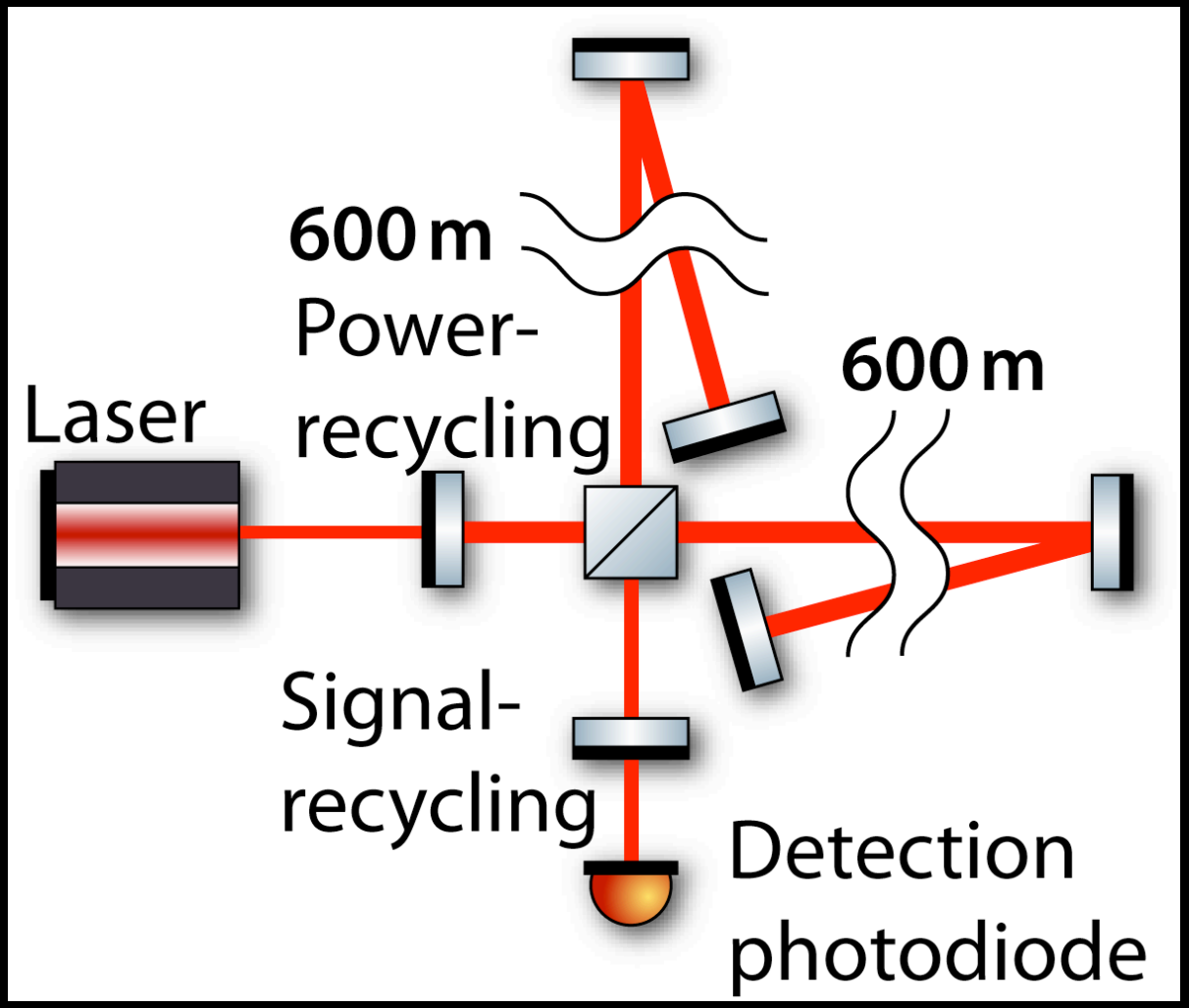
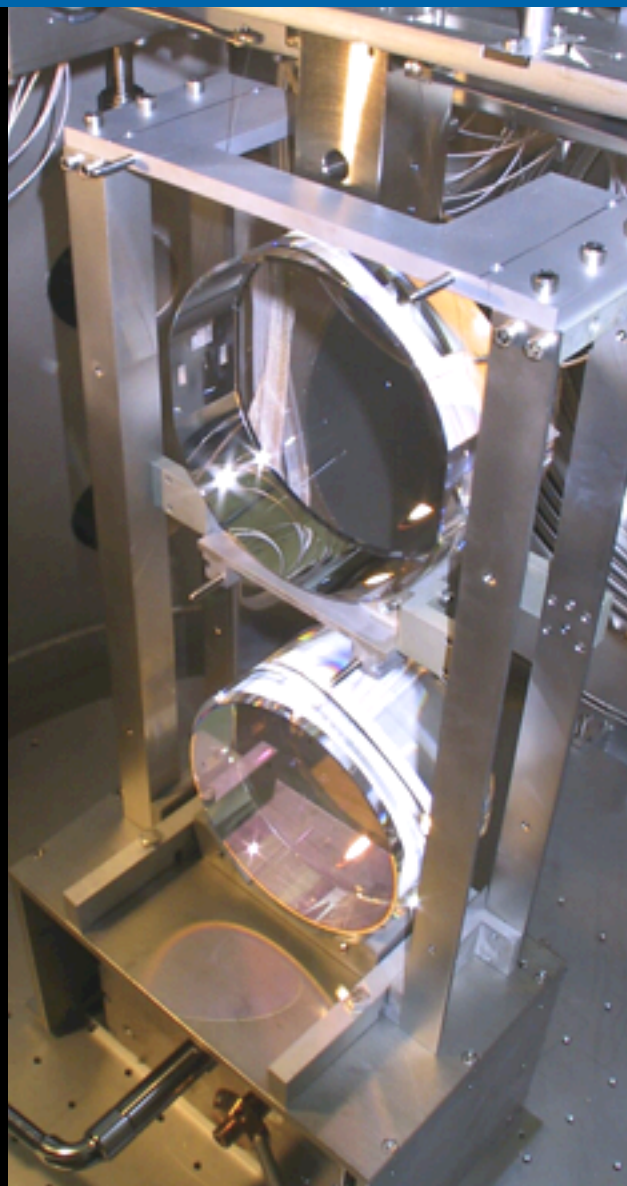


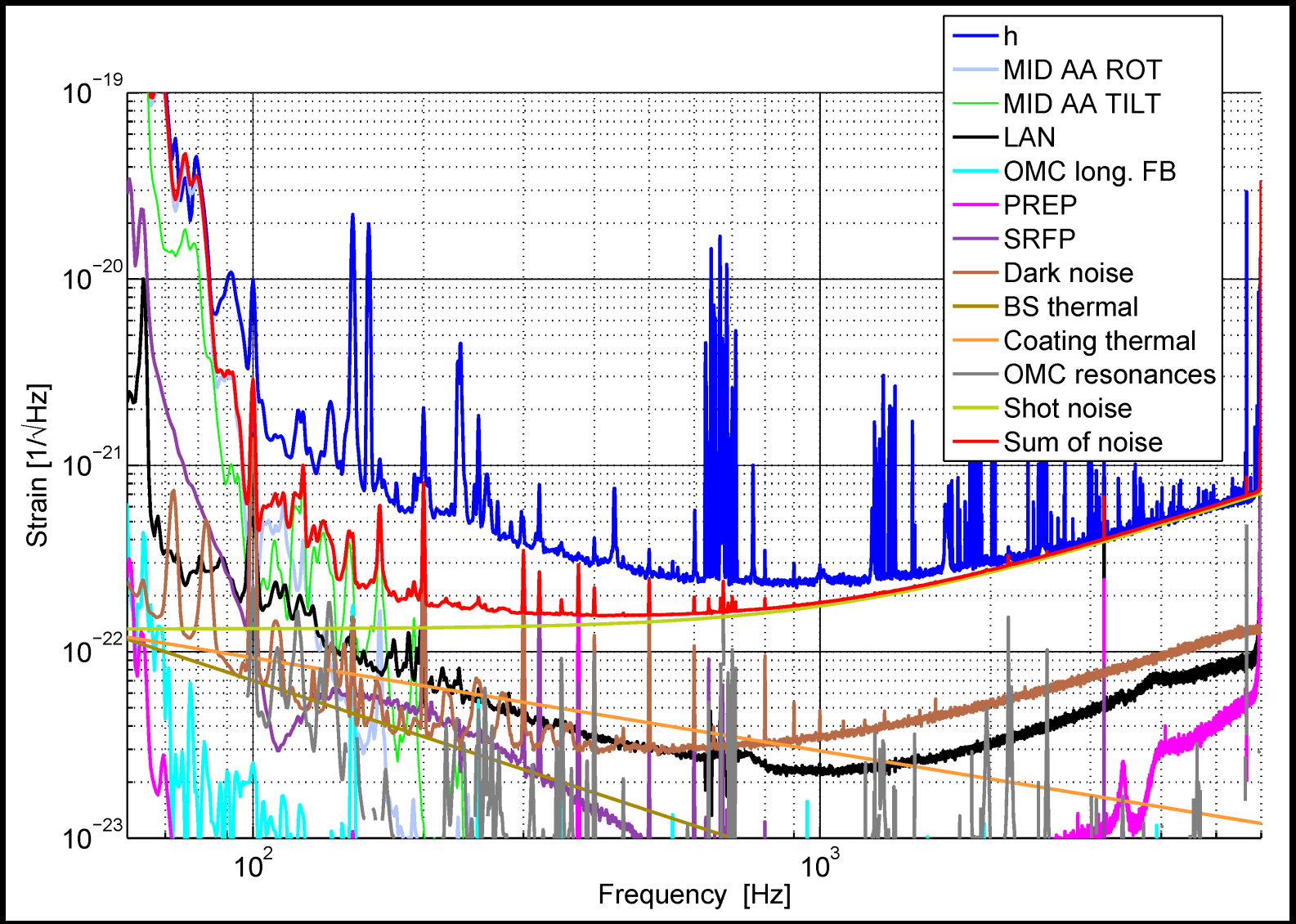


GEO 600: detector and technology development

- Unique position as detector and technology test bed
- GEO 600 more freely examines new techniques
- GEO pioneers techniques
  - Signal-recycling
  - Monolithic fused silica suspensions
  - Electrostatic actuators
  - Squeezing & its control

- GEO techniques have propagated to LIGO / VIRGO detectors

GEO High Frequency (HF)



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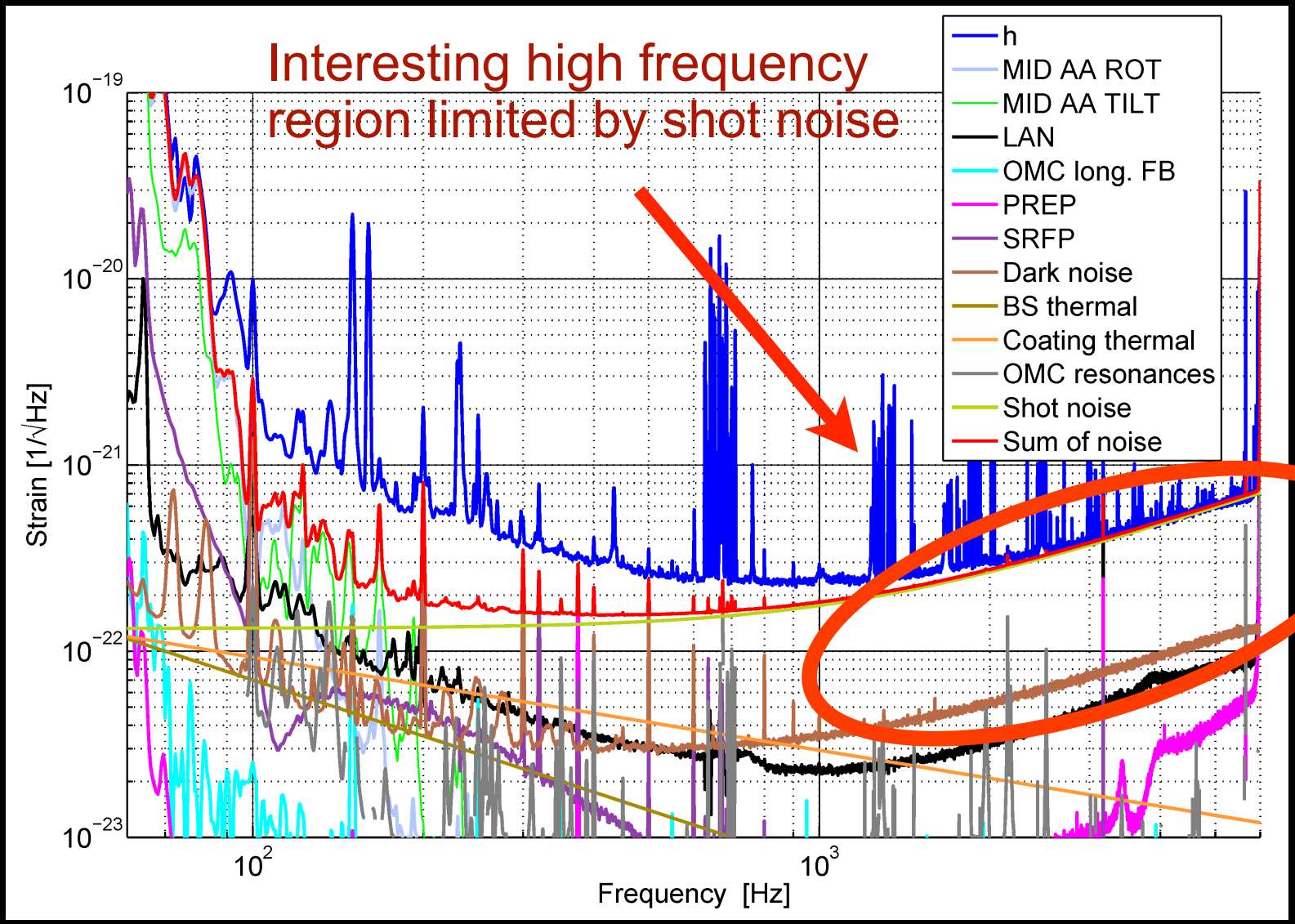
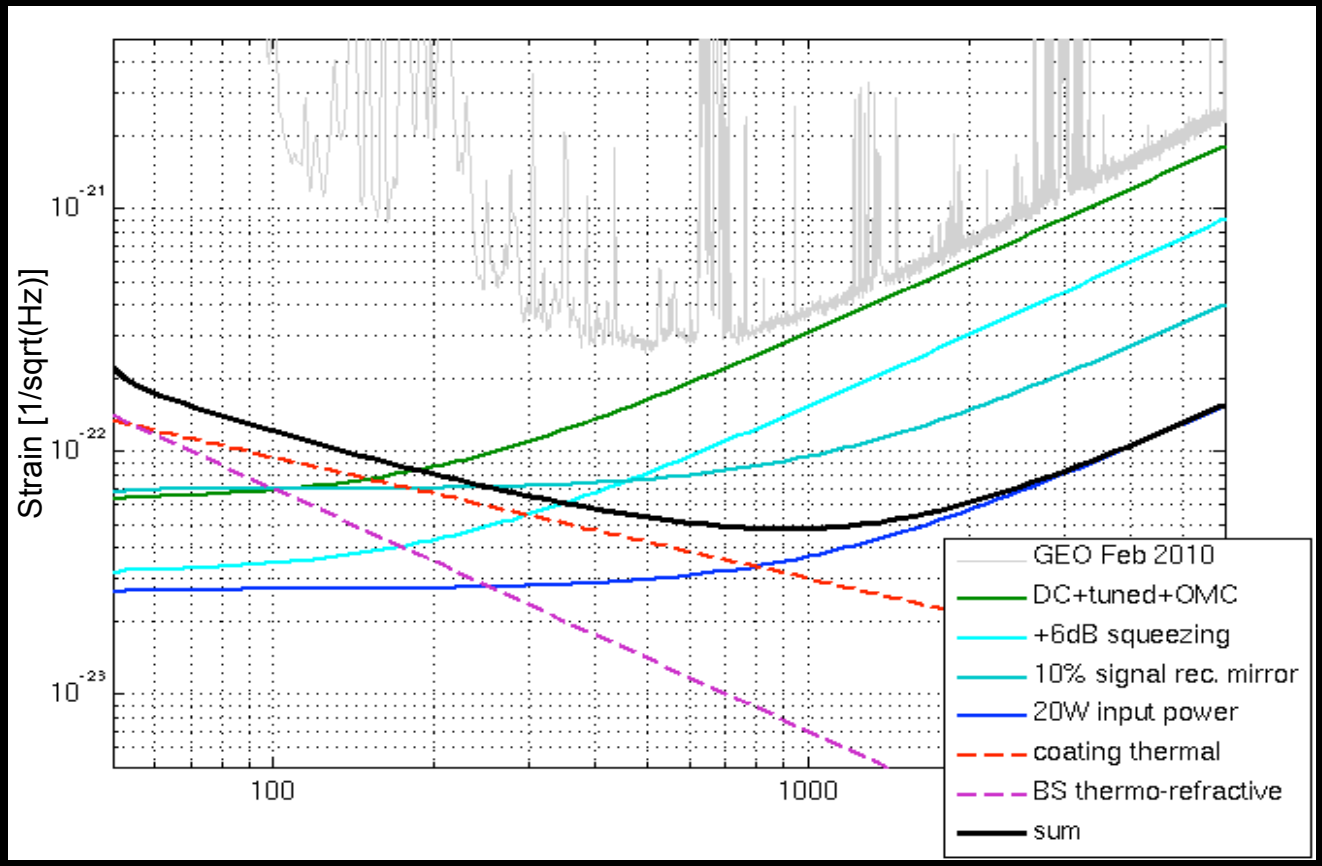


GEO-HF upgrade program

- Implementation started in 2009
- Seismic, thermal, and unexplained noise below 500 Hz
- Goal: Improve sensitivity at frequencies > 500 Hz
  → Improve shot noise limited sensitivity

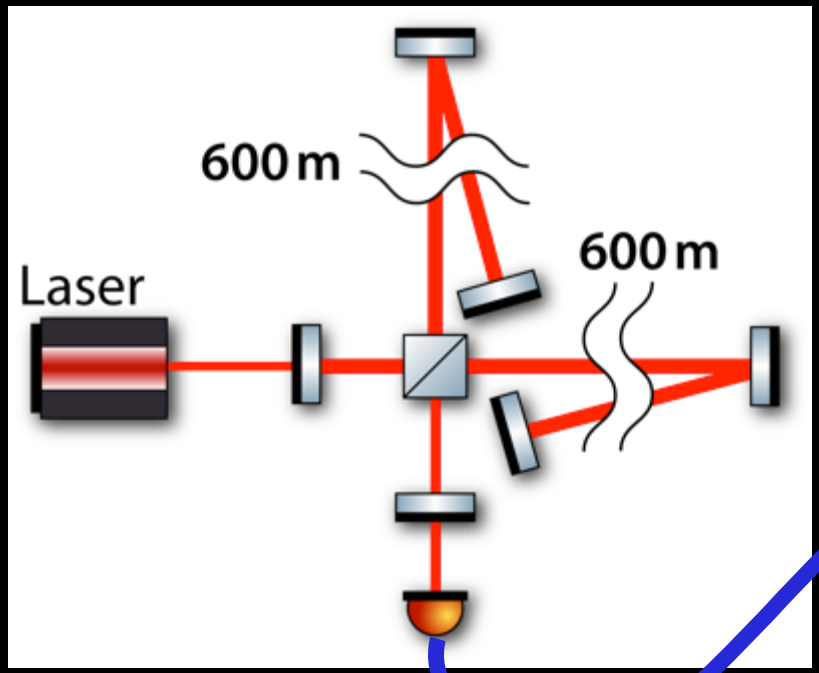


GEO-HF program components

- Output Mode Cleaner (OMC)
- Switch to Homodyne / DC readout
- Signal-recycling configuration change
- Squeezed vacuum injection
- Light power increase
- `Astrowatch' whenever possible!

Output Mode Cleaner (OMC)

Dark fringe contrast defect, due to mode mismatch and misalignment of the interferometer arms



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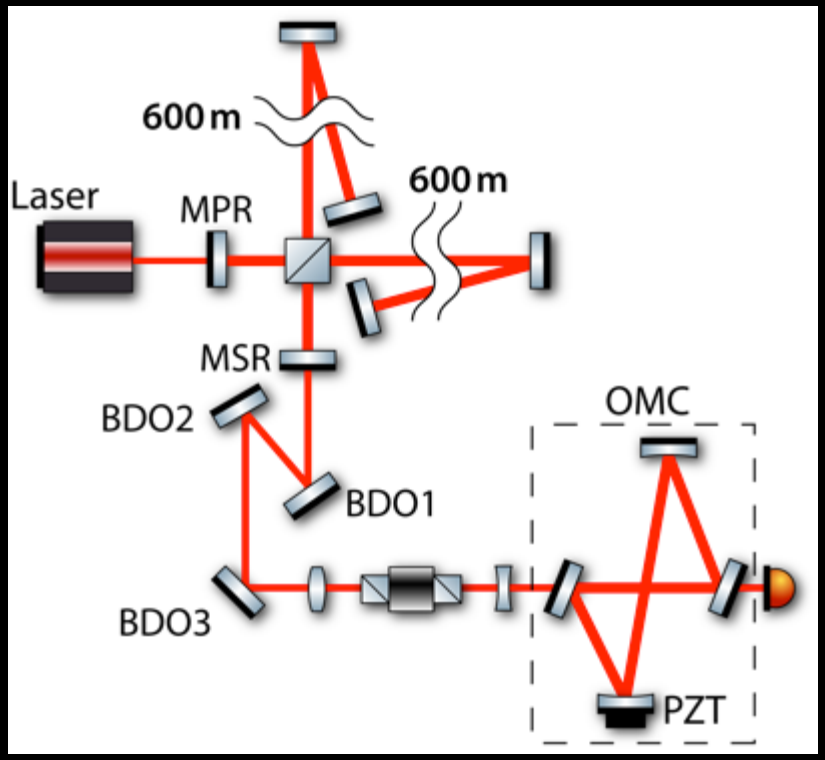
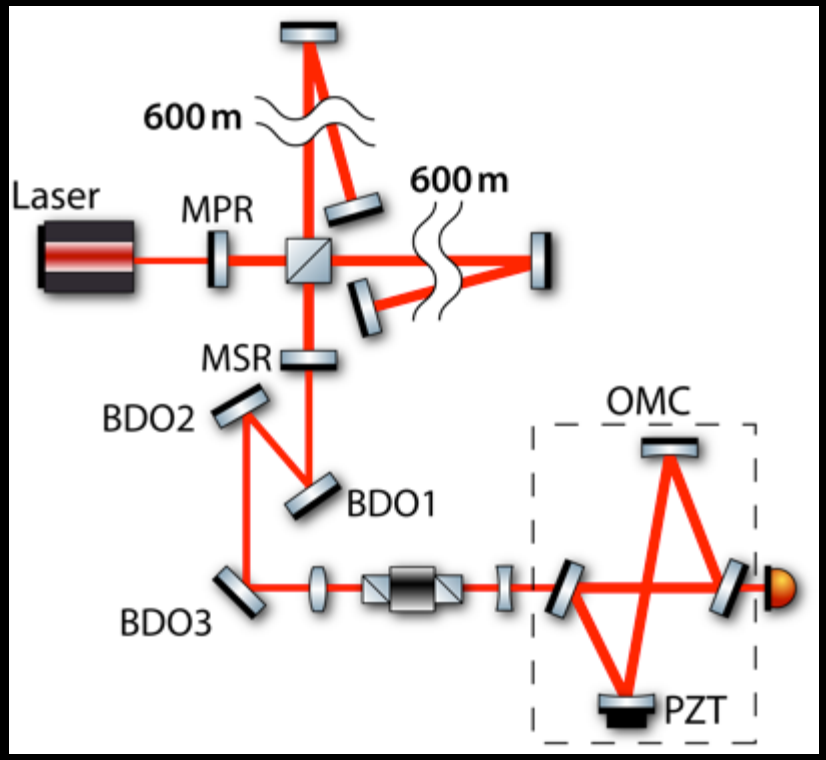
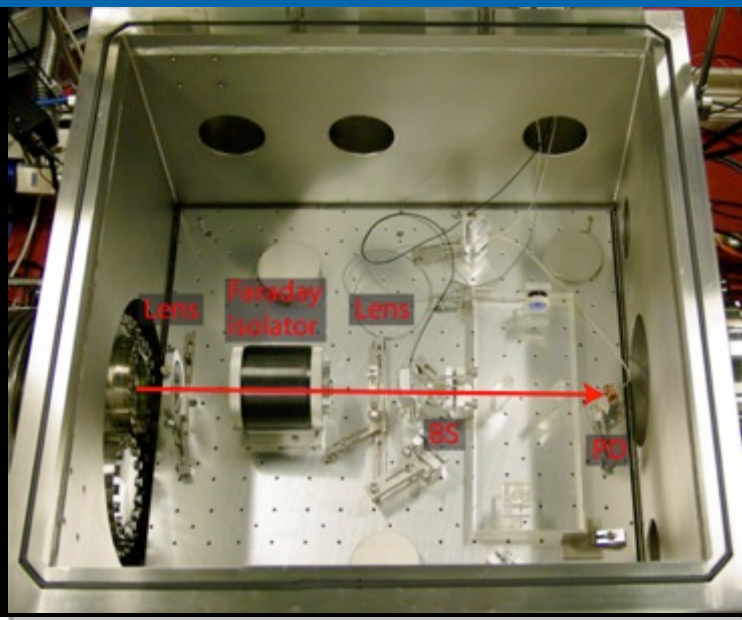
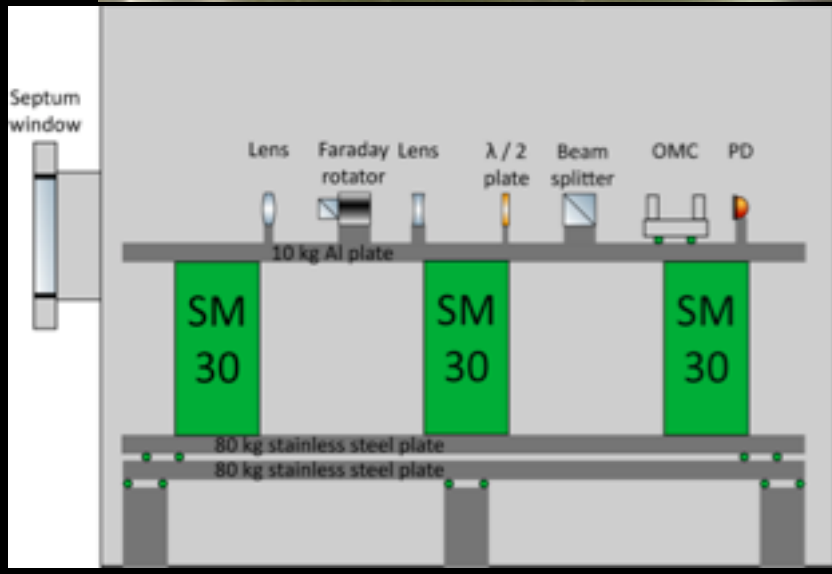


Output Mode Cleaner (OMC)

- OMC housed in vacuum tank
- Multi-stage seismic isolation starting at 1 Hz

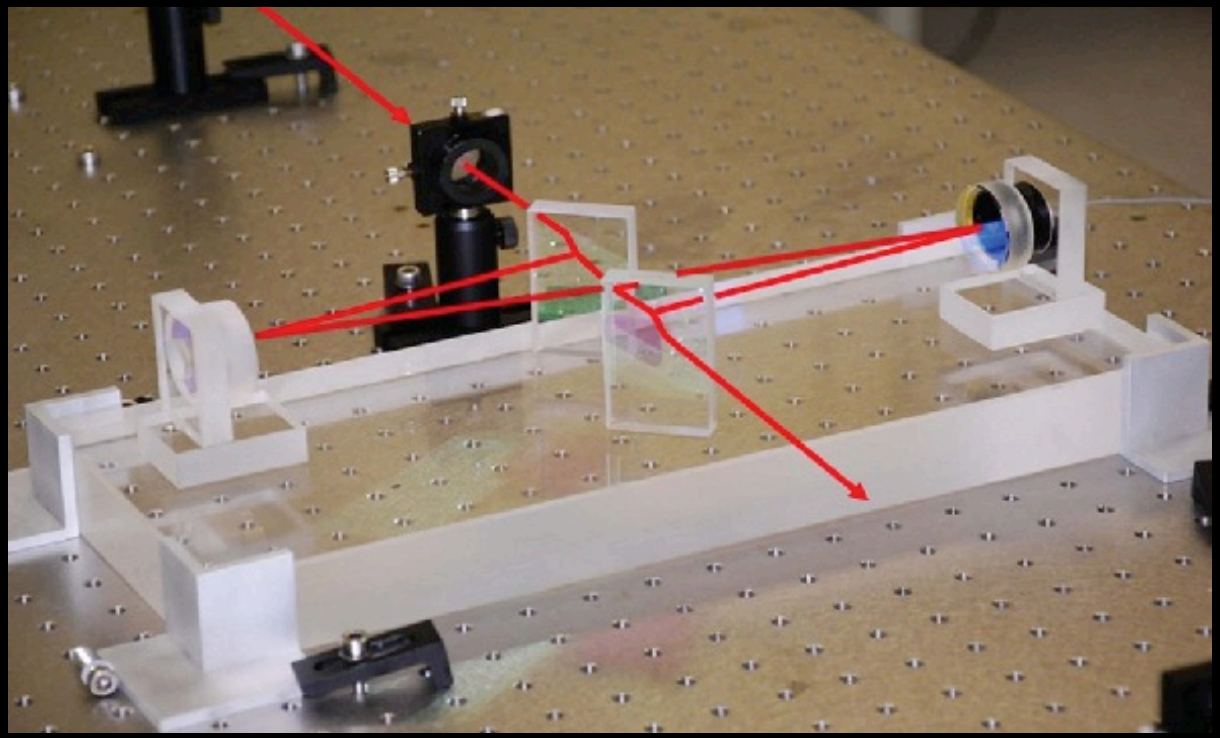




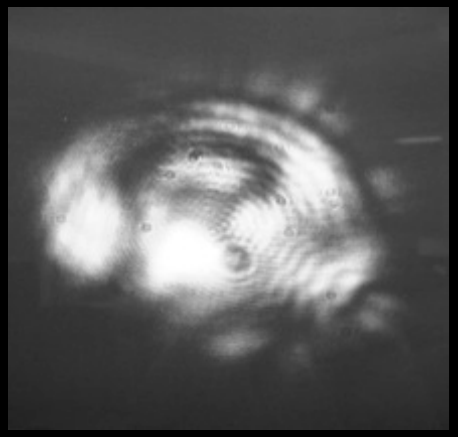


Output Mode Cleaner (OMC)

- Design: (optimised for DC readout)
  - Quasi-monolithic
  - Four mirror cavity
  - Length actuation via PZT



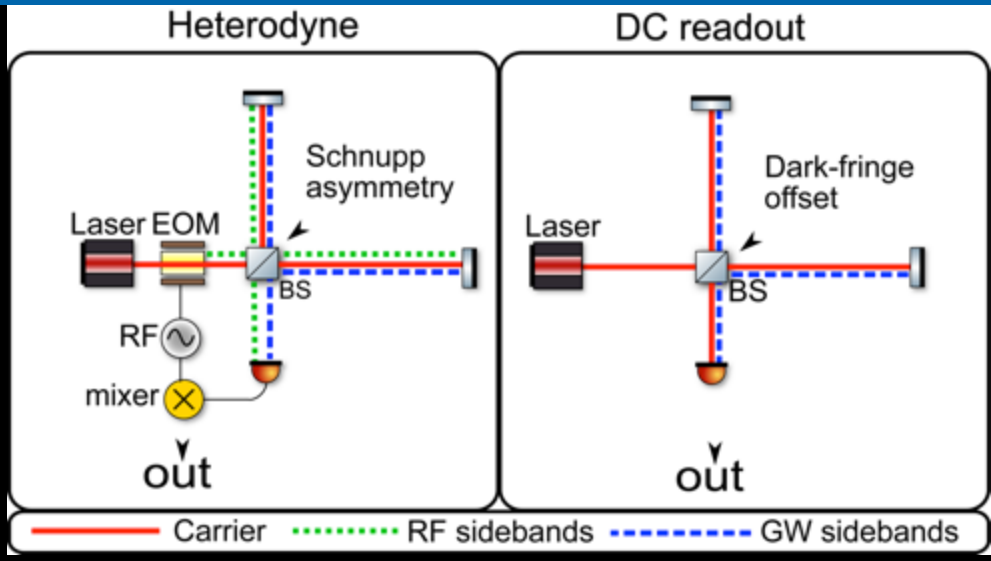
Before OMC (≈60 mW):

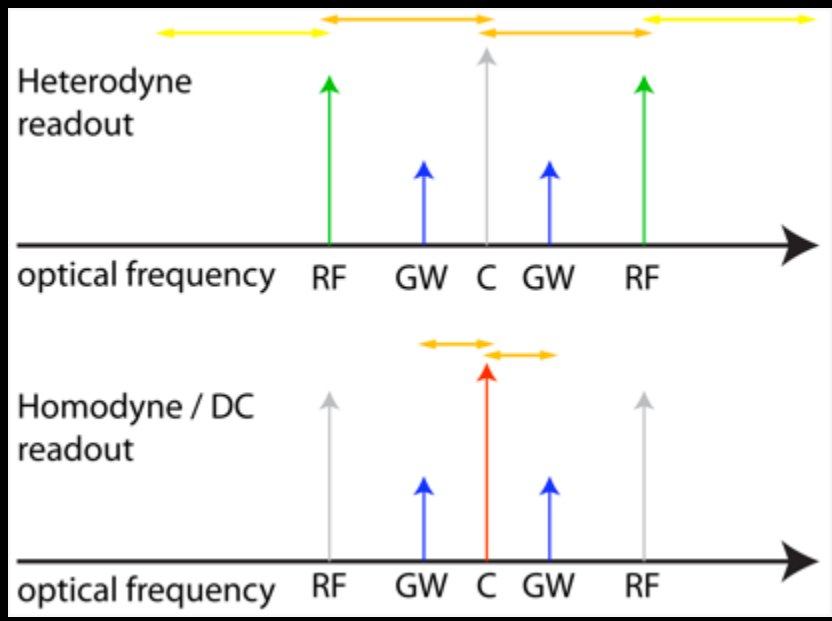


After OMC (≈6 mW):

Heterodyne vs DC readout

- Heterodyne readout
  - GW information in beat of GW-SBs ↔ RF-SBs
  - (Almost) no carrier at IFO output
- DC readout
  - GW information in beat of GW-SBs ↔ carrier
  - Some carrier light at the output required
  - GW signal directly in detected power

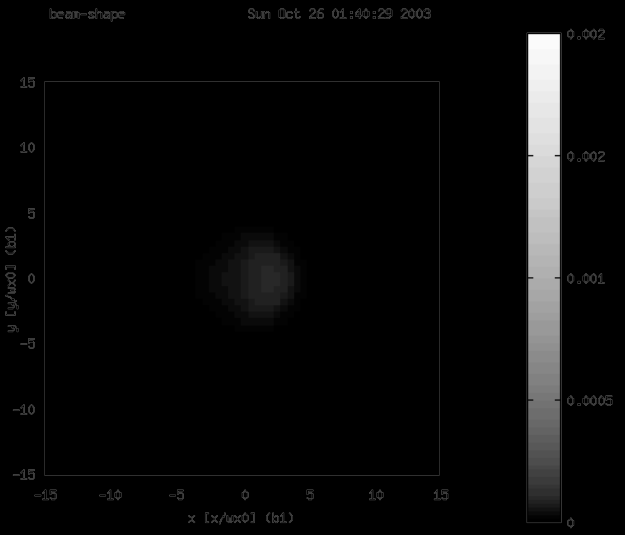


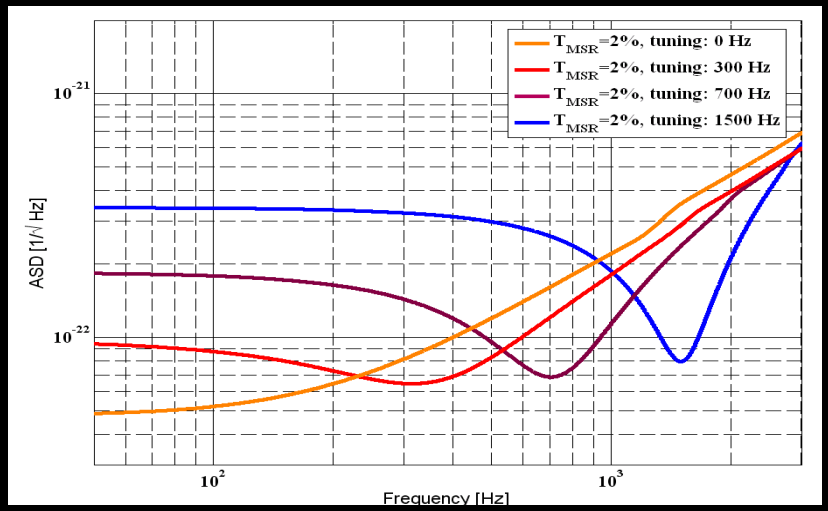


Signal Recycling

Signal Recycling:

- makes GEO resonant to GWs
- Allows shaping of the shot noise
- Influences higher-order modes in the dark fringe





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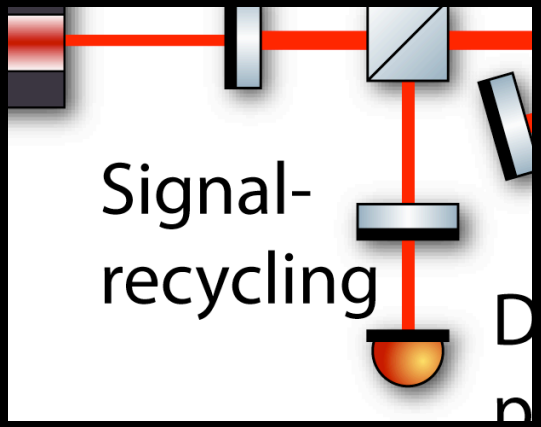
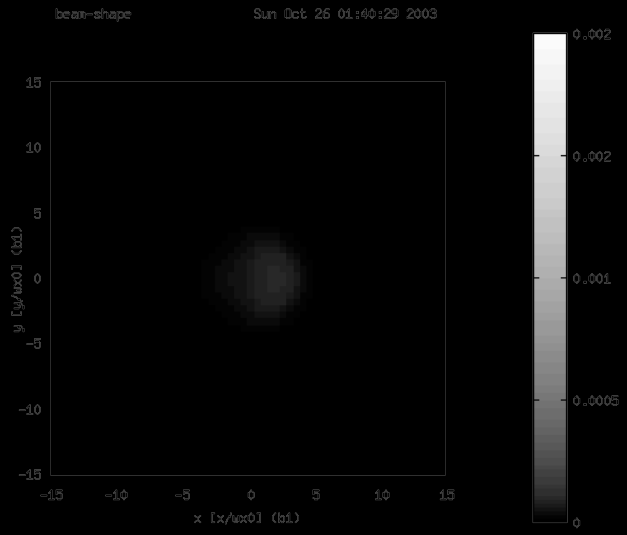
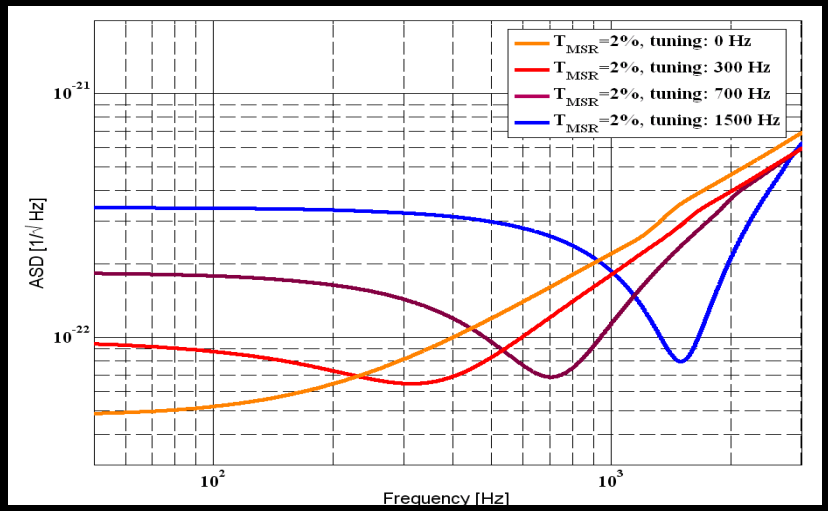
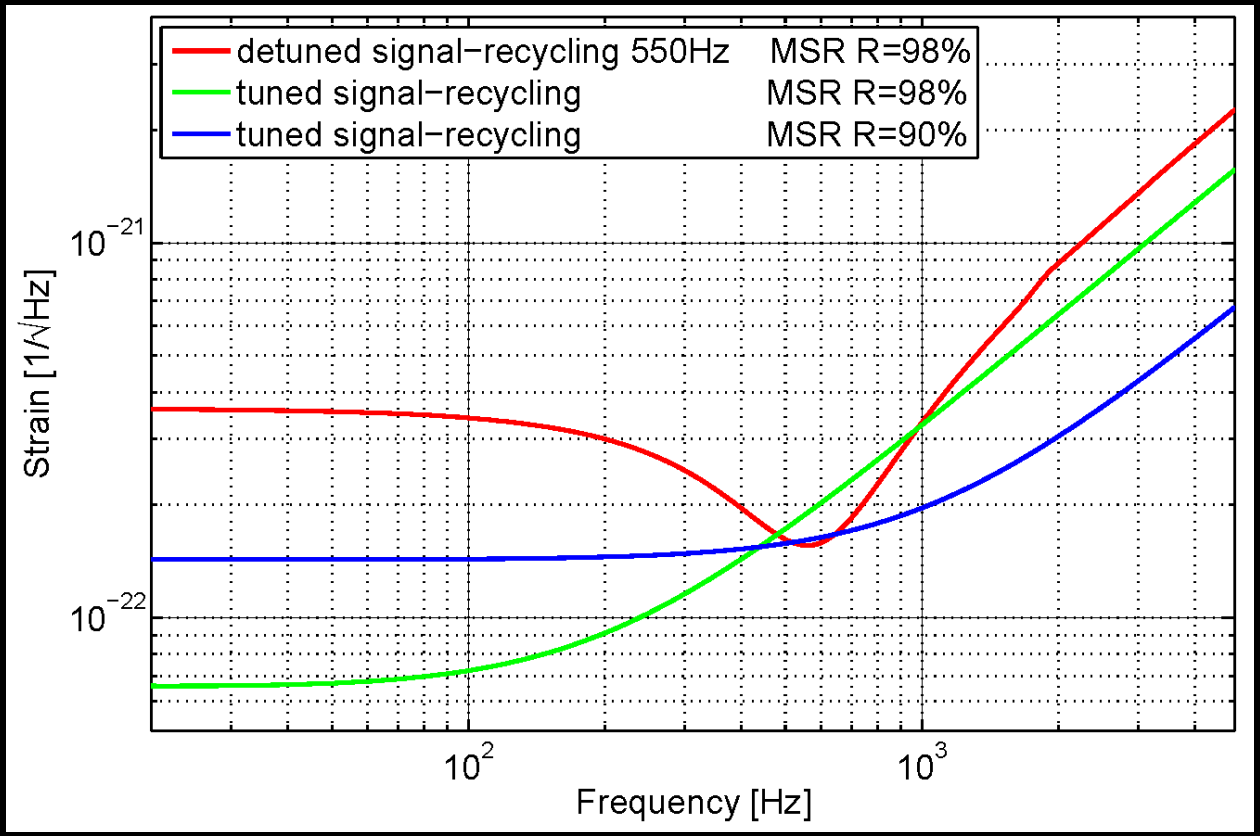






Signal Recycling Change (2010)

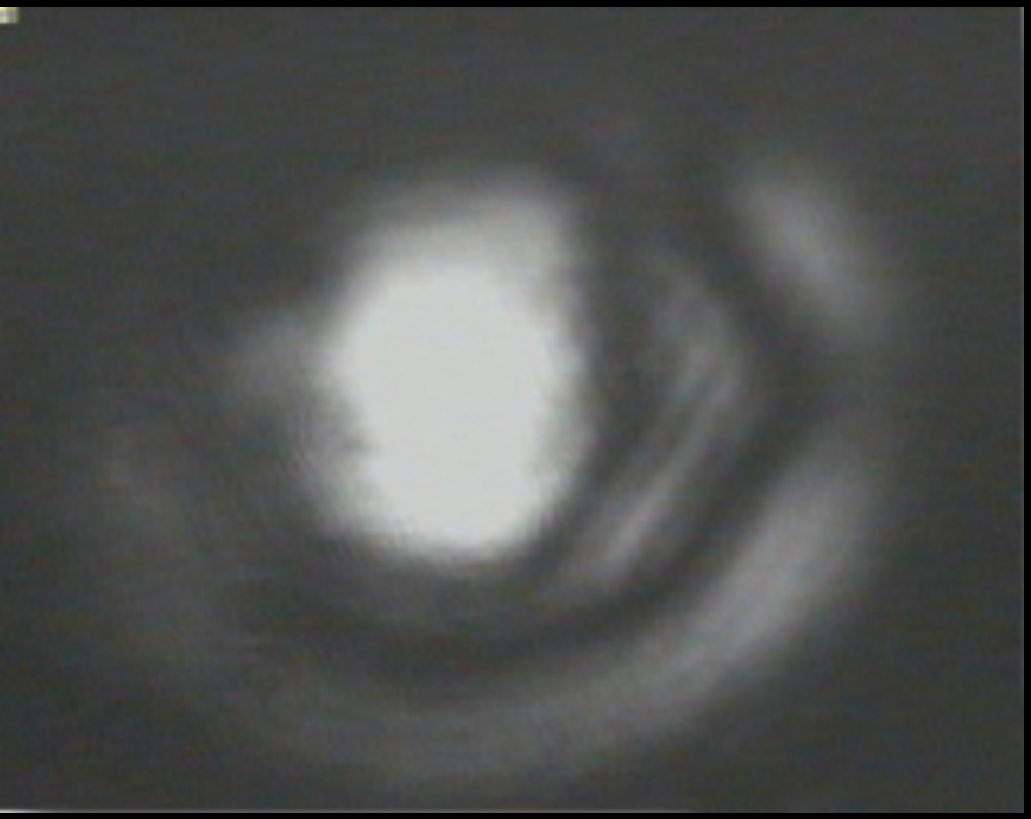
Increase transmission of Signal Recycling mirror to reduce shot noise at high frequencies



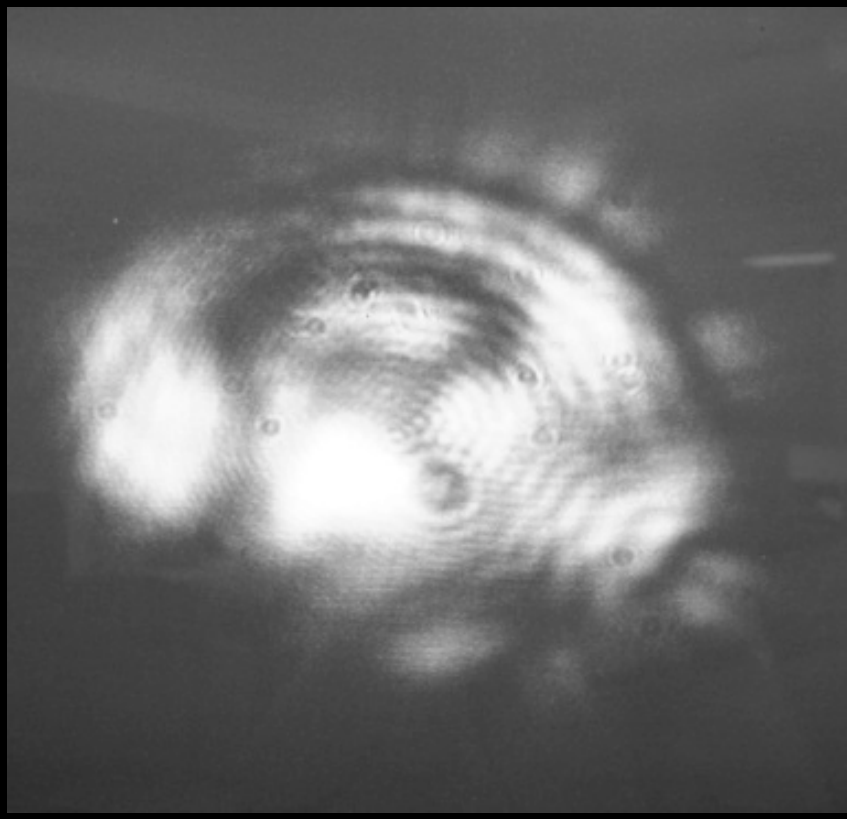
Changed signal-recycling

- More HOMs with
  reduced signal-recycling mirror reflectivity

R=98 %

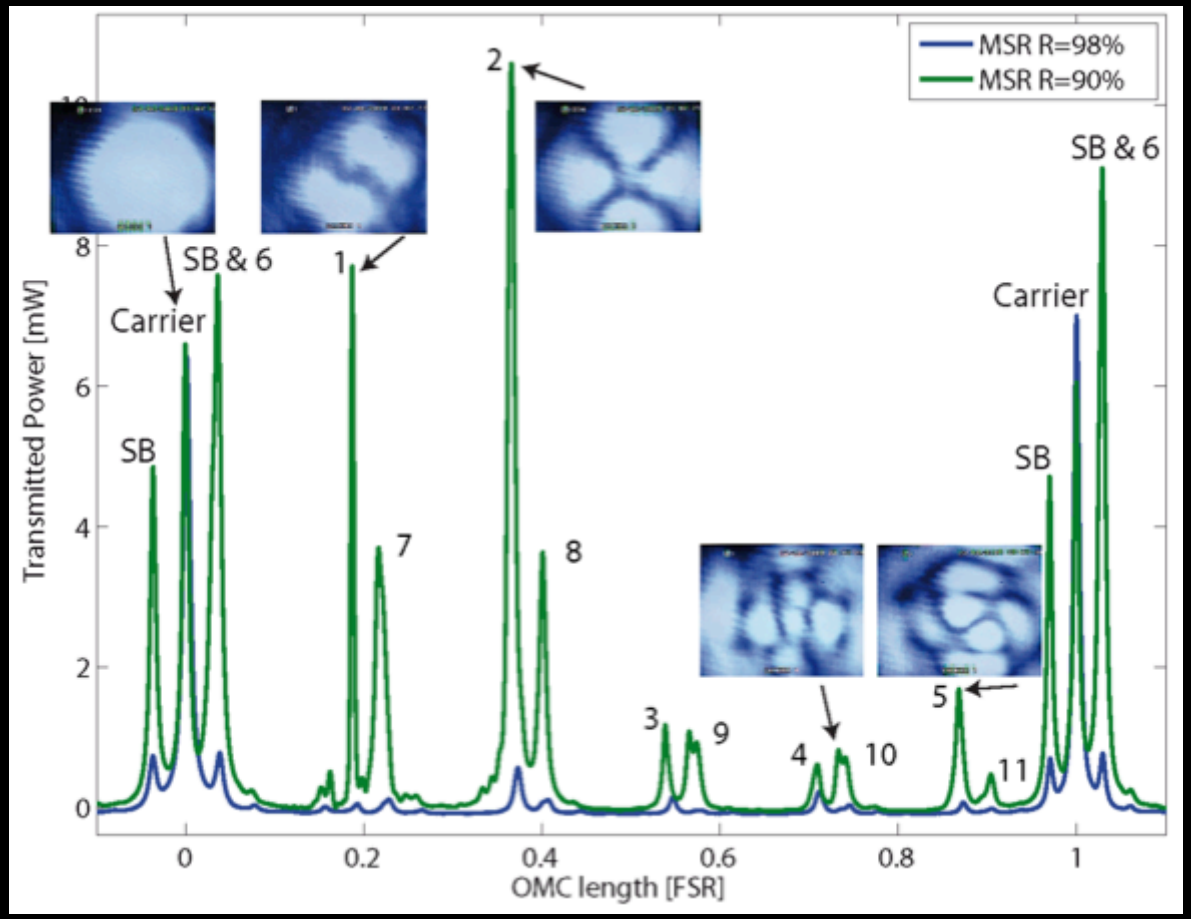


R=90 %



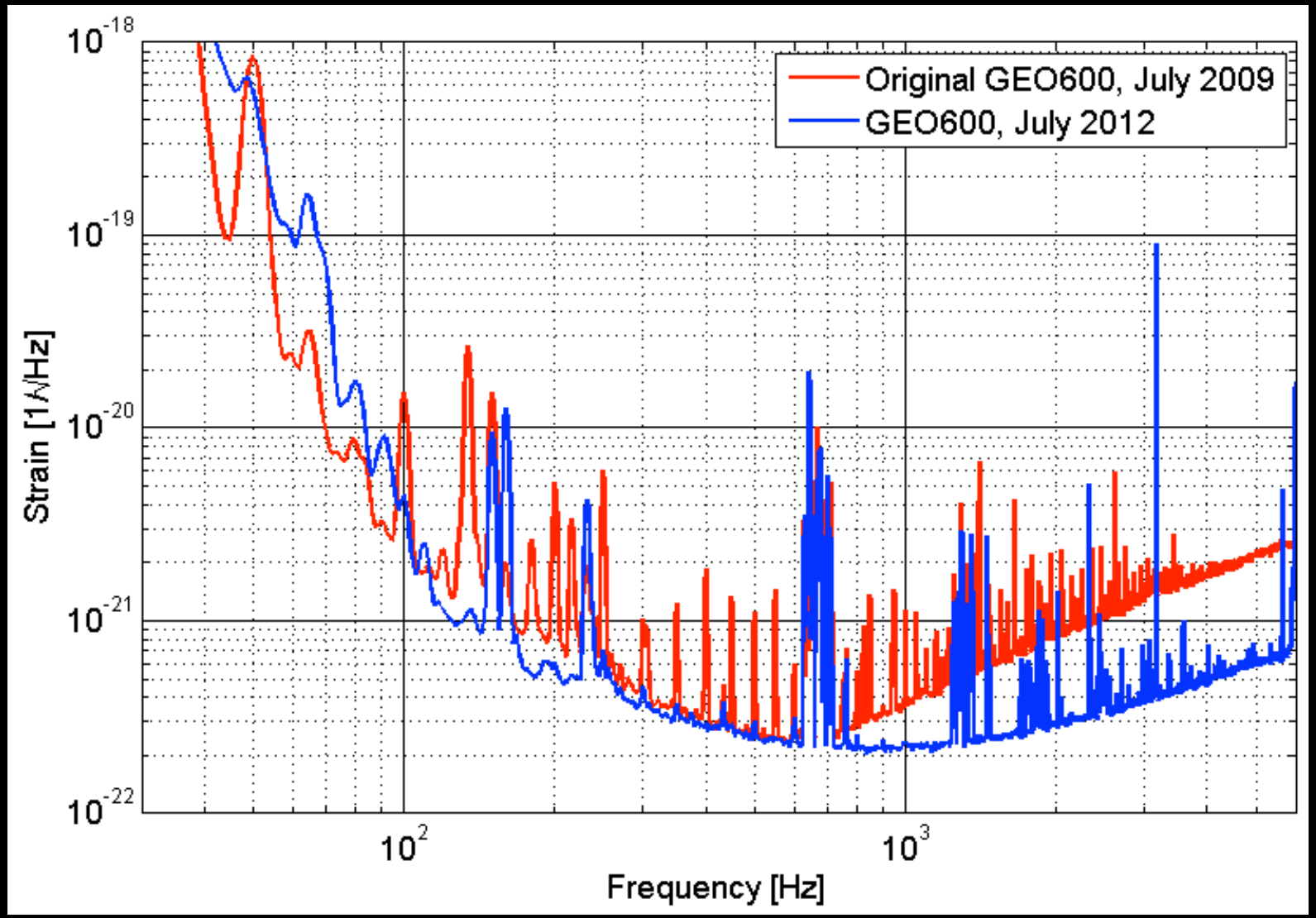
Changed signal-recycling

- Analyze interferometer output beam using the OMC



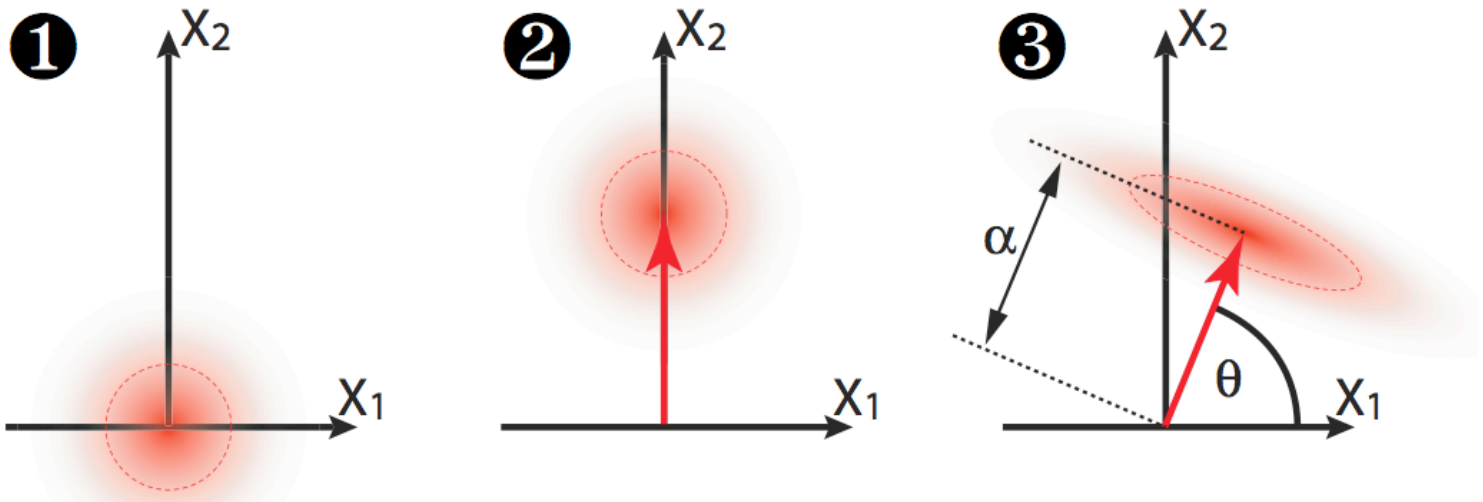
Mode order	Power
0	6.3
1	7.7
2	10.6
3	1.2
4	0.6
5	1.7
6	3.6
7	3.7
8	3.6
9	1.1
10	0.8
11	0.5

Signal Recycling: Sensitivity Comparison

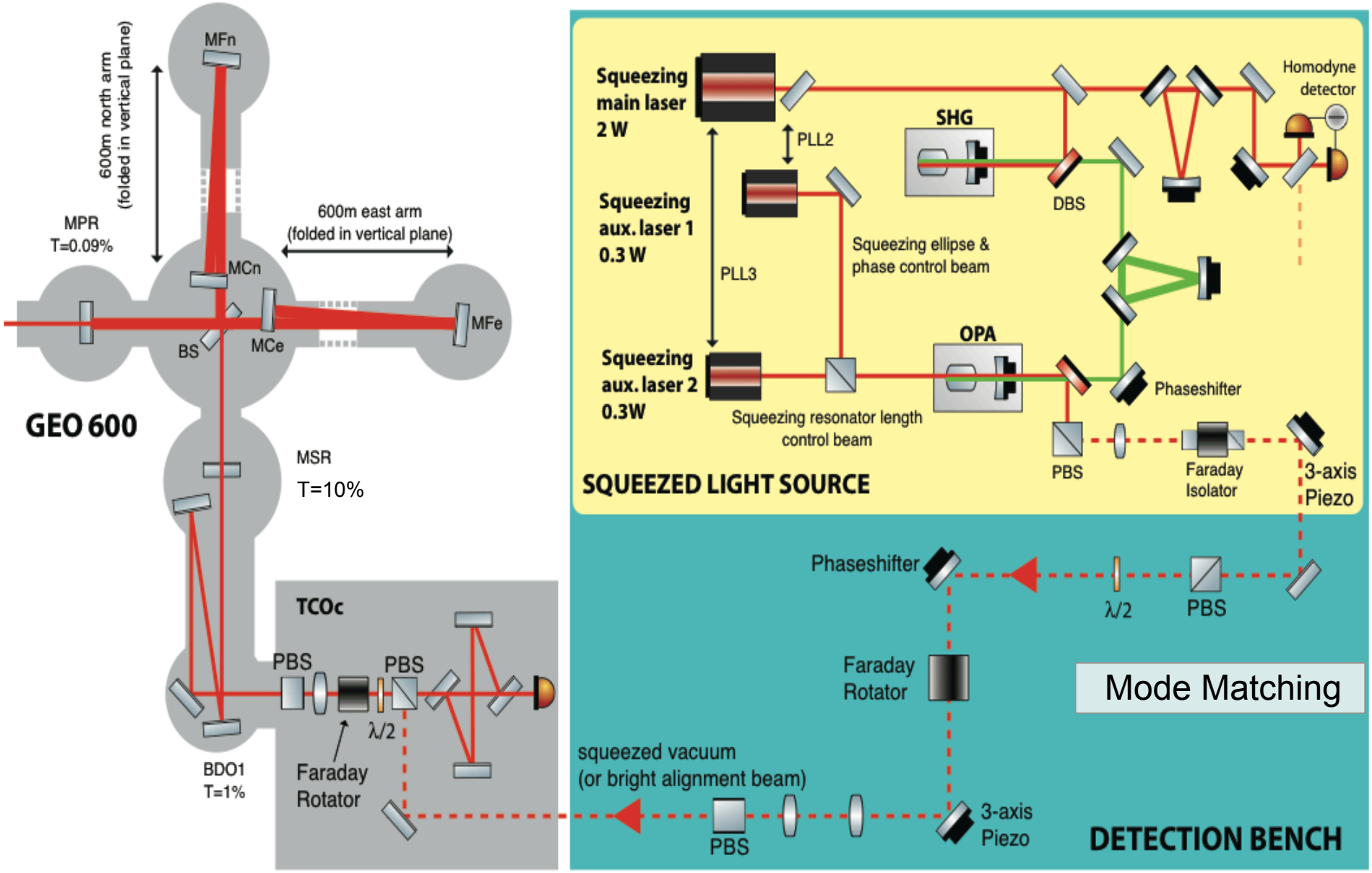


Squeezed vacuum injection

- Directly reduces shot noise
- (Frequency independent) squeezing is similar to an increase in laser power
- 10 dB squeezing source developed at the AEI



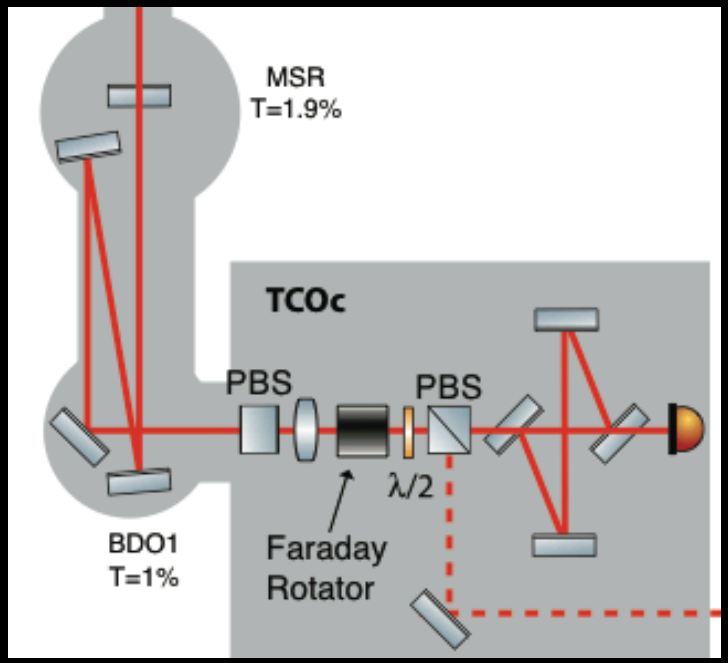
GEO 600 and Squeezed Light



Squeezing Phase Lock

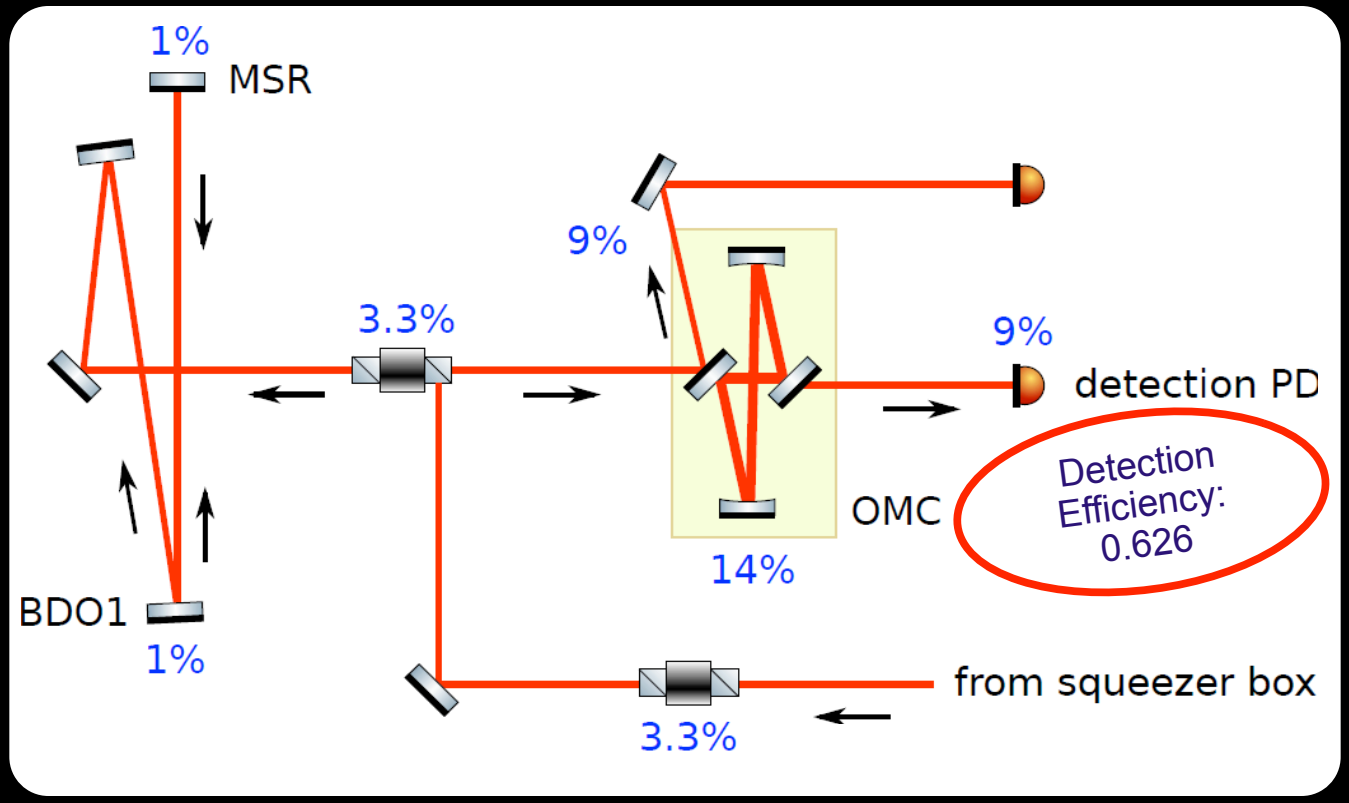
- Start with SQZ master to IFO main laser (fiber/PLL)
- Error signal in refl. of IFO
  (Coherent Control signal)

different ports / possibilities



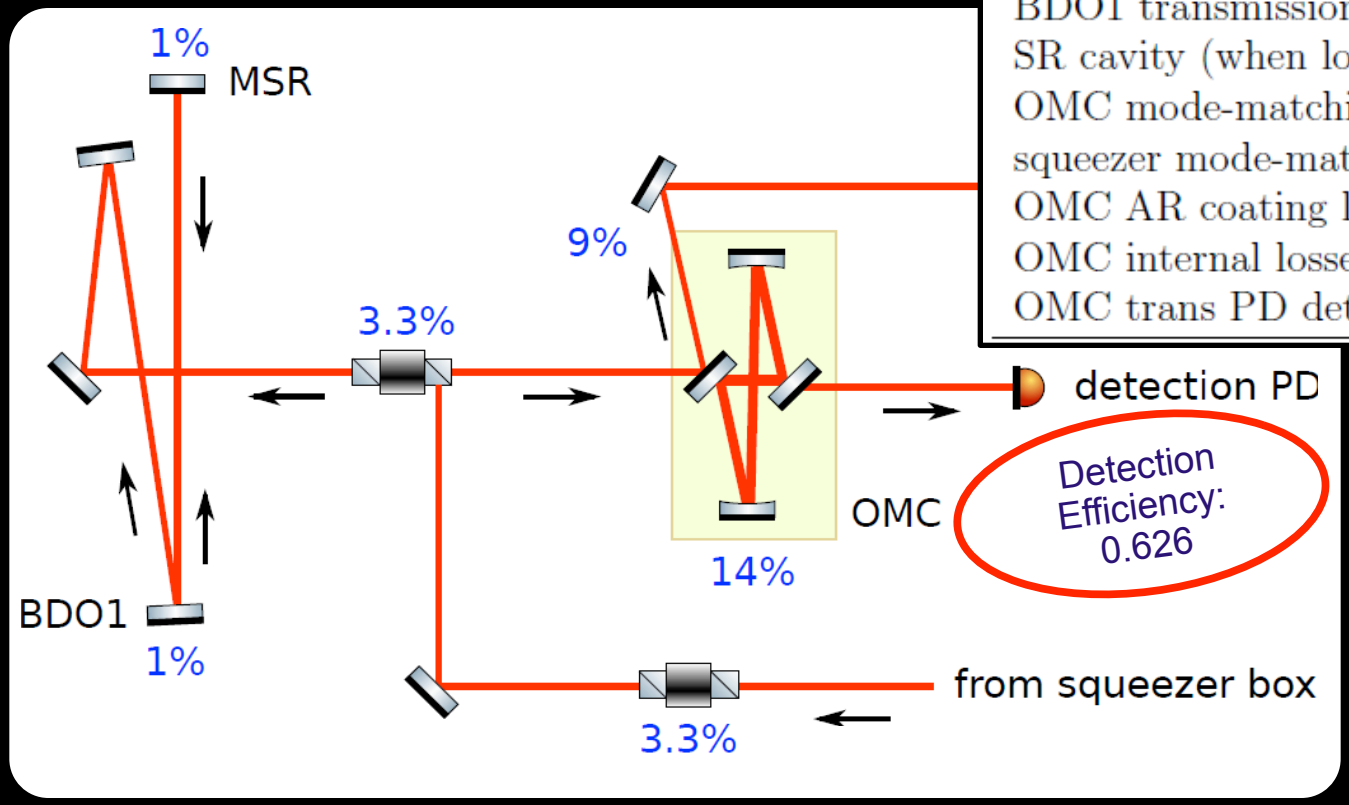
- Feedback to SQZ master frequency (DC-2kHz)
- Low-freq. Error signal (<0.01Hz) from noise dither

Optical Loss

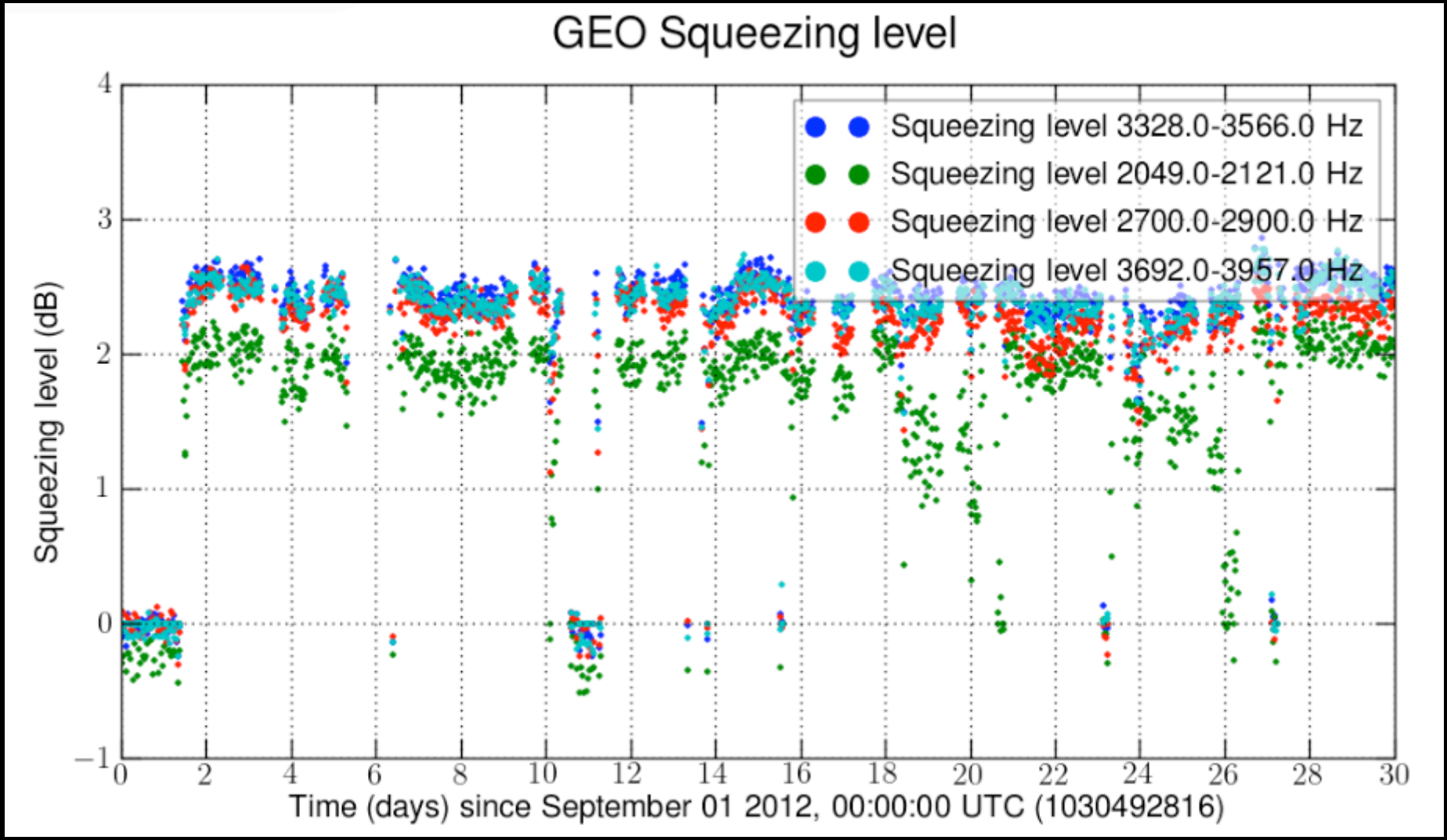


Optical Loss

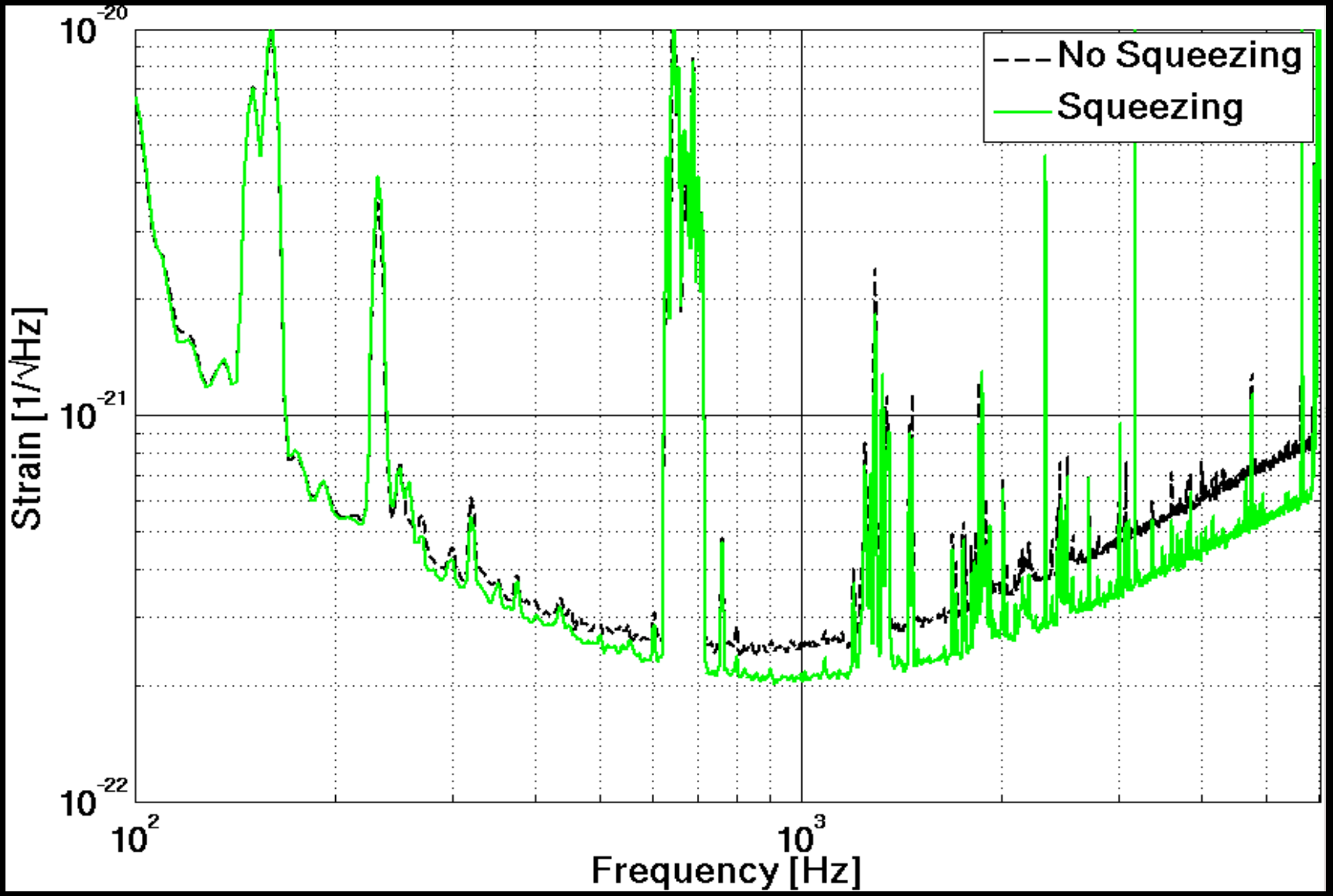
component	power loss
squeezer path Faraday	3.3%
output port Faraday	3.3% × 2
BDO1 transmission	1% × 2
SR cavity (when locked)	1%
OMC mode-matching loss	6%
squeezer mode-matching loss	2%
OMC AR coating loss	1%
OMC internal losses	14%
OMC trans PD detection loss	9%



Stable operation of squeezing!



Spectrum (August 2012)

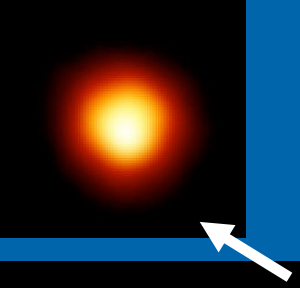


Next steps on Squeezing (GEO)

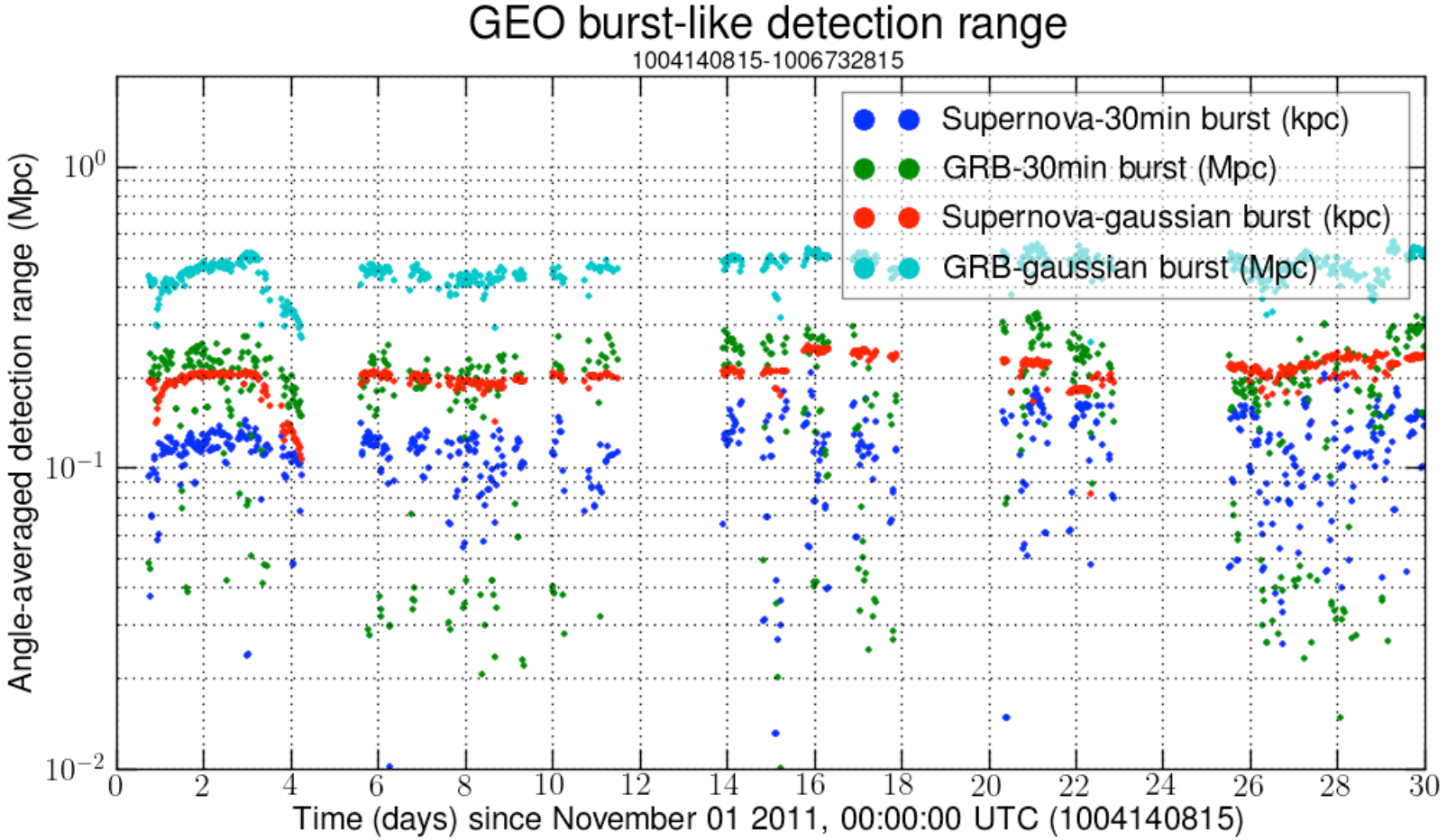
- Need Automatic Alignment (started)
- Need OPA temp set-point control
- Lower OMC loss (->2%), high-QE PD (->1%)
- New Phase noise budget after OMC change
- Lower det. Noise (main IFO)
- ->6dB look realistic, perhaps little more...

Percent of time operated in Astrowatch (Science) mode: 70%
Percent of Science mode, operated with squeezed light: 90%

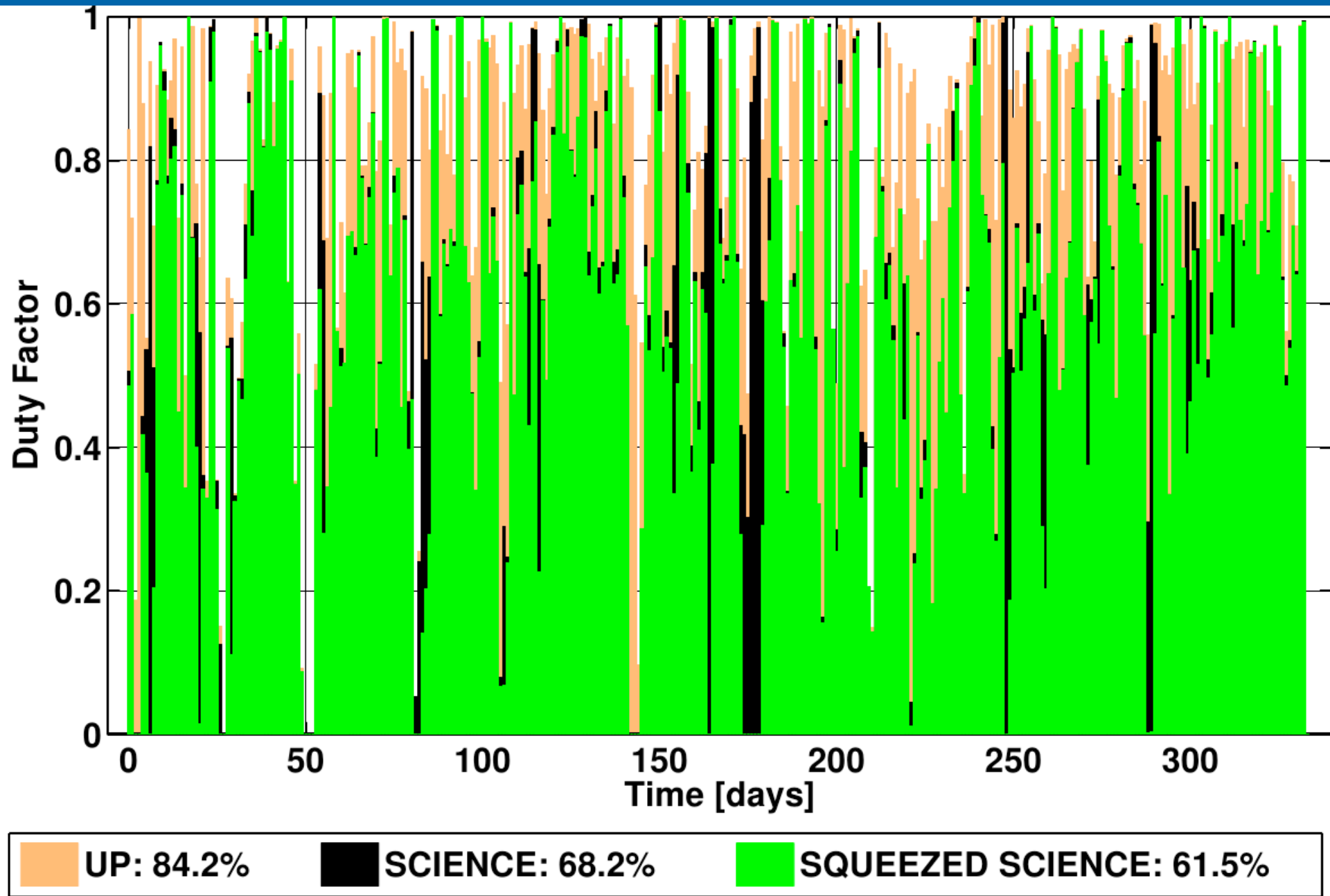
Burst Detection



Hubble image of Betelgeuse (@200 pc)



Detector Status from Nov 17, 2011 to Oct 15, 2012



Star trails over GEO 600, by Jerome Degallaix

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Next Steps

- Squeezing
  - Try new control schemes
  - Try new optical / low loss components
  - Automatic alignment
- OMC
  - Try alternative alignment control techniques
- Thermal compensation
  - Test mass side heaters (recently installed)
  - Compensation of beamsplitter lens with thermal radiation
- Astrowatch!

Timeline

- **07-2009:** Tuned signal-recycling
- **09-2009:** DC-readout
- **12-2009:** OMC installation
- **04-2010:** Squeezing installation
- **05-2011:** Output optic suspension
- **06-2011:** Use 5W input power, Routine Squeezing
- **06-2011 to 09-2011:** Joint GEO - VIRGO run
- **09-2011:** Laser upgrade
- **11-2012**: IMC upgrade, baffle installation, side heater
- **2013:** Input mode cleaner change, TCS, power increase, mid freq. Noise hunting, baffle installation