Chasing Noise: Experiences at GEO

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Summer 2011: science run with Virgo
Since then:
- 2/3 astrowatch mode
- continued commissioning (squeezing integration, high power, mid-freq. noise)

Commissioning topics

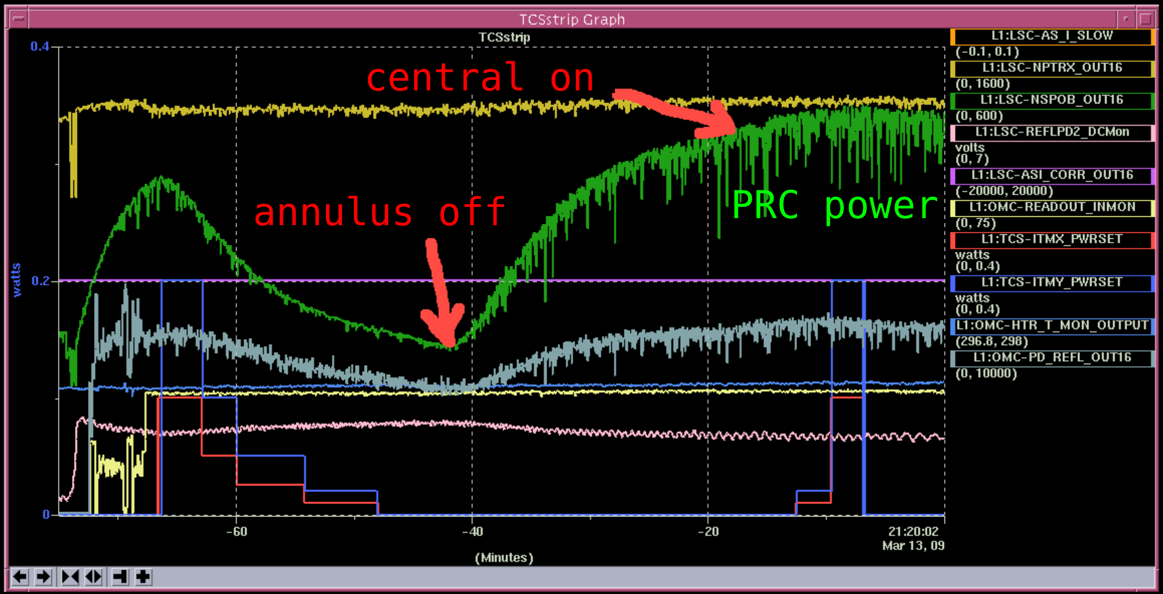
A selection of recent commissioning topics at GEO with lessons relevant for advanced detectors:

- "Cold locking": how to re-lock after a high power lock loss
- Wavefront sensing technique for OMC alignment

And, a reminder:

- The endless search for stray light

High laser power



We spent long hours fighting thermal issues in eLIGO. (40 kW circ.)

aLIGO: 700 kW circulating, 8 kW at BS
ring heater, CO2 laser

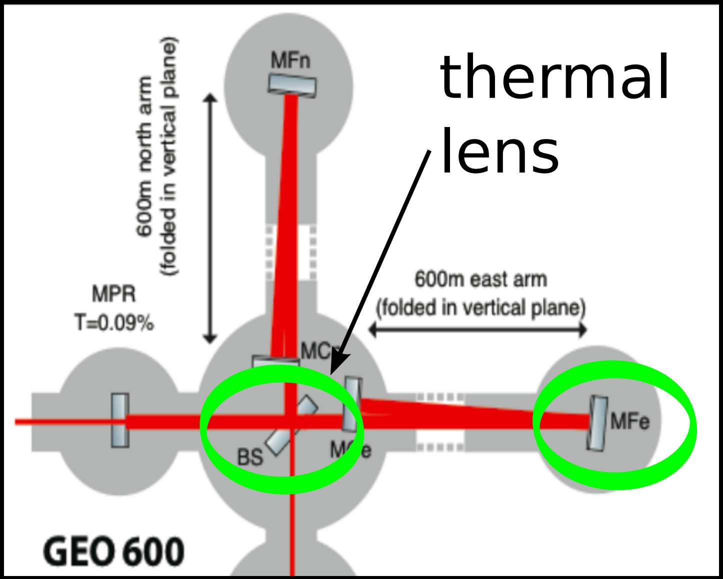
aVirgo: 650 kW circulating, 5 kW at BS
ring heater, CO2 laser

GEO: 3 kW (currently)
ring heater, side heaters

Thermal compensation

Thermal compensation challenges will only become more severe for advanced detectors.

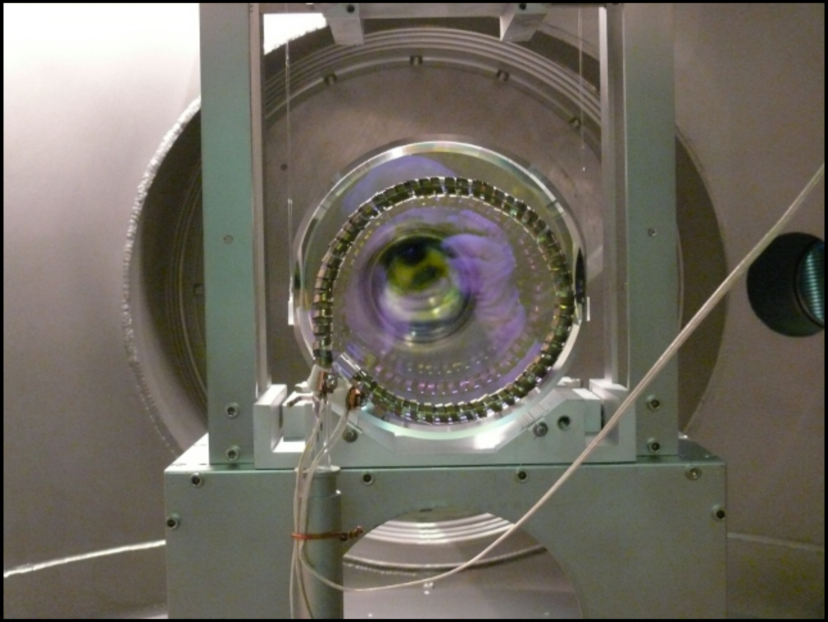
Some examples from GEO: - imperfect compensation
- varying time scales

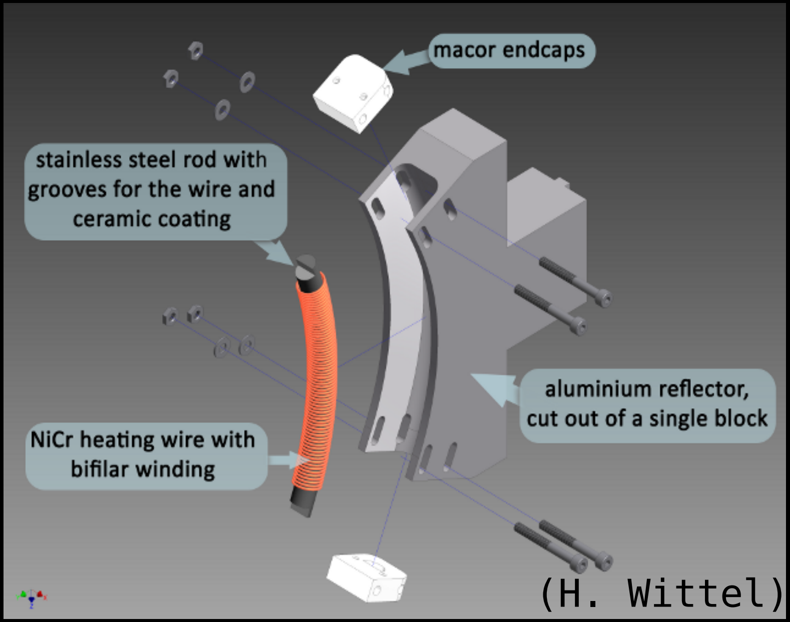


thermal compensation

Astigmatism

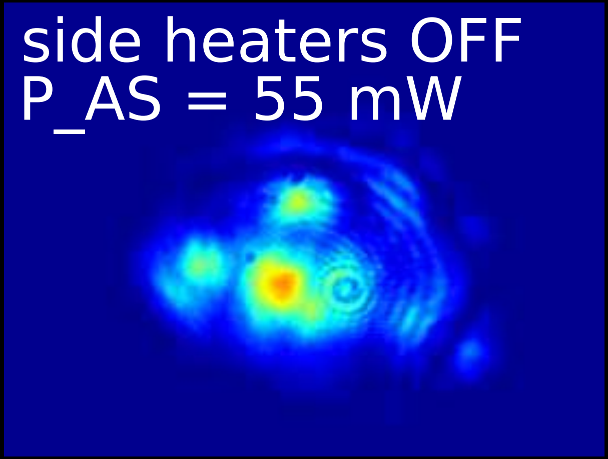
Ring heater at far (elbow) mirror:
- corrects for incorrect RoC
- compensates for BS thermal lens

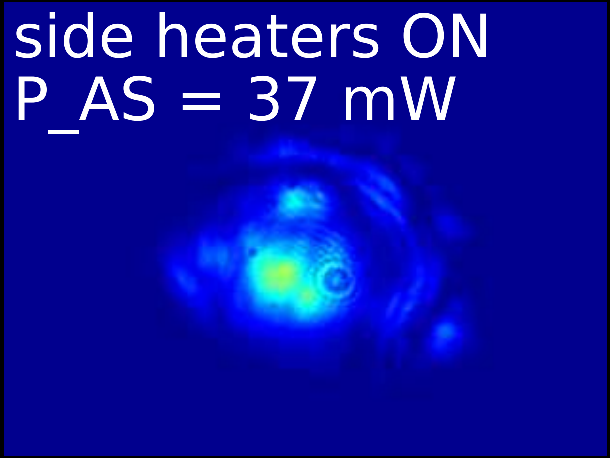


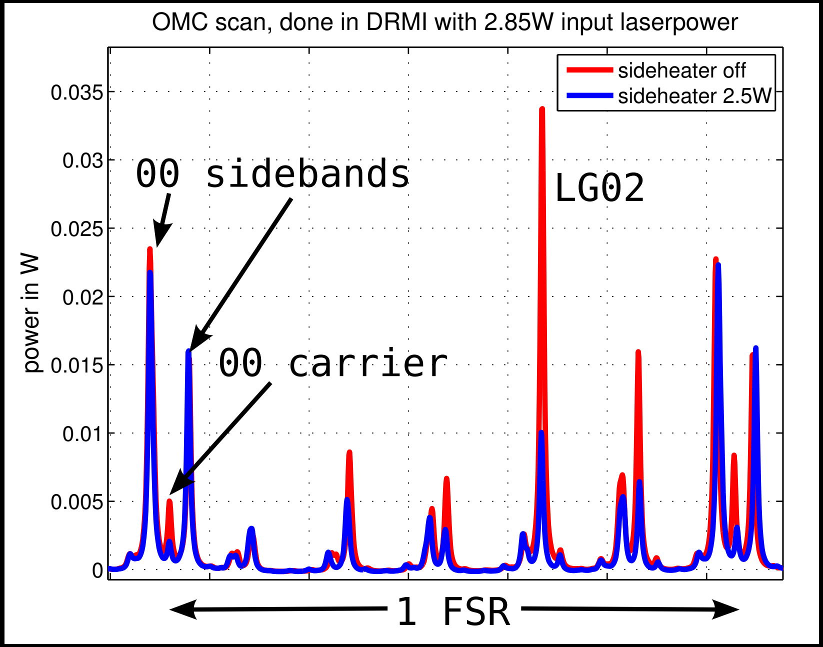


But.. introduces an astigmatism.
Installed side heaters in December..

Side heaters work!





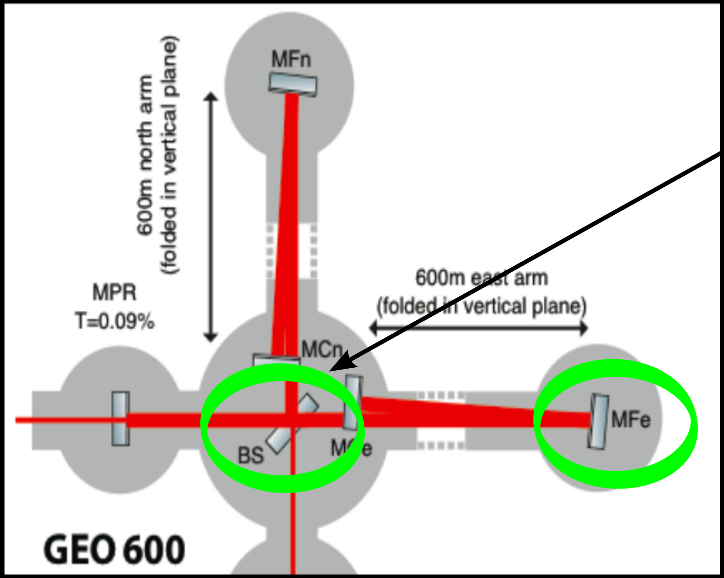


- less shot noise
- smaller offsets in ASC/LSC

A TCS servo: modulate TCS power ~1 mHz
minimize power at the dark port

"Cold locking"

Relocking an interferometer that had recently been in a high power state may prove challenging and result in down time.

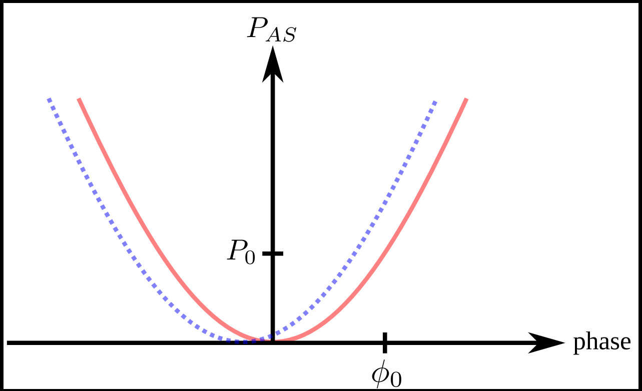


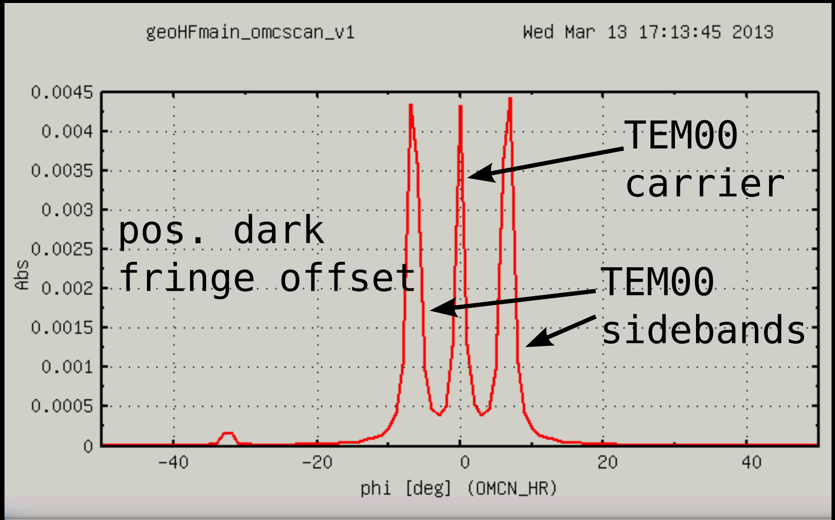
thermal lens gone in 10 min.

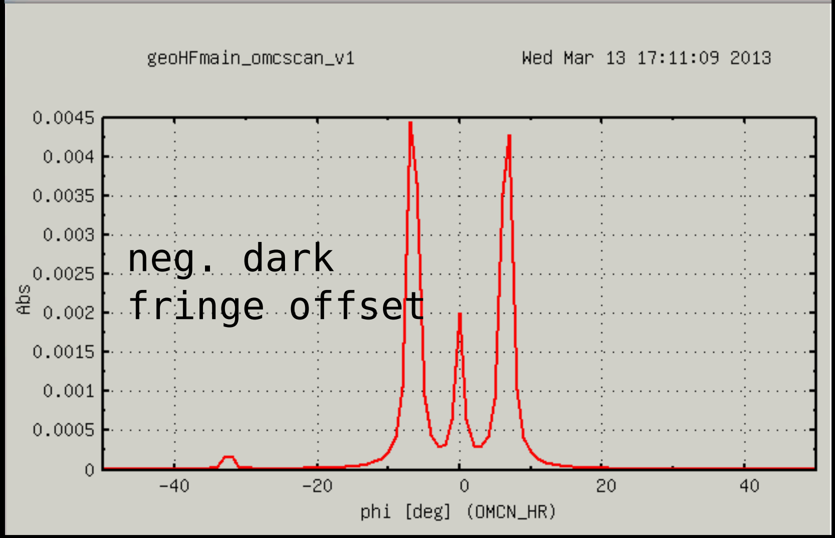
thermal compensation effect remains for 30 min.

Relative mode mismatch

Differential thermal lensing creates offset on dark fringe







Cold locking lessons

Example of a minor problem:
OMC locking algorithm no longer works

Solutions:

- sophisticated OMC locking algorithm
- high power RF lock, then transition to DC readout
- pre-heating of BS
- compensate the BS thermal lens at the BS

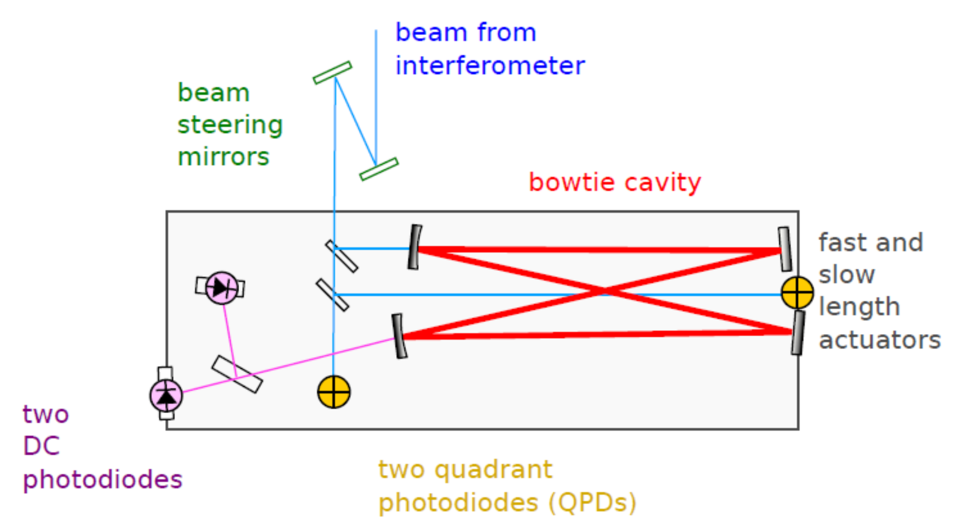
near future plans (thermal radiation)

What other "cold locking" challenges will advanced detectors face?

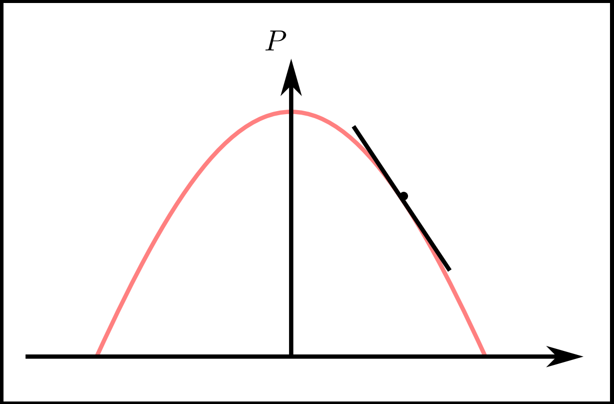
aLIGO: self-heating 40 min.
CO2 laser 1.5 hours
ring heater 4 hours

OMC alignment

Between eLIGO and GEO, finding a good OMC alignment technique has proven difficult.



Options:
- optimize power
- optimize optical gain

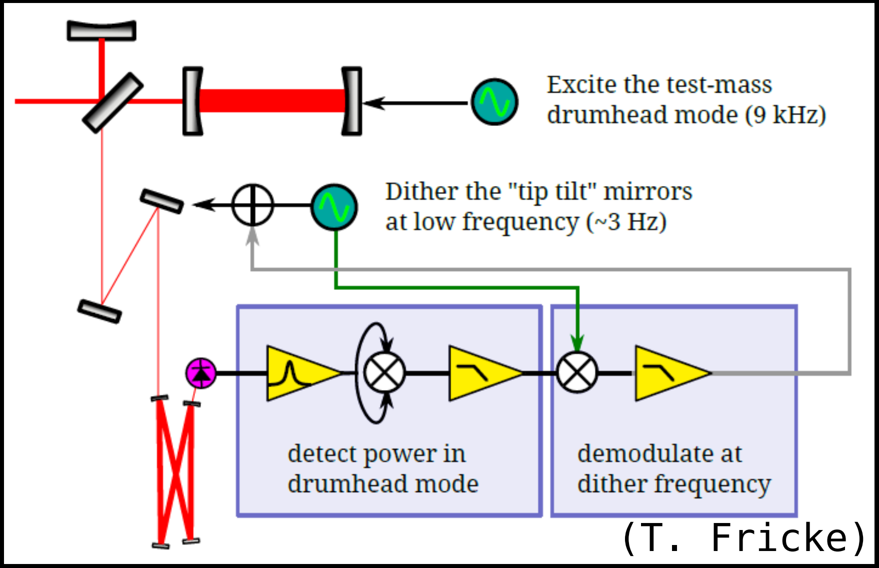


Challenges:
- HOMs
- beam jitter

OMC alignment techniques

DITHER: Dither steering mirrors and demodulate in OMC trans. (Couples HOMs, thus reducing optical gain.)

BEACON DITHER: Extension to dither technique. Modulate a test mass at high freq. to mark the TEM00 carrier and double demodulate in OMC trans. (Sensitive to beam jitter.)



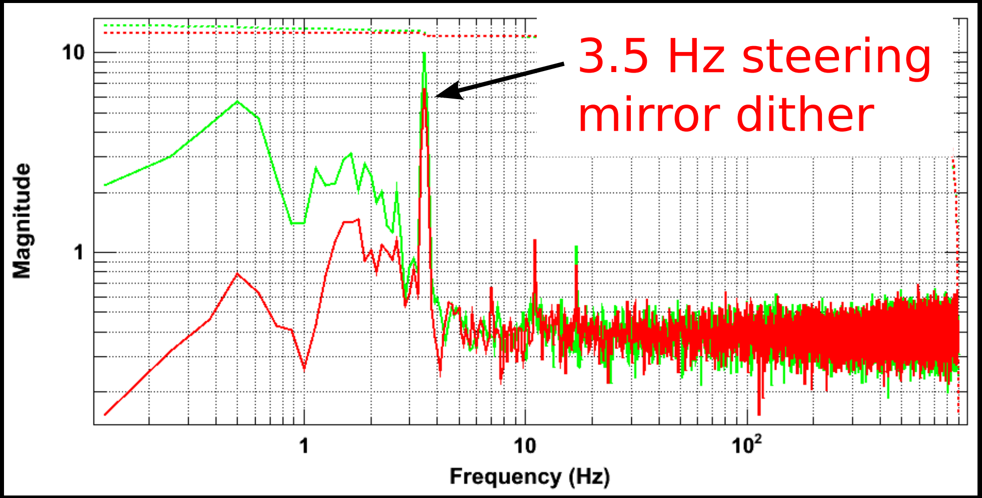
+ some variations

(Smith et al. arXiv:1110.4122)

Eliminating dither lines

Beacon dither used in LIGO and GEO. Downsides:

- bandwidth limited to less than 100 mHz
- low freq. dithers dominate RMS of residual beam motion on OMC (both GW carrier and squeezer)
- increased coupling of output beam jitter to strain



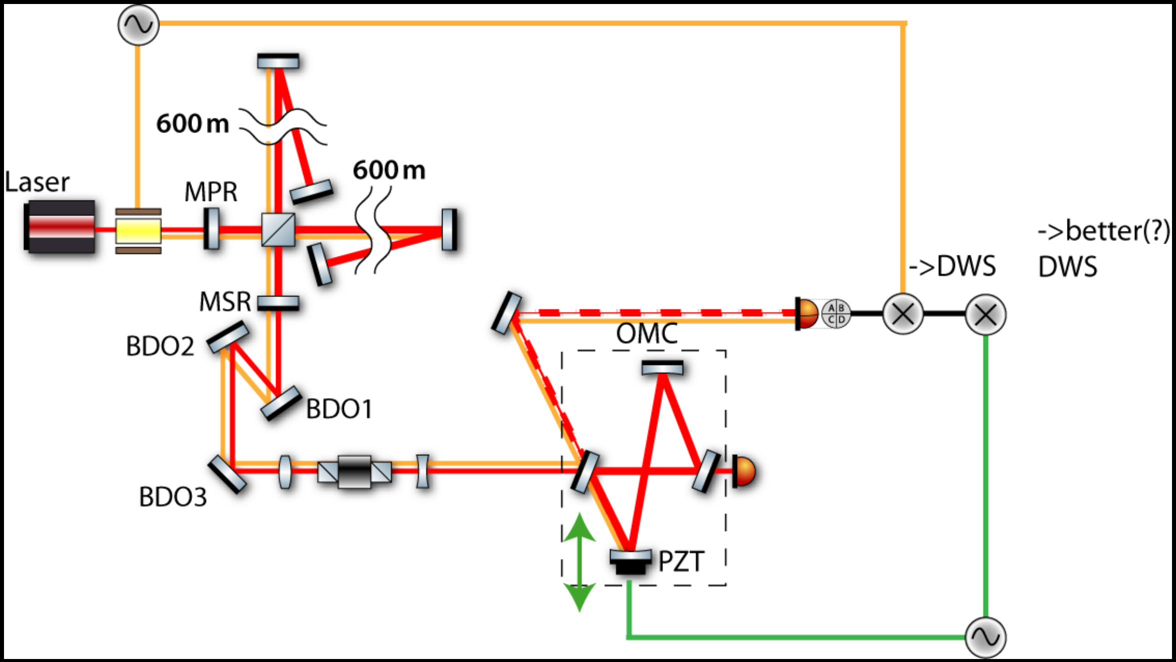
open and closed loop squeezer alignment signal

Advanced detectors need a better alignment scheme.

Wavefront sensing method

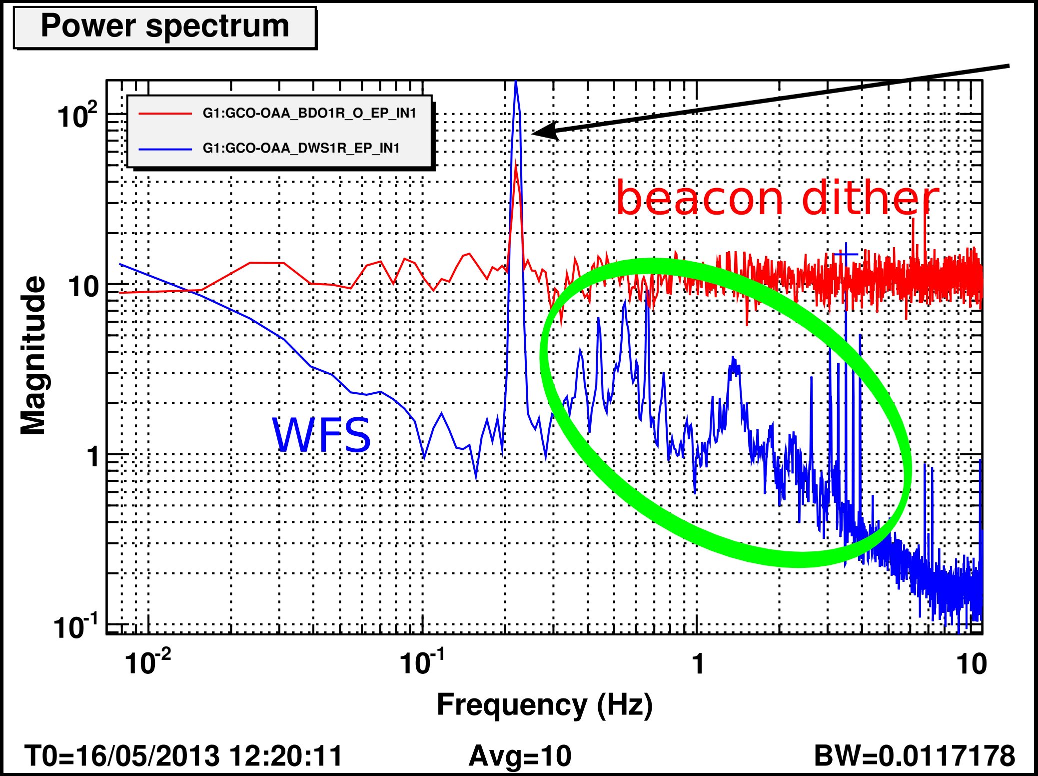
Use wavefront sensors in OMC reflected beam, demodulating twice:

-- RF sidebands (14.9 MHz)
-- OMC length modulation (6 kHz)



Better SNR

Double-demodulated WFS signal has higher SNR.



20 times higher SNR

structure where we expect it

Commissioning is ongoing.

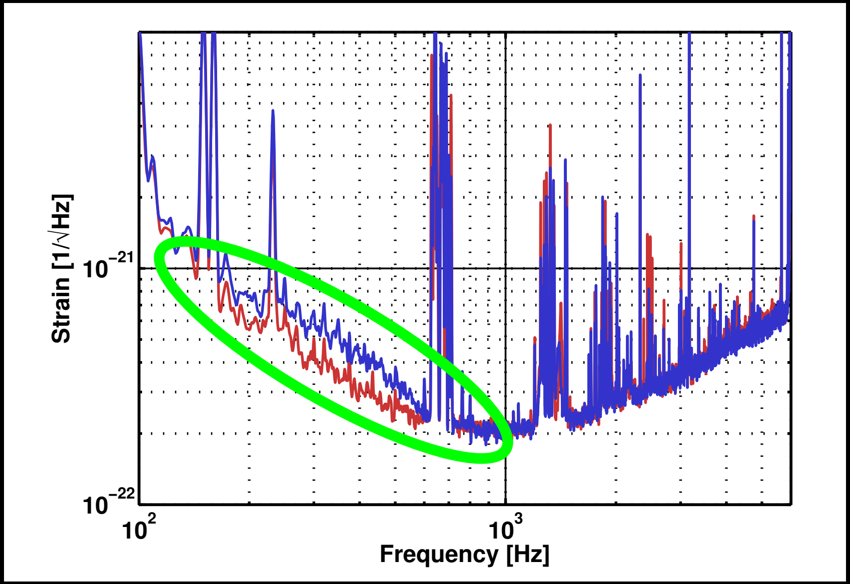
Do not yet see out-of-loop improvement.

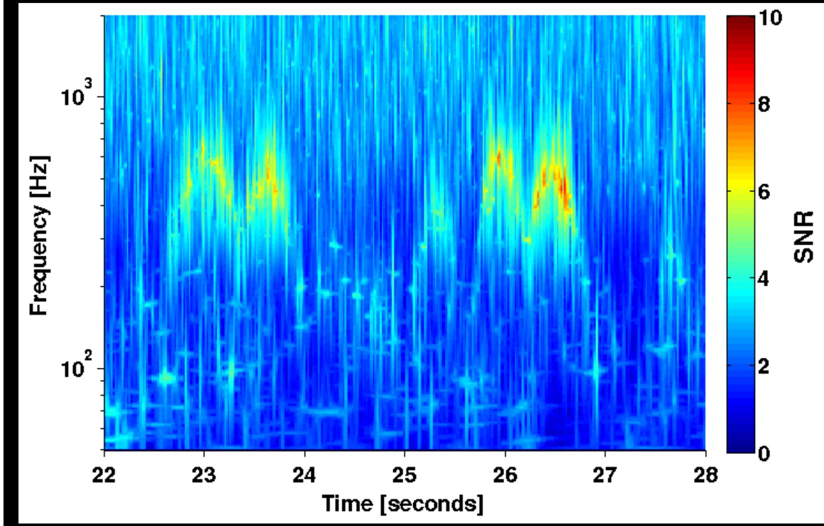
GEO mid-frequency noise

We are forever on the search for explaining the mid-frequency (100 to 1000 Hz) noise.

In particular, the noise level is not constant.

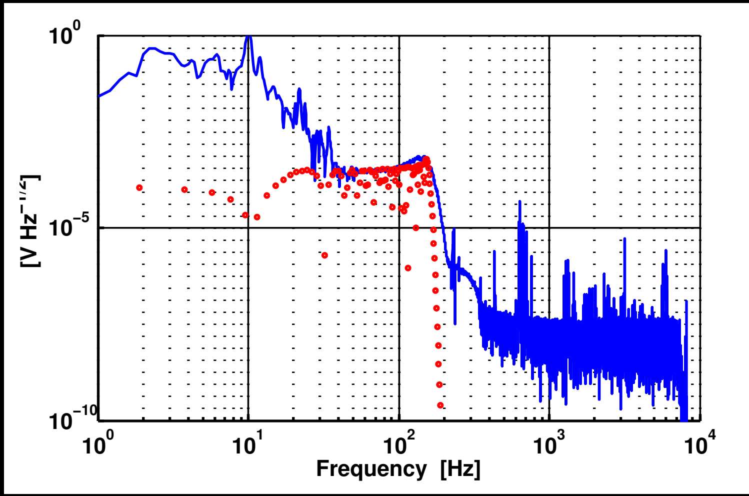
In the last year, identified stray light as a component.

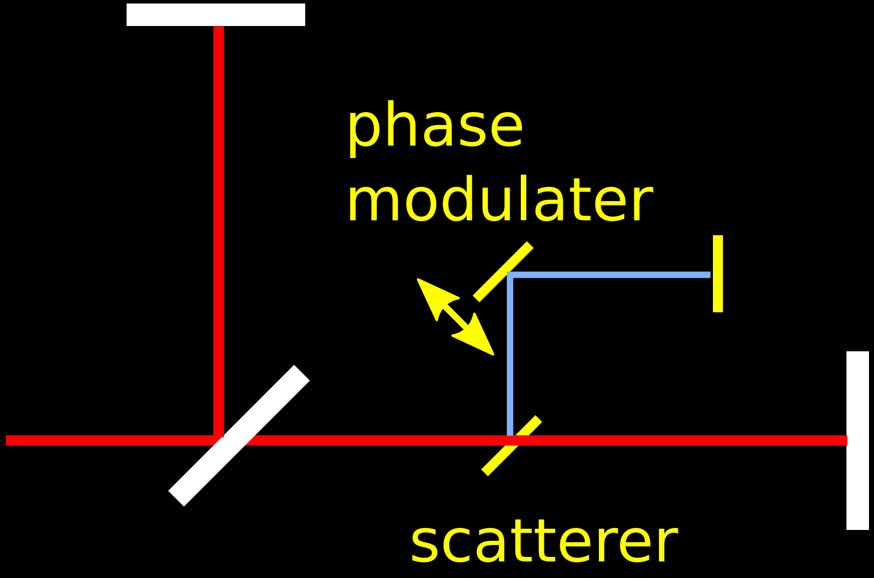




Stray light

Stray light is identified as one of the top concerns for commissioning of advanced detectors (see T1200464).



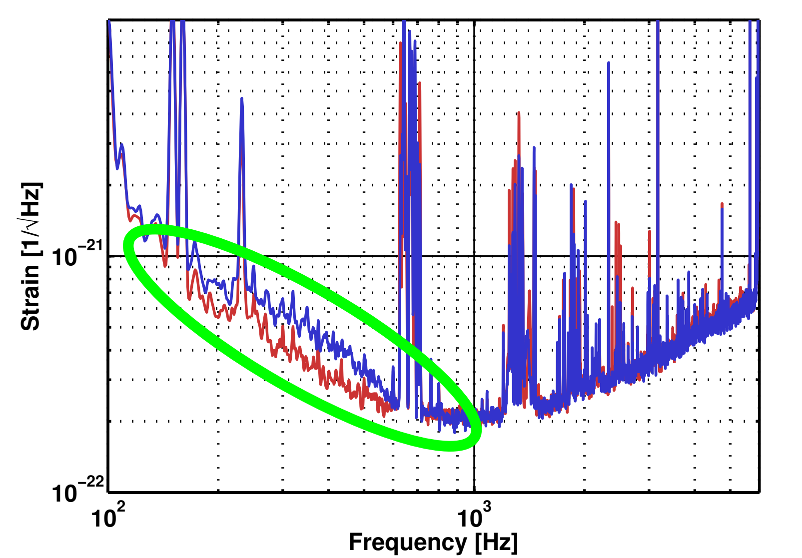


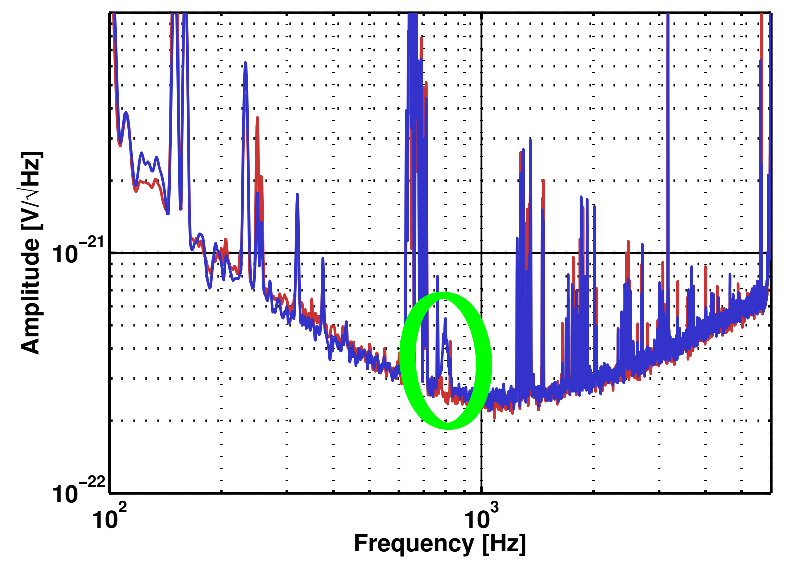
Stray light

Two regimes:

Phase wrapping
(scatterer with large amplitude)

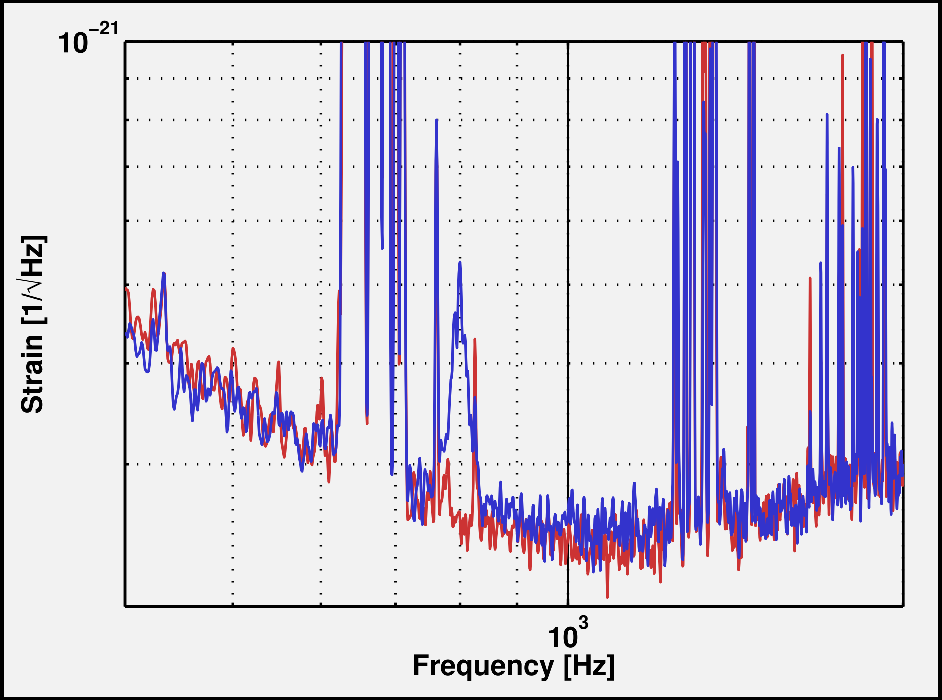
Linear coupling
(scatterer with small amplitude)

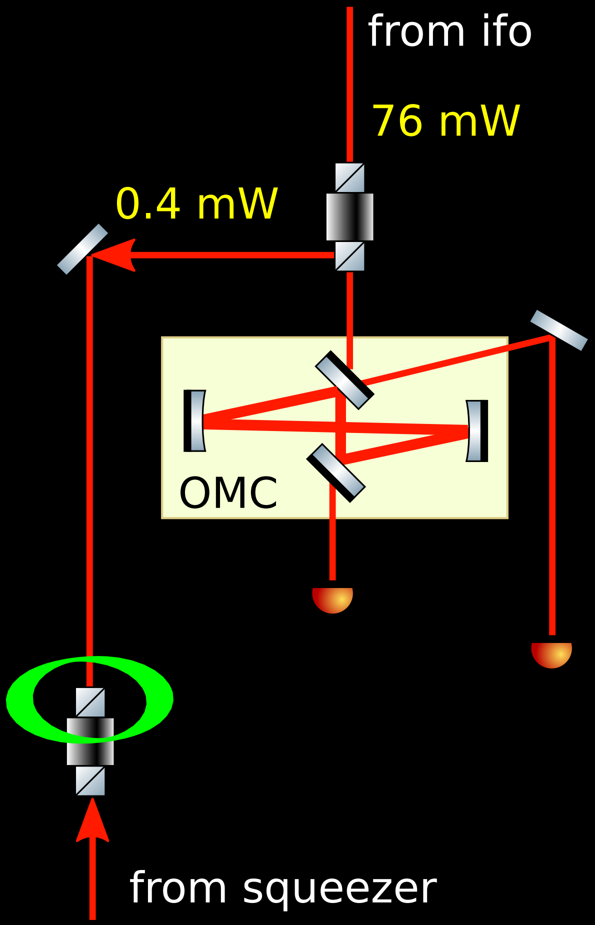




Example: redirection

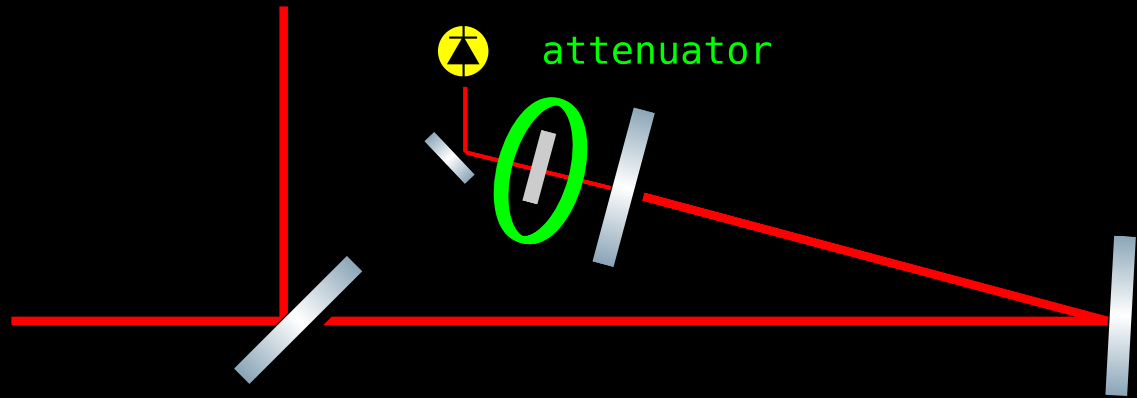
Point the stray light field away from getting coupled into the interferometer mode.

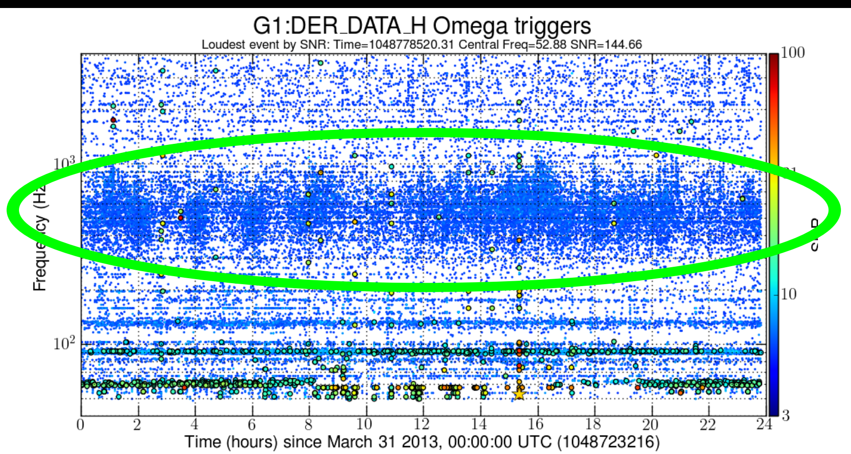


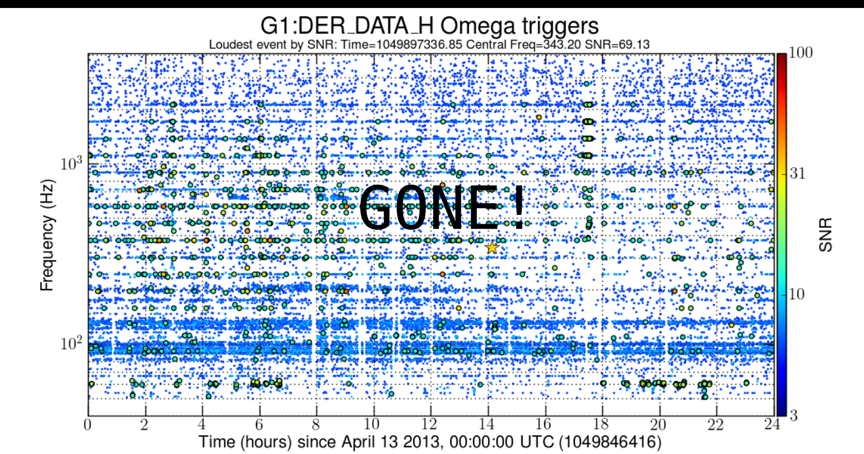


Example: attenuation

Reduce the power in the scattered field.







identified as scattered light via
listening and finding arches in omegagrams

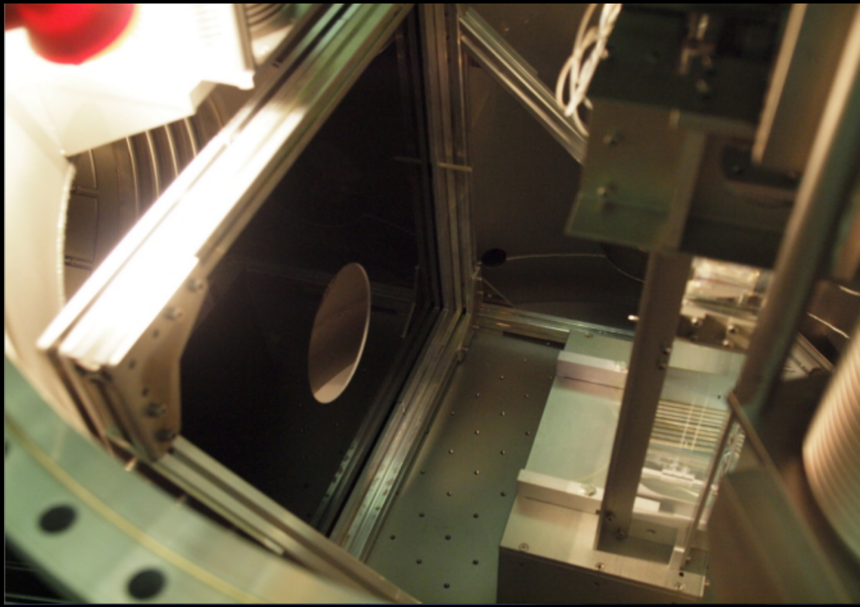
Stray light outlook

We have found and eliminated a stray light coupling --> no longer see rise and fall of mid-frequency noise.

A background of many scatterers may exist. Most of the power ends up in chambers due to small angle scattering.

1/4 baffles installed

May need new scattering search methods.



Summary

Thermal compensation

(benefits from new dof of heating compensation; we see and expect more "cold locking" challenges which may need more simulation)

New OMC alignment

(trying new control signals with potential use in reducing beam jitter coupling, reduce squeezer losses; investigate role of ifo to OMC alignment wrt squeezing)

Stray light

(no discrete new message from us other than this continues to be important)