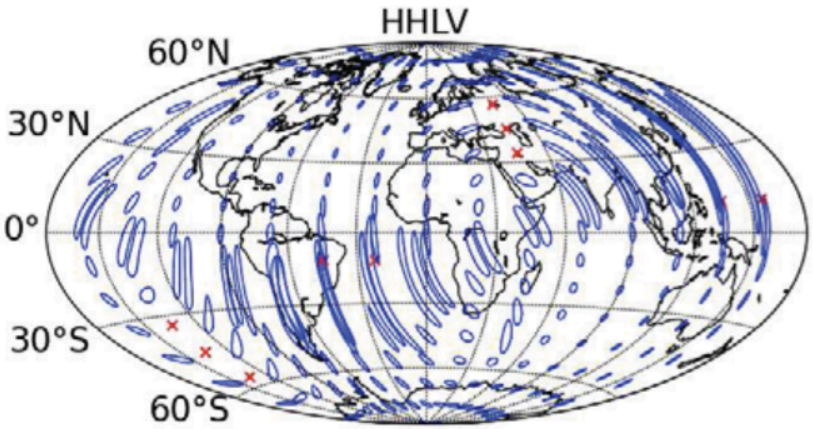
Current status of ground interferometers

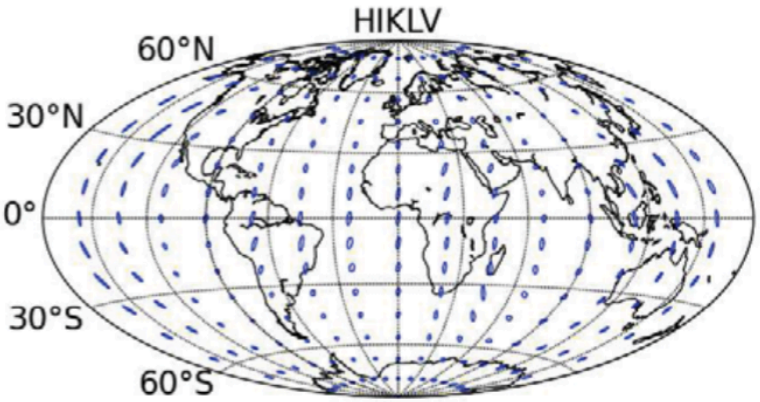
Kiwamu Izumi (LIGO Hanford)
for the LIGO scientific collaboration

GWPADW 2016 at Hyannis, June 15 DCC-G1601161-v3

Need multiple detectors

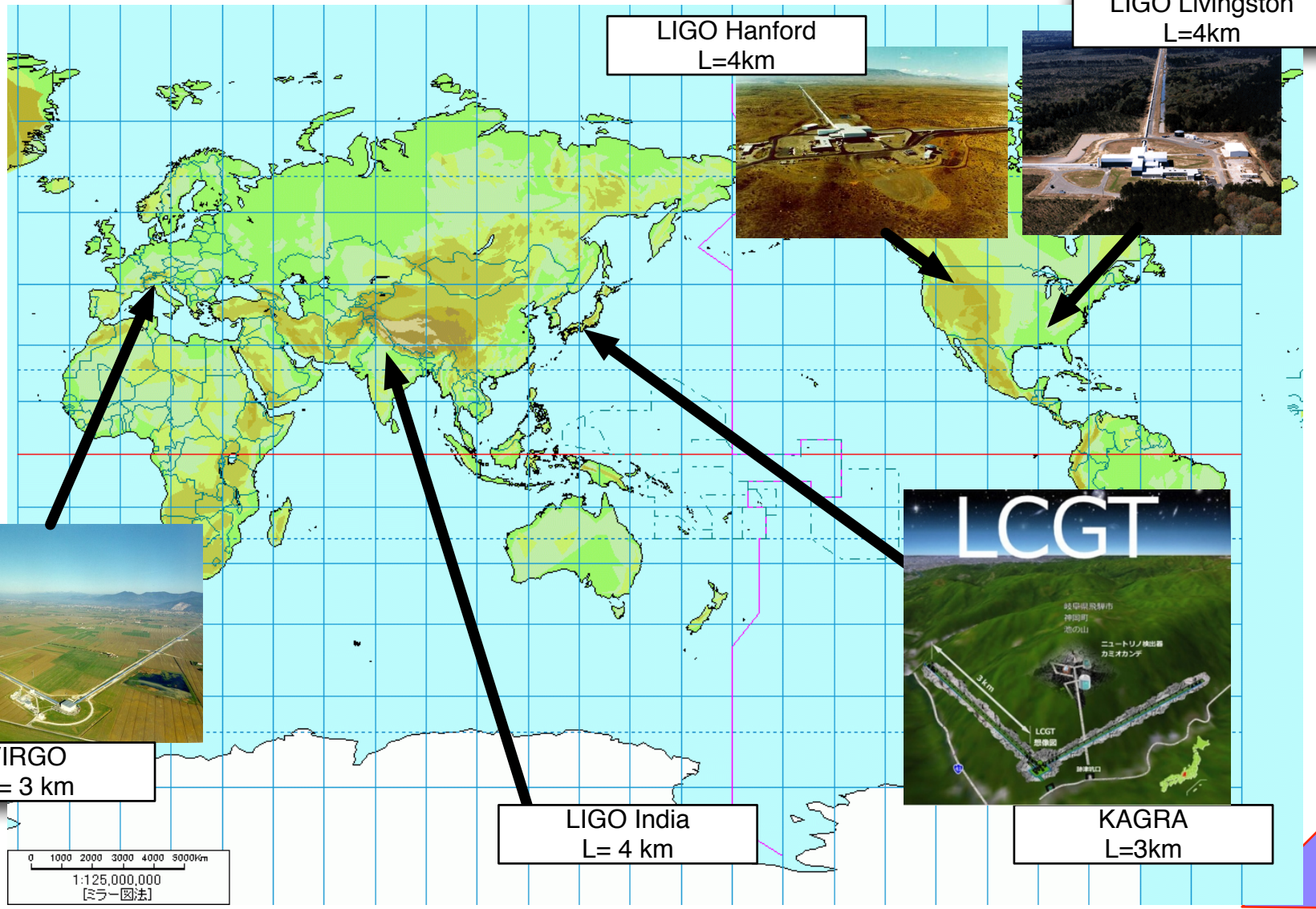
Having multiple detectors improves sky localization.
Important for astronomy.





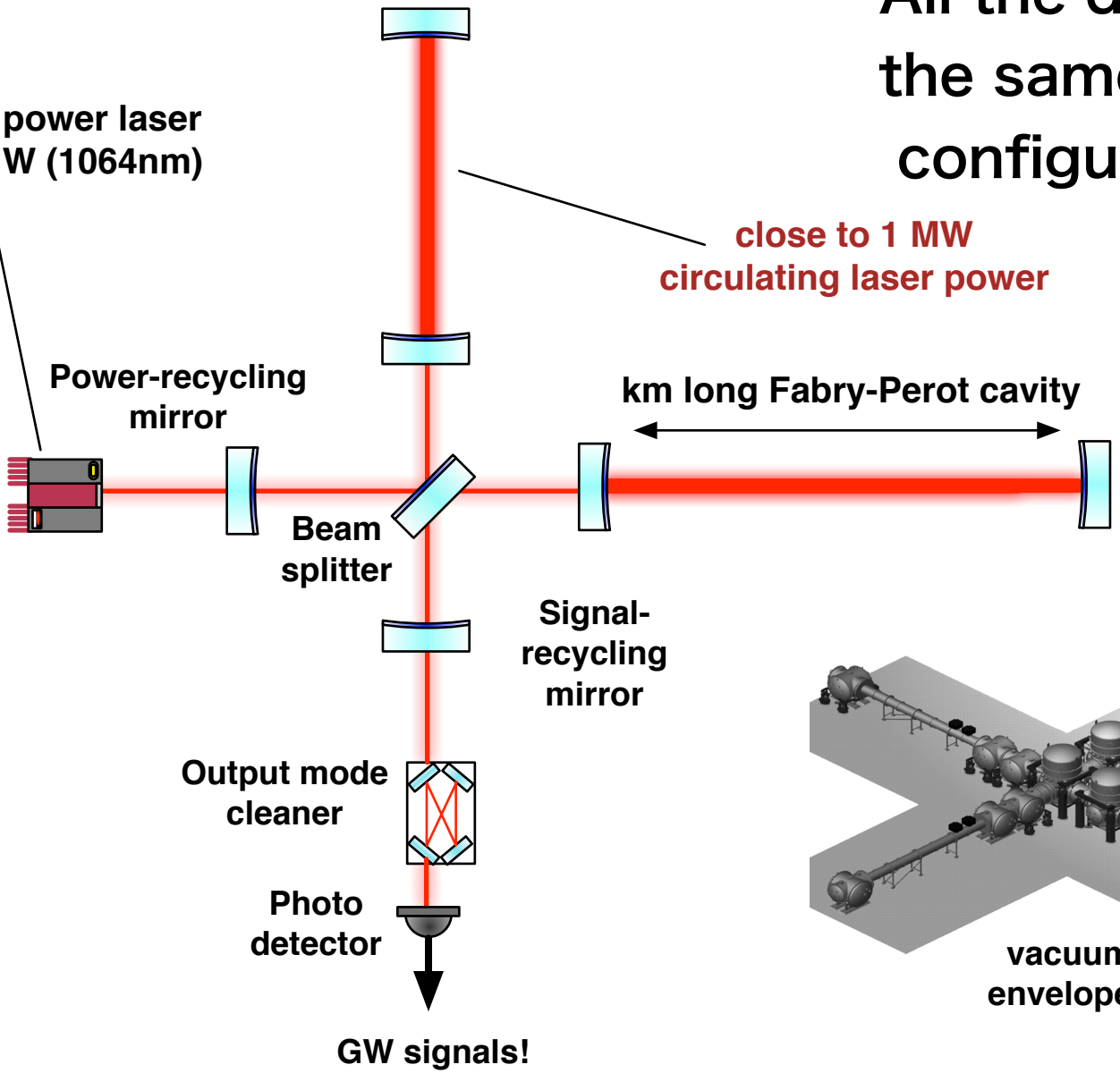
Plots: S. Fairhurst, J.Phys.: Conf. Ser. 484 012007 (2014)

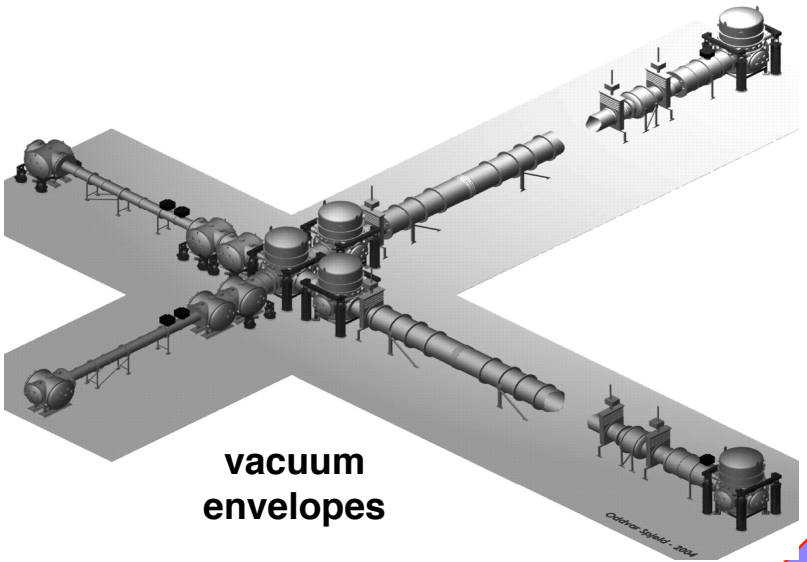
Wold wide network



2G interferometer

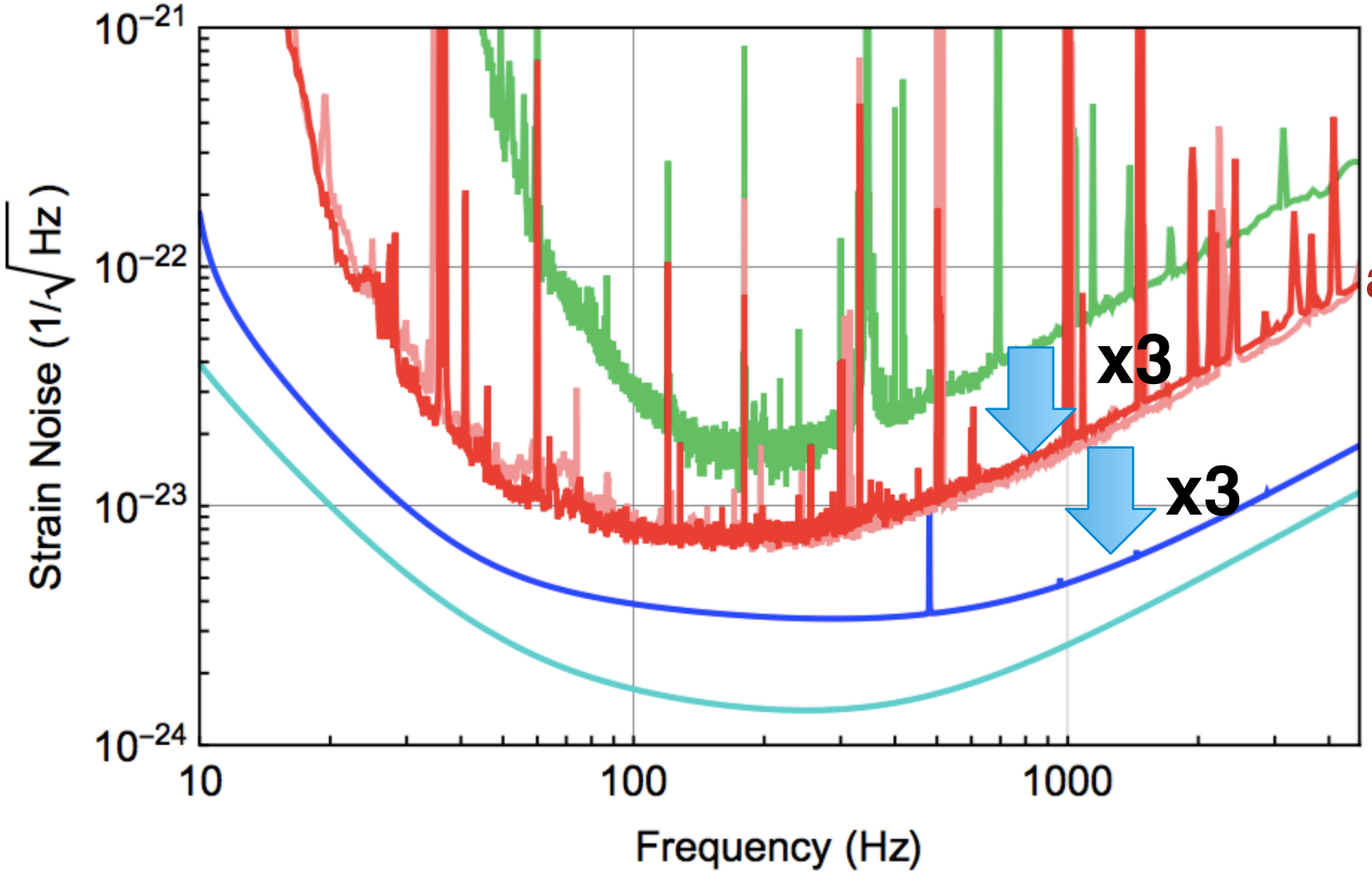
All the detectors will have the same interferometer configuration





vacuum
envelopes

Sensitivity



iLIGO

aLIGO(O1)

aLIGO (design)

a+LIGO

B.P. Abbott et al. Phys. Rev. Lett. 116 131103 (2016)

aVIRGO, north arm locked!

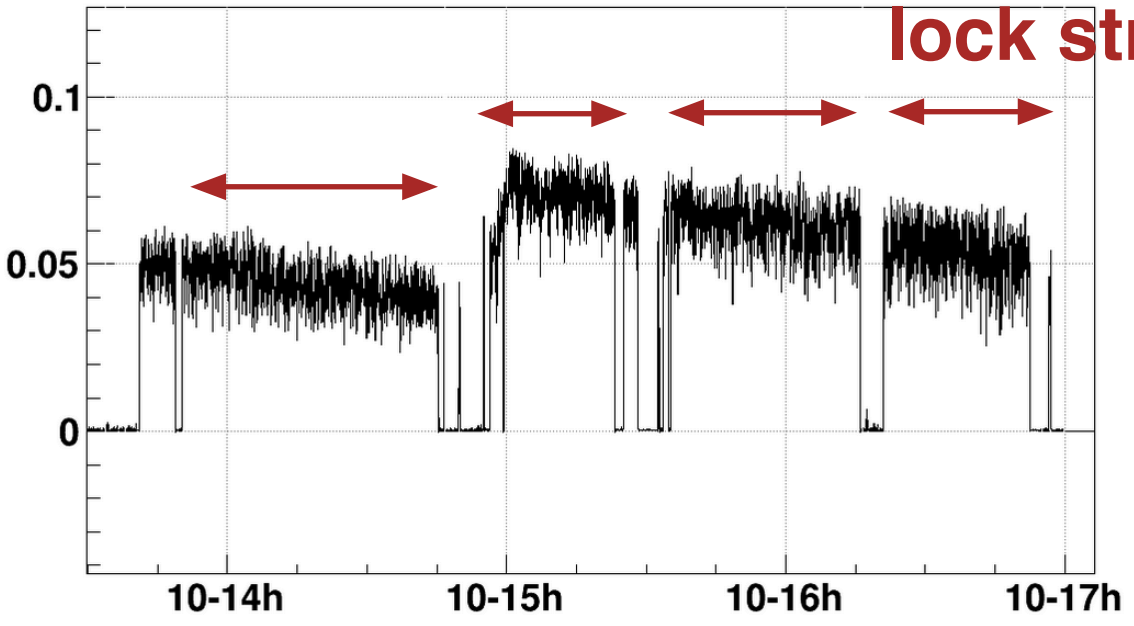
Recent big news from VIRGO

AdV-COM (AdV commissioning (1st part))

hoak, bersanetti, casanueva, swinkels, genin, allocca - 19:39, Friday 10 June 2016 (34010)

north arm locking much more robust

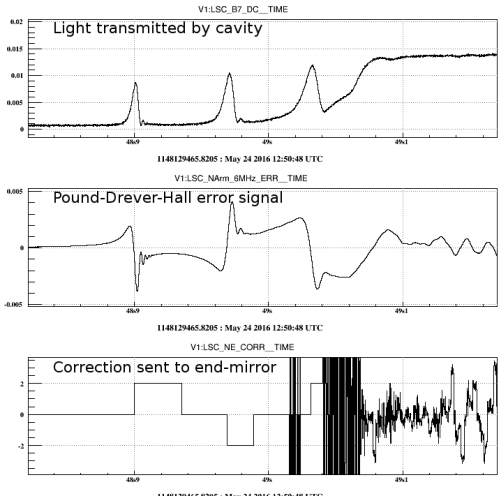
Tonight everything worked! We locked the north arm several times, and our lock duration was se
the alignment degraded). We had no issues with suspension control, communications between F



Advanced Virgo installation

- Experienced some delays in installation due to various technical issues (cracks in maraging blade-springs of suspensions, breaking of anchors of monolithic payloads, ...), but all major issues now resolved
- Installation of all major parts finished (infrastructure, vacuum, laser, ...)
- Still completing installation of some smaller components: last photodiodes, some baffles, several parts of Thermal Compensation System
- Last mirror (West-End) suspended ~1 weeks ago, now need 3 weeks of pumping before valves of West arm can be opened

Commissioning



- Locked PR-NI cavity ~1 month ago. Very low finesse, but important validation of all real-time sensors, actuators and software
- Aligned and locked North arm cavity locked ~2 weeks ago, first 3km long, high finesse cavity. Now improving locking robustness, implement automatic alignment
- Power-recycled short Michelson will be next, first test of some sensors and actuators of Thermal Compensation System

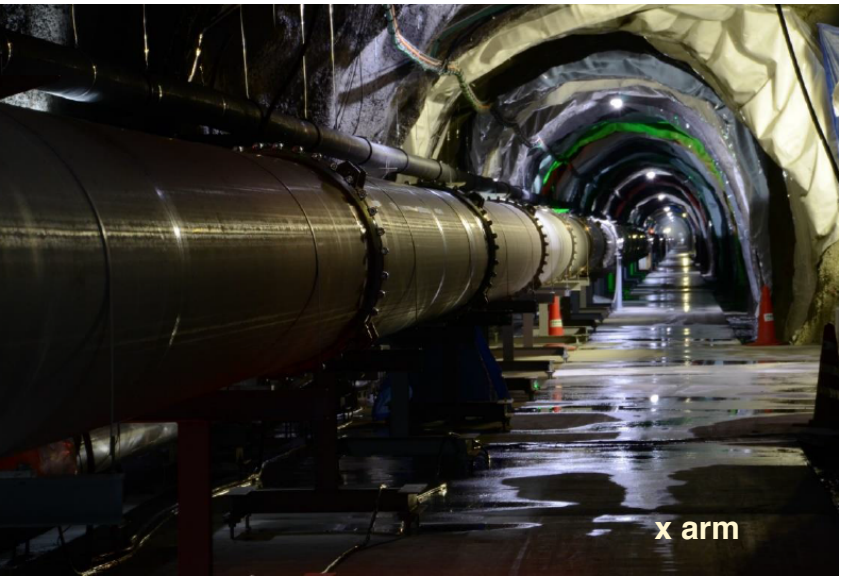
Next steps

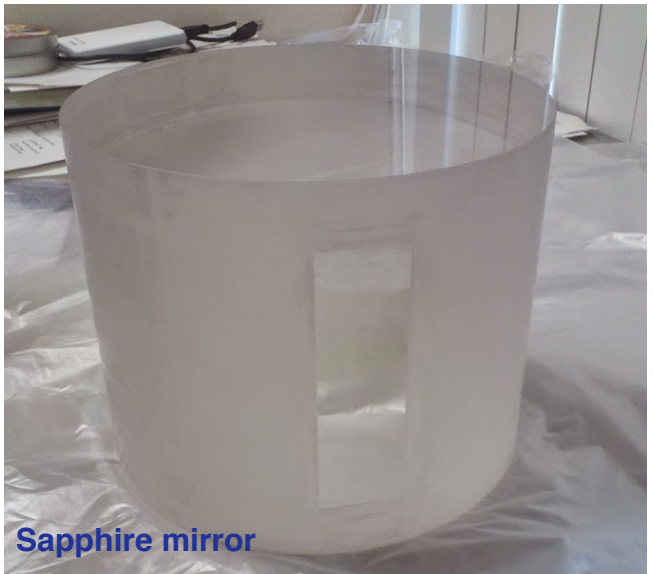
- Still need to change temporary metal wire suspension of North-Input mirror to glass fibers. Planned for early July, will align and lock West-arm while North arm is vented
- Full interferometer available towards the end of July
- Implement full lock acquisition. Will use Variable-Finesse technique as used for Virgo+. Marginally stable cavities, requires good performance of TCS system
- Use any remaining time for noise hunting
- Tight schedule, but goal remains to be online by the end of the year and join LIGO in second part of O2 run

KAGRA status

courtesy of Y. Michimura

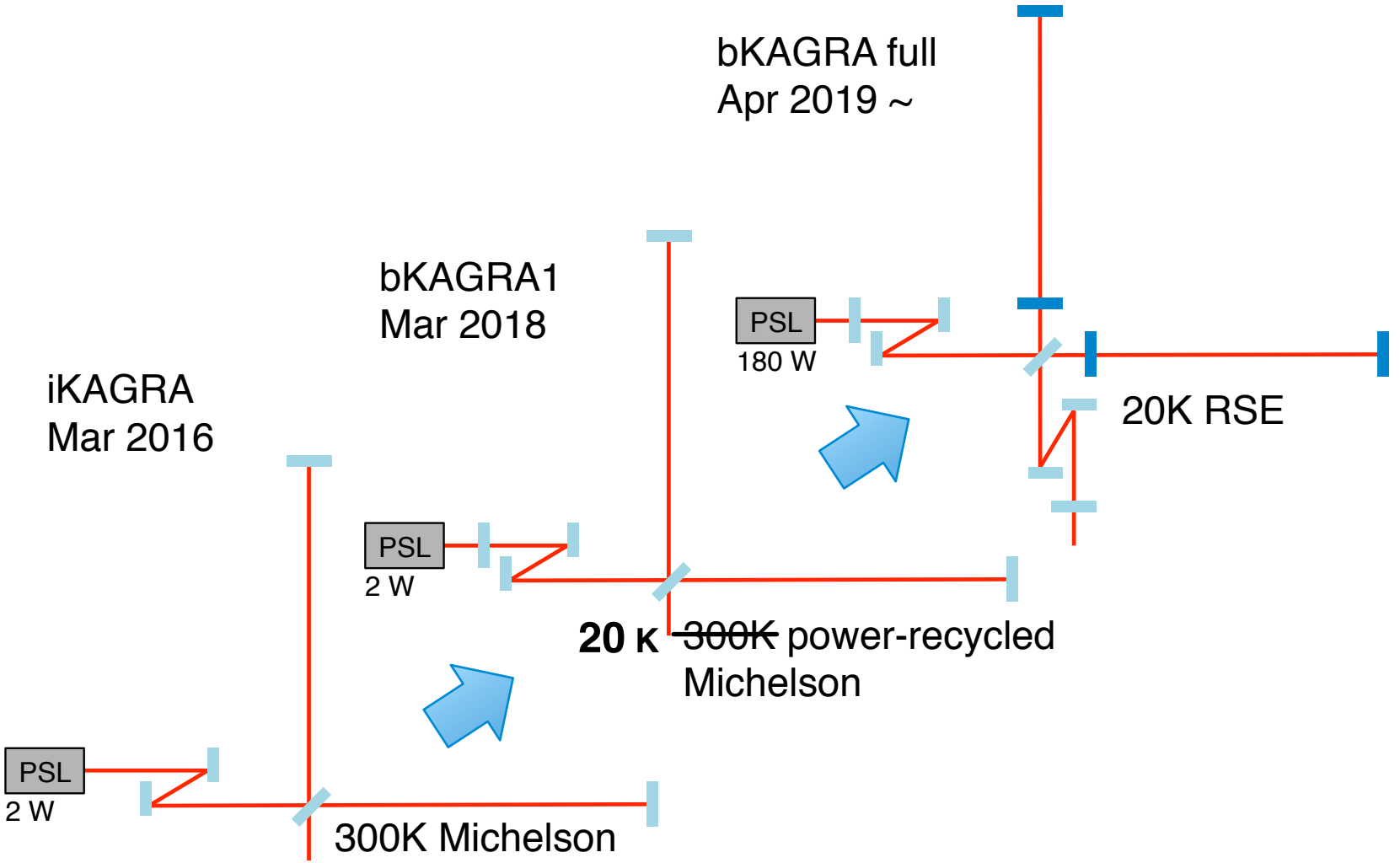
* Currently in installation/commissioning phase
* Concluded an initial test run with a simpler configuration (iKAGRA: Mar/Apr 2016)
* Gearing up toward an intermediate configuration (bKAGRA1)
* Getting cryogenic payloads ready by early ~~2019~~ 2018





KAGRA Roadmap

courtesy of Y. Michimura



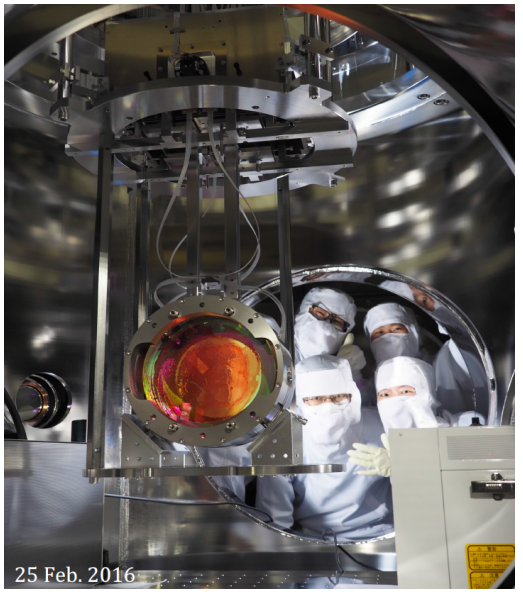
iKAGRA run concluded

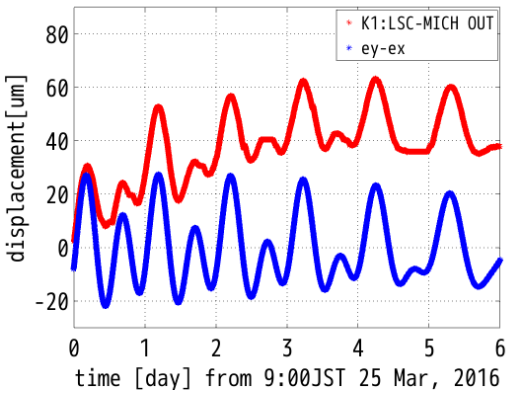
courtesy of Y. Michimura

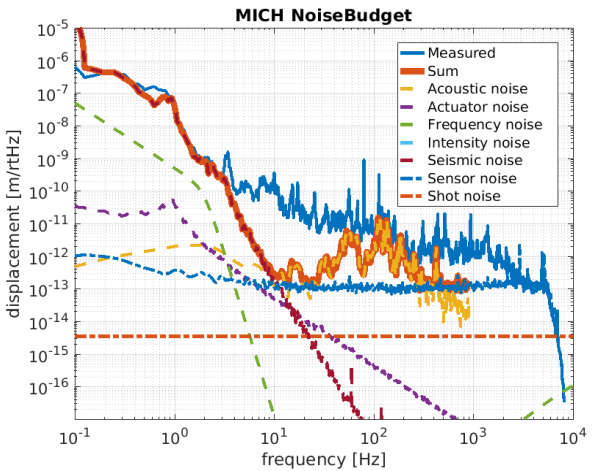
3-km room temp. Michelson (iKAGRA)
test run carried out on March and April 2016 for 3 weeks

- monitor environment inside the tunnel
- check alignment of vacuum ducts
- check data transfer/analysis flow
- check observation shift procedure

duty cycle: 88.6 %
longest lock stretch: 21.3 hours
strain sensitivity: 6e-16 /rtHz @ 100 Hz
tidal drift: ~30 um/day
acquired useful data
and experience
toward full KAGRA







LIGO commissioning status

Main goals of commissioning

* Operation with a higher power (20 W -> 50 W)
* Identification of low frequency noise

Livingston status

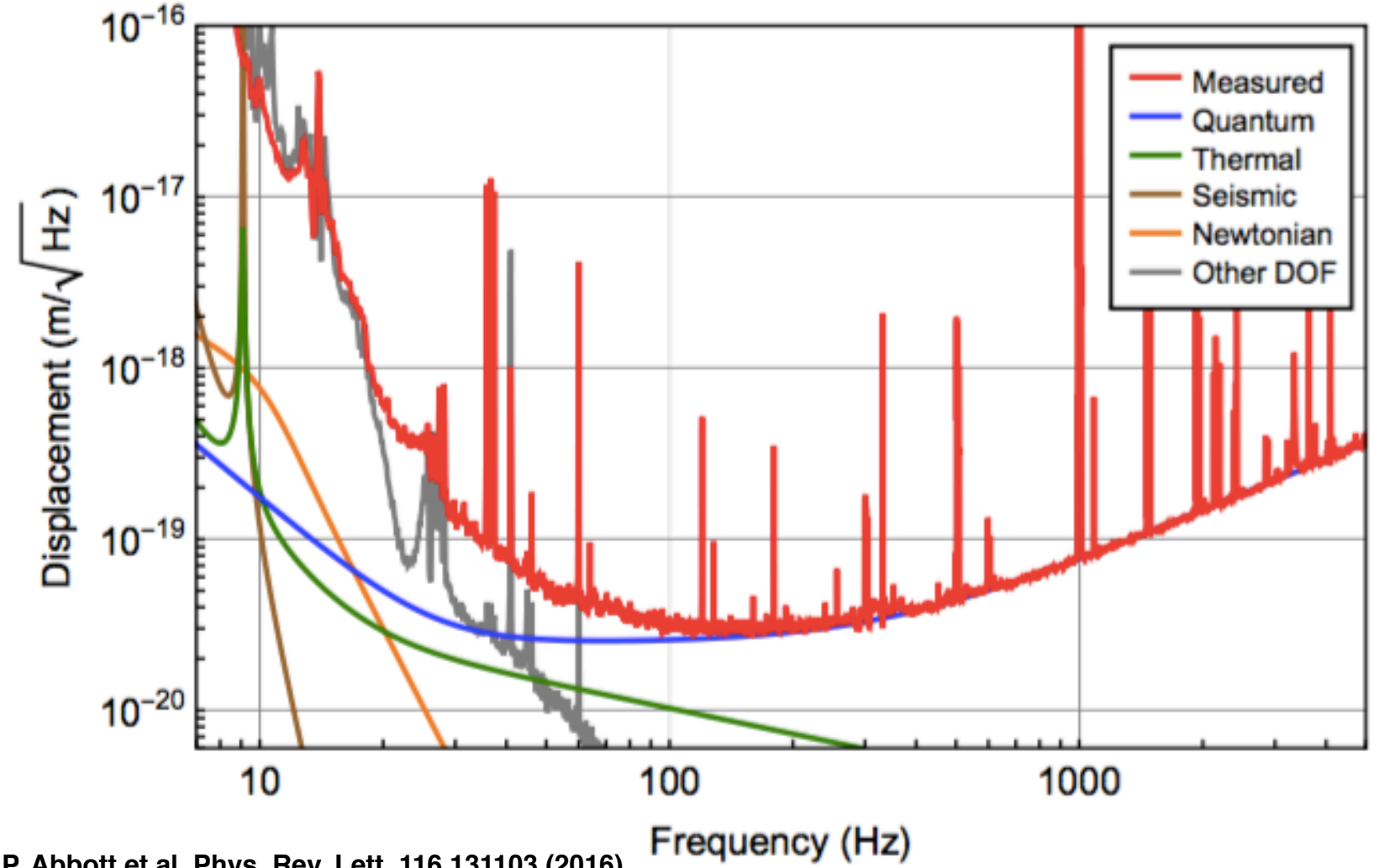
* Low freq. noise study.
* Trouble commissioning high power oscillator (HPO).
* Currently in-chamber hardware upgrade underway.

Hanford status

* HPO successfully commissioned
  (capable of a 50 W input laser power)
* Trouble operating higher power interferometer.
* Low freq. noise study.

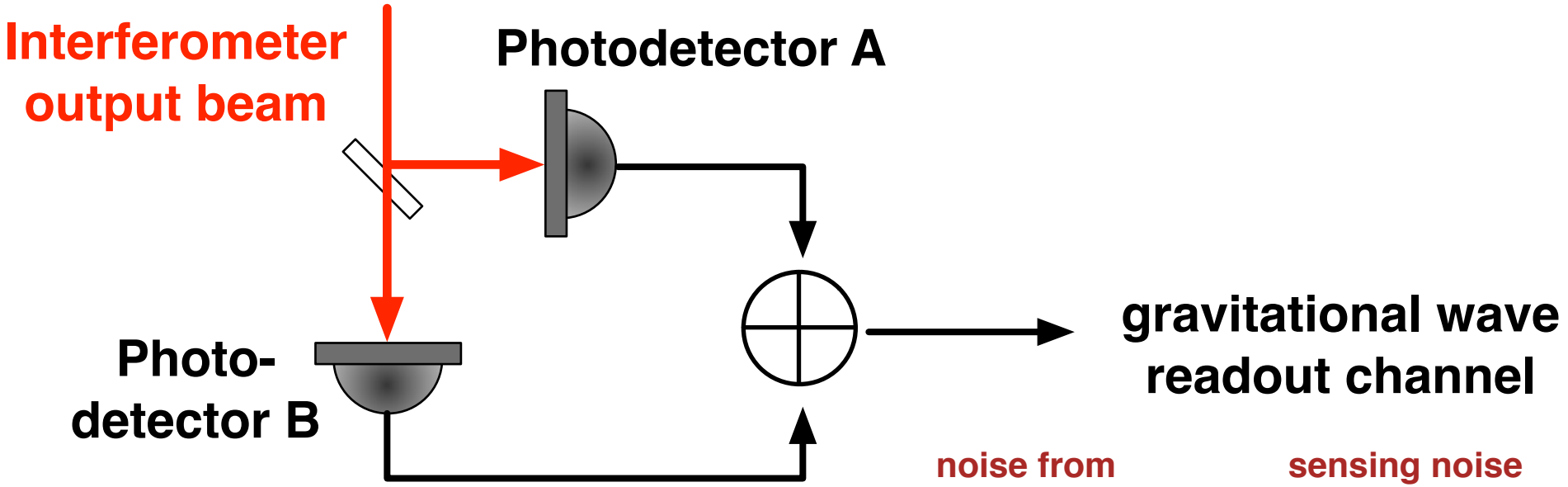
Noise identification

Understood except for 20 - 100 Hz



B.P. Abbott et al. Phys. Rev. Lett. 116 131103 (2016)

Removing sensing noise



noise from interferometer

sensing noise (uncorrelated)

Output from each photodetector:

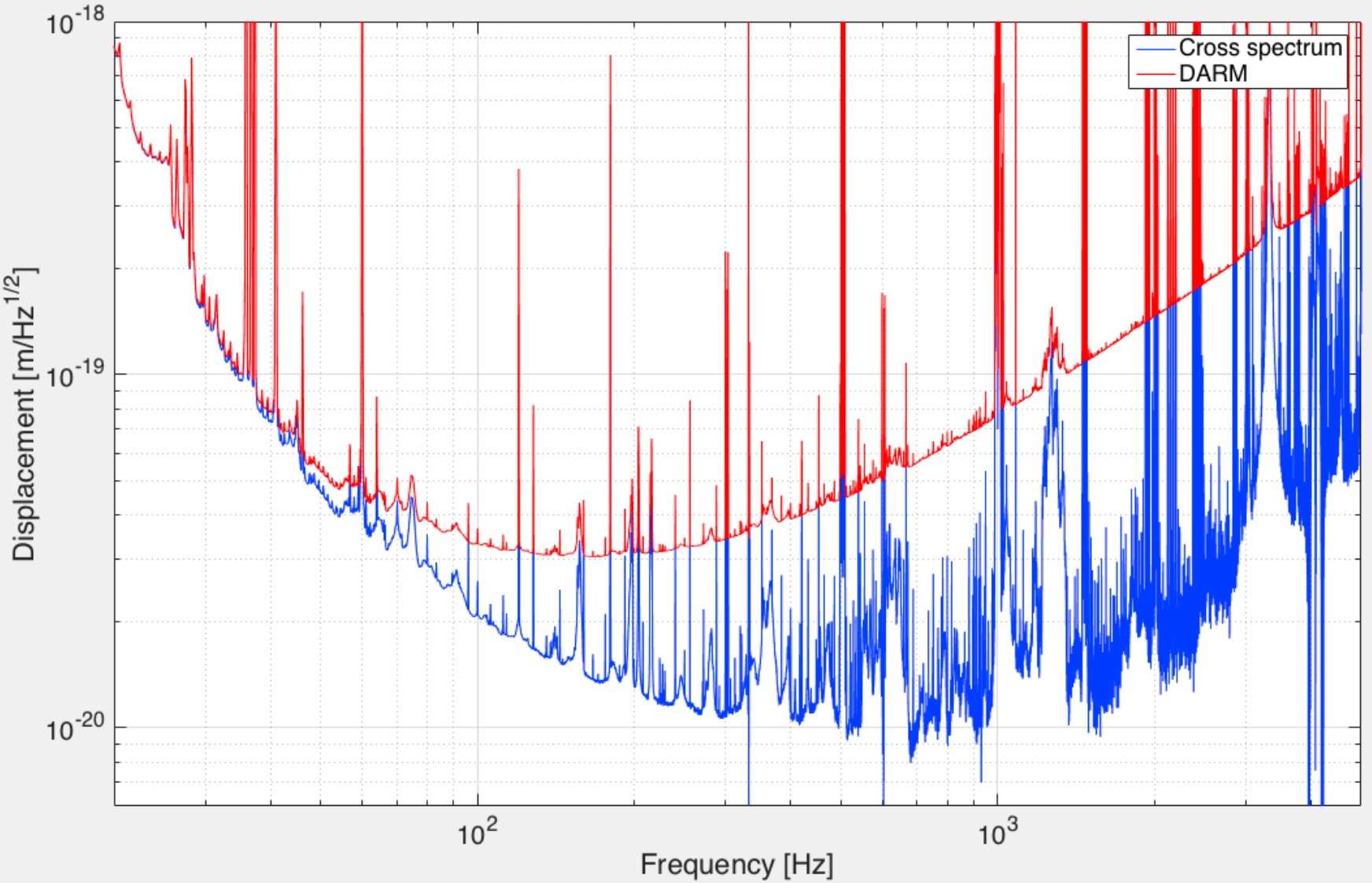
$$S_{A,B}(f) = x(f) + n_{A,B}(f)$$

Cross spectrum of the two photodetectors:

$$\left\langle S_A(f) S_B^*(f) \right\rangle = \left\langle |x(f)|^2 \right\rangle$$

Insensitive to sensing noises (e.g. shot noise)

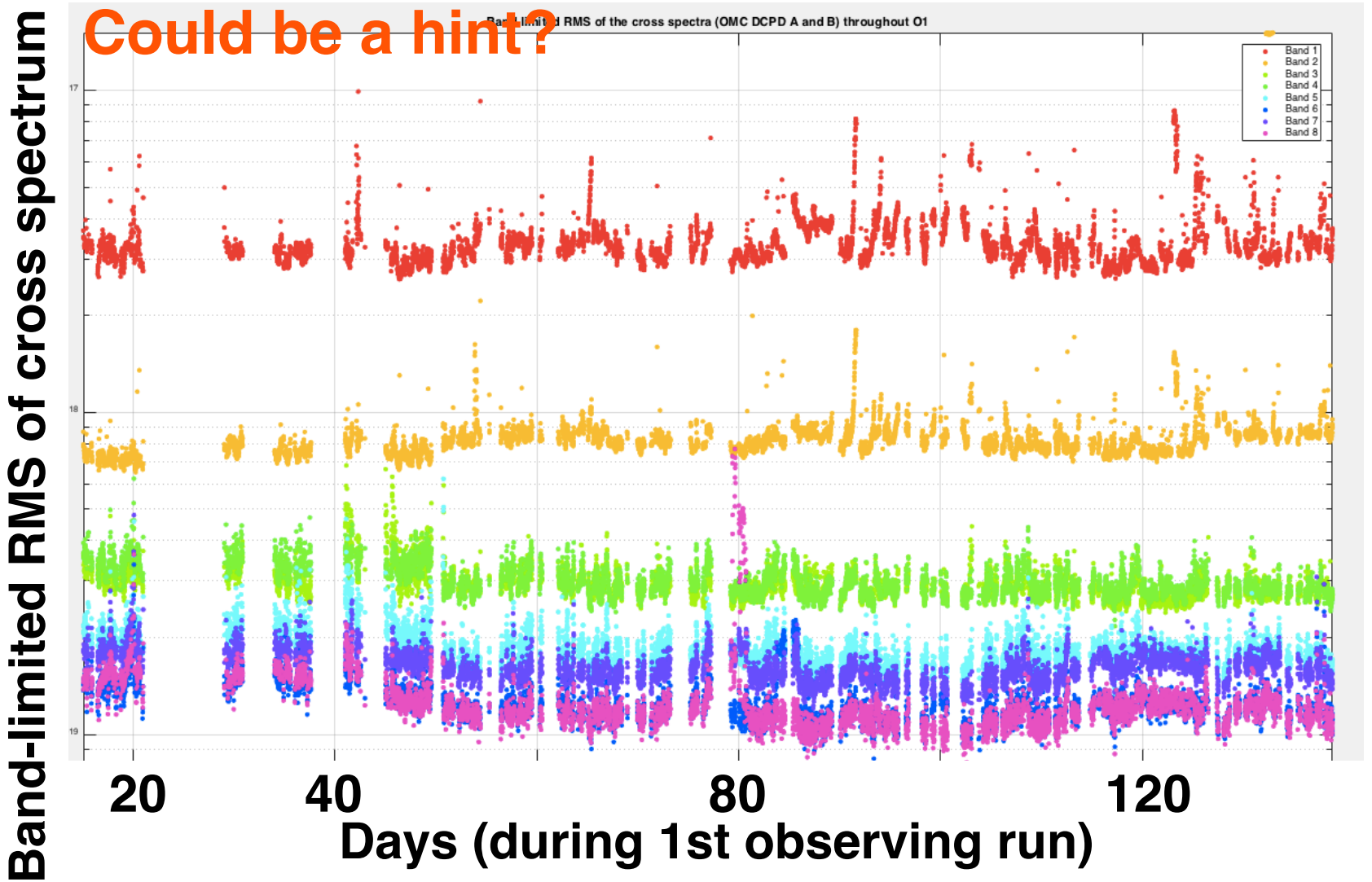
Getting below sensing noise



Stability of noise level

Noise level above 40 Hz varied by 10-20%.

Could be a hint?



Still unidentified

It does not seem to be

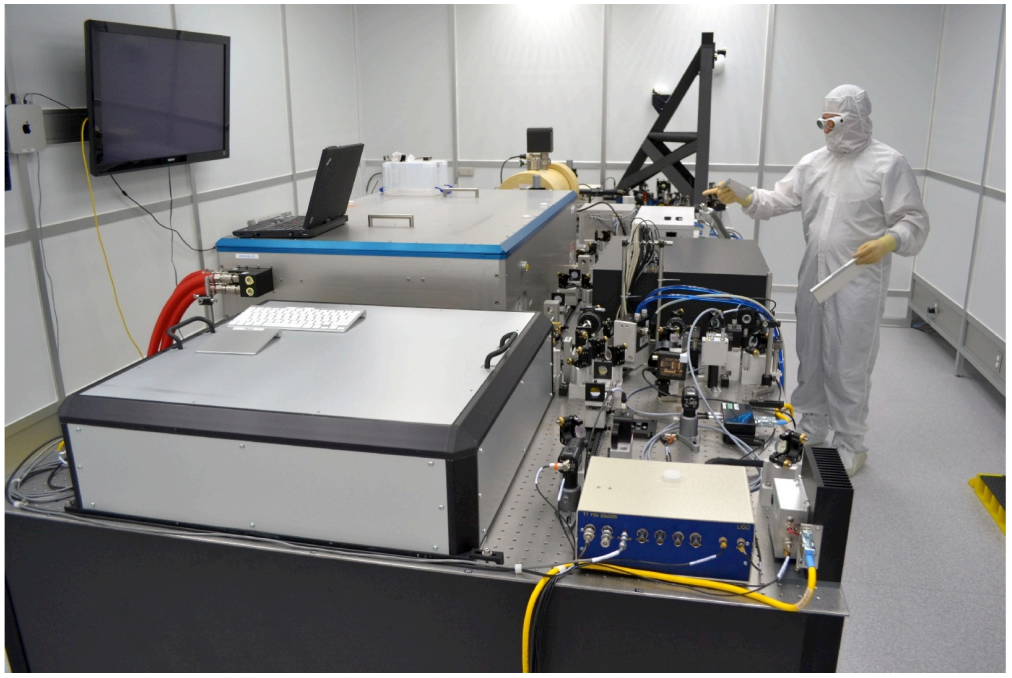
* Scattering noises
* Various mirror thermal noises
* Nonlinearity in sensing or actuation
* etc.

Next approach:

Once stably locked with high power (50W), low freq. noise will be more exposed. We will study characteristic of the noise

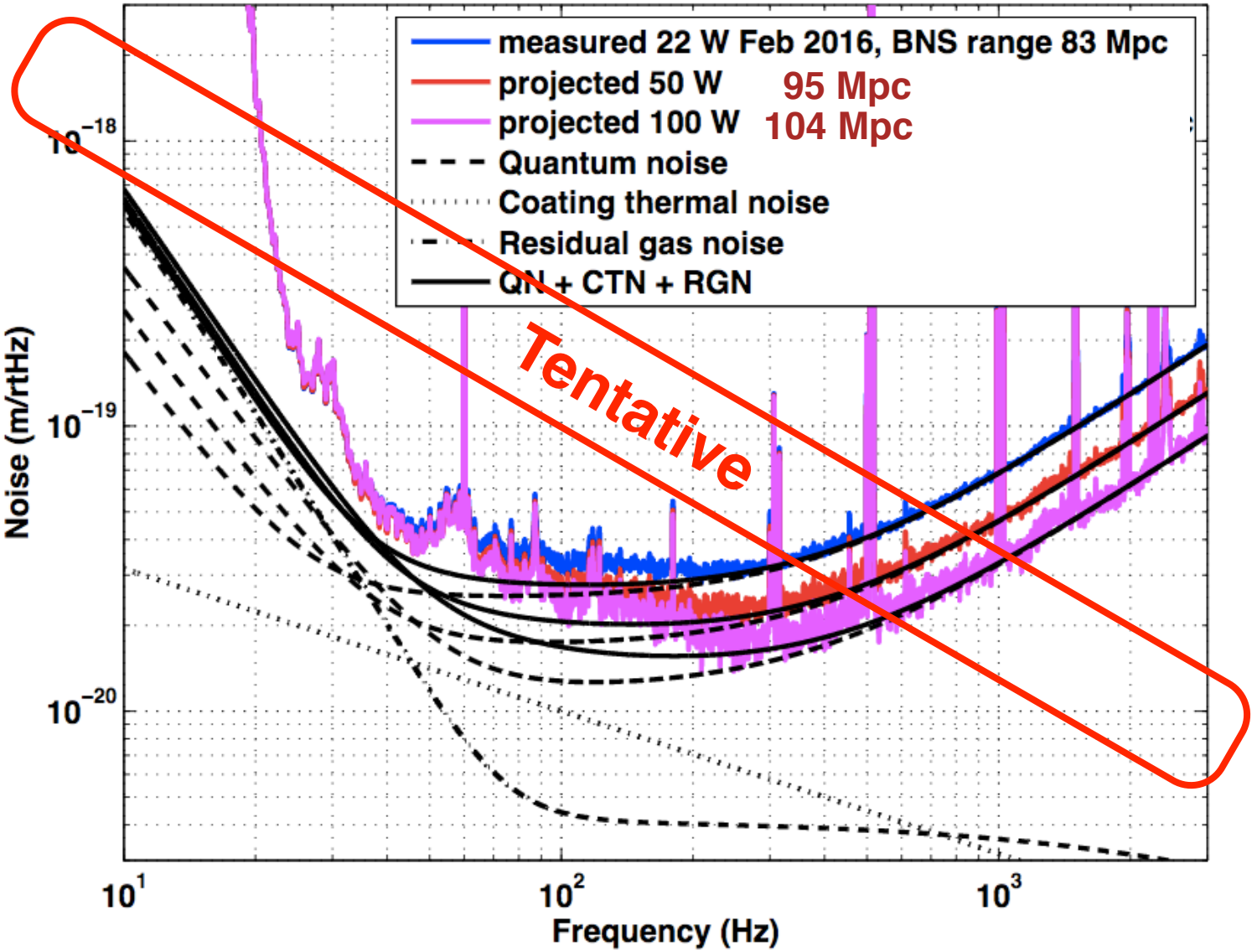
High power

* Increasing the laser power reduces shot noise
* It is NOT trivial in practice
  - Thermal state of the interferometer can change
  - Parametric instabilities may occur
  - Radiation pressure changes the optomechanical responses.



While none of them are fundamental issues, they can prevent from smooth commissioning.

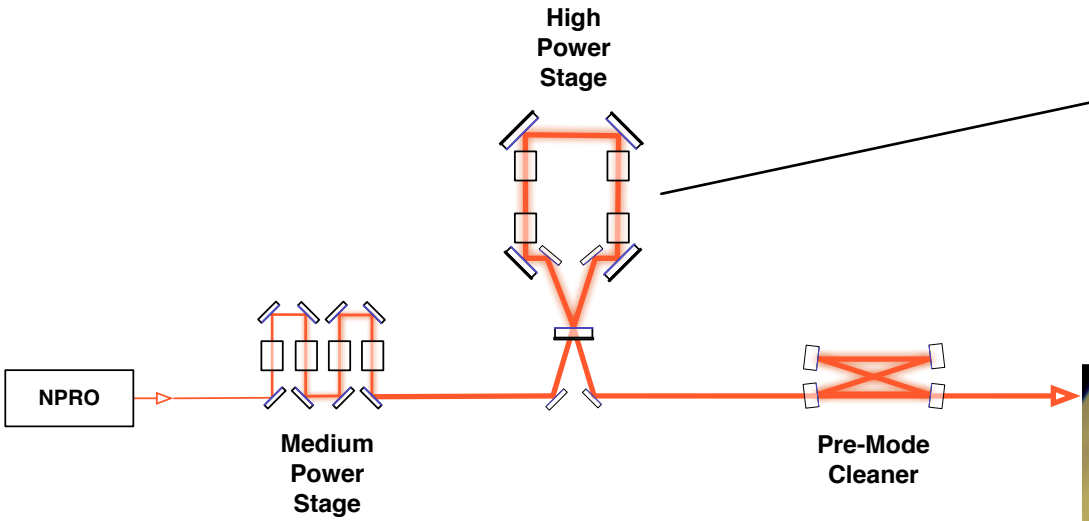
Expected Sensitivity



plot from LLO alog 25092

Trouble in Livingston's HPO

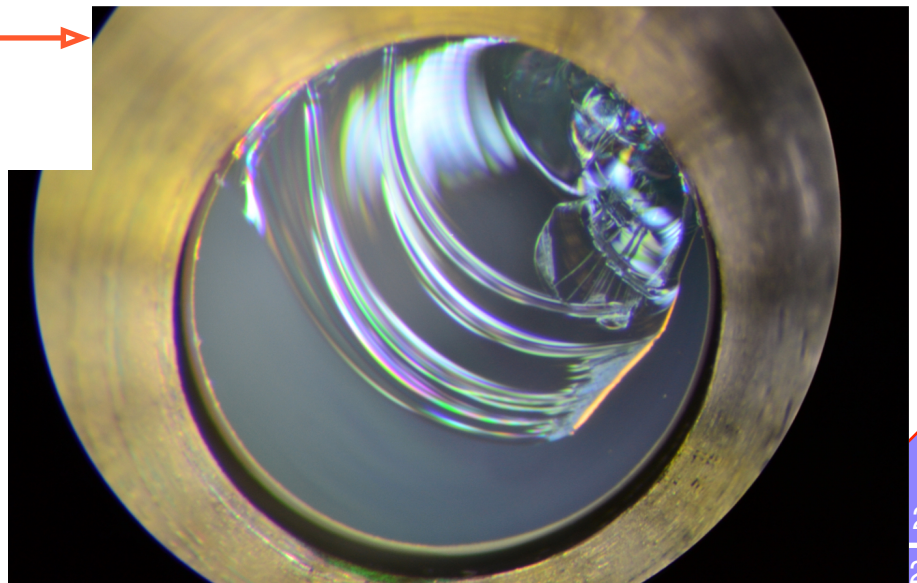
- Broke laser crystals in HPO multiple times
- The cause is being investigated
- Alternative amplifier is being considered



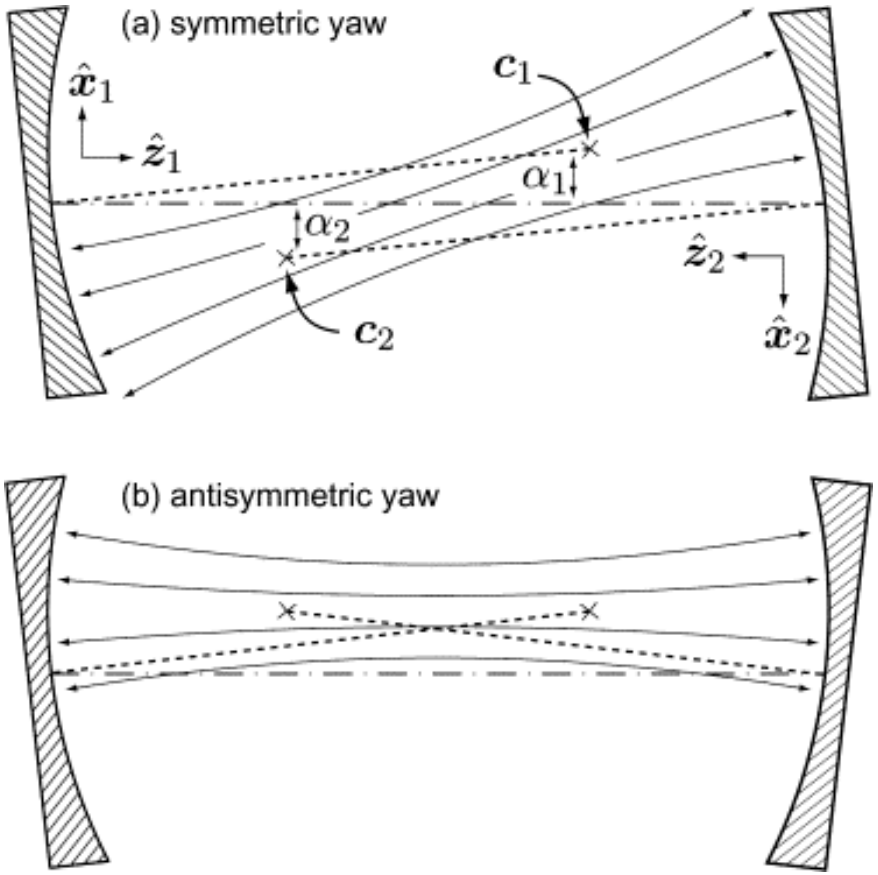
High power oscillator (HPO)

diagram from
Willke, B., et al. *CQG* 25.11 (2008): 114040.

a microscope picture of a broken crystal
(LLO alog 26178)



Radiation pressure torque

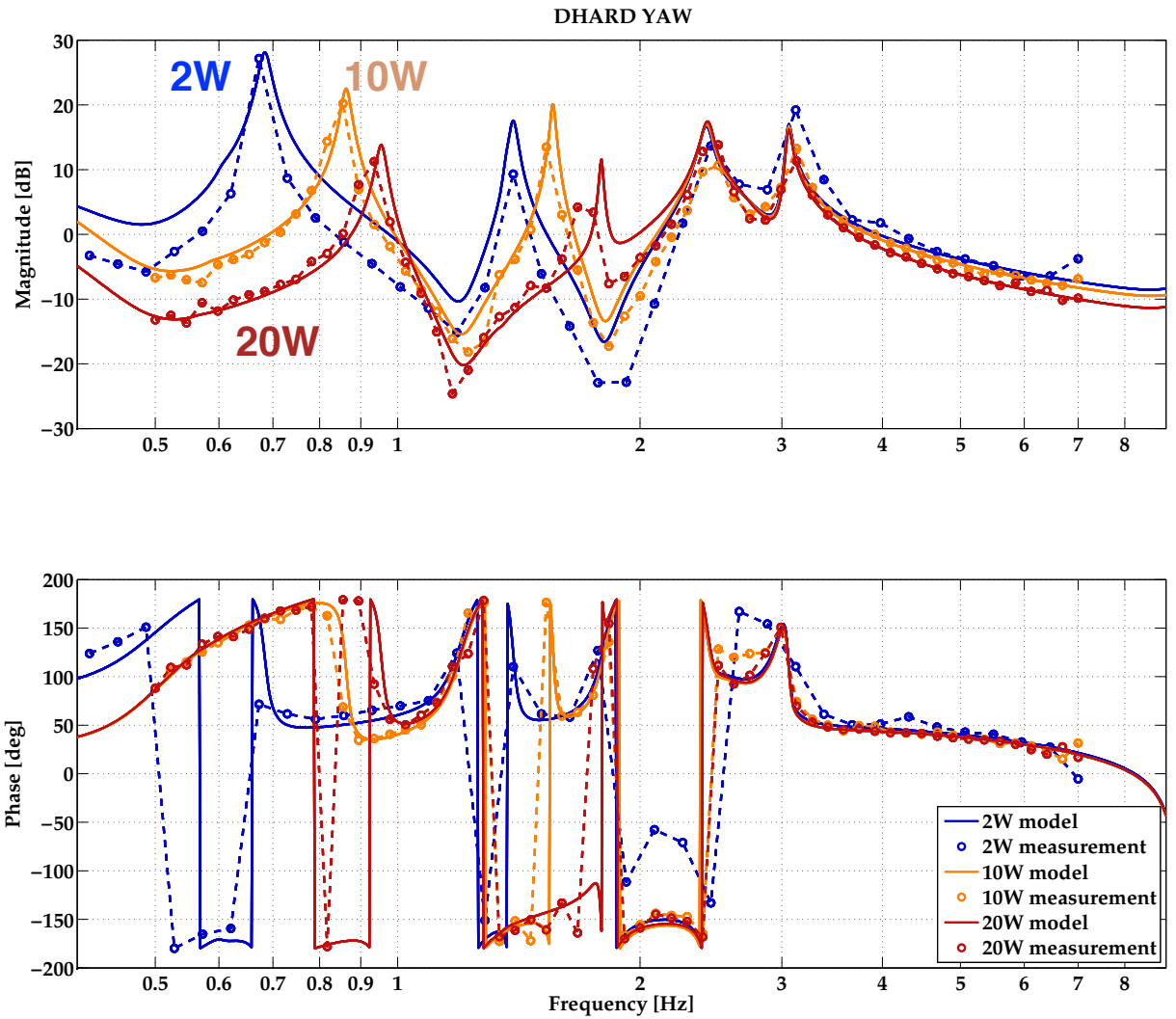


- Radiation pressure links two test masses (mirrors)
- The mechanical response gets modified.
- This complicates the control loop designs.

Diagram: J.A.Sidles and D.Sigg, Phys. Letters A, 354,3,167 (2006)

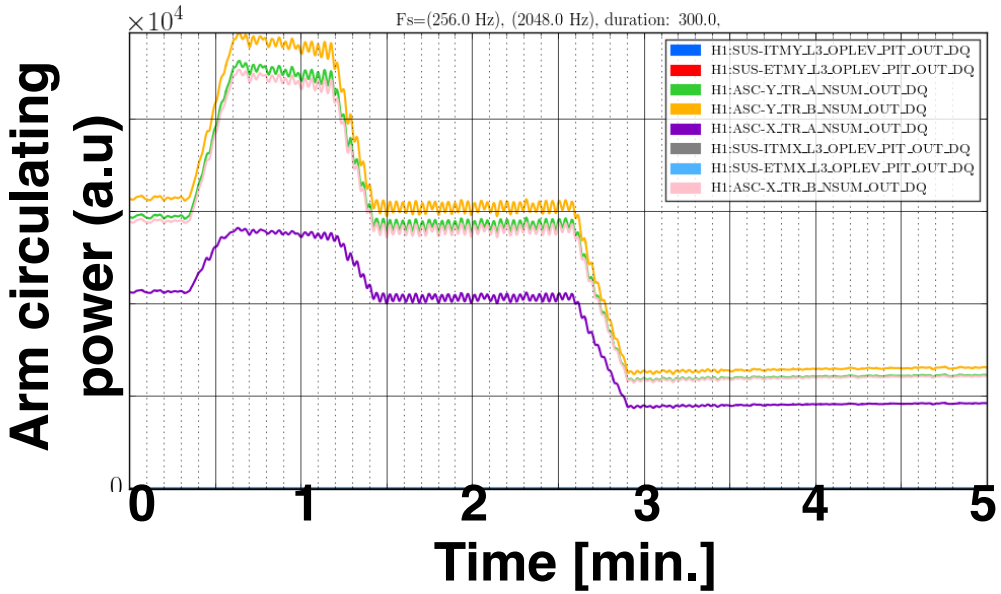
Alignment control

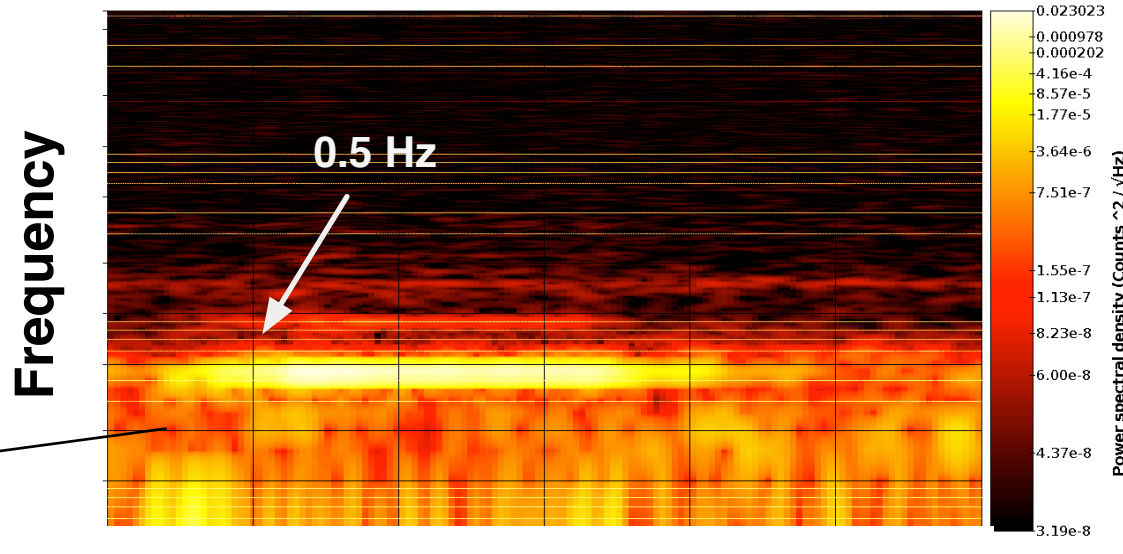
- The opto-mechanical response changes as a function of laser power => more control designs to do



A rad. press. instability

- Hanford has seen an instability driven by radiation pressure.
- The instability caused lockless many times.
- Being addressed by a new arm power stabilization control.





Spectrogram of angle of a test mass (ITMY)

LIGO time line

- Engineering run (ER9)
  Jul.6-8 (Hanford only)
- Engineering run (ER10) in this summer
- 2nd observing run (O2) starting
  sometime in this year for 6 months

Highly depend on the commission progress.

Summary

- Virgo and KAGRA making progress in their installation/commissioning.
- Virgo's goal is to be online during O2.
- The low frequency noise remains unidentified in LIGO.
- Various technical issues with high power slowing the commissioning in LIGO.
- LIGO's 2nd observing run (O2) nominally starts in this year.