Future Challenges: Interferometric sensing for the AEI-10m

Leibniz Universität Hannover

LSC LIGO Scientific Collaboration

quest Centre for Quantum Engineering and Space-Time Research

IGR

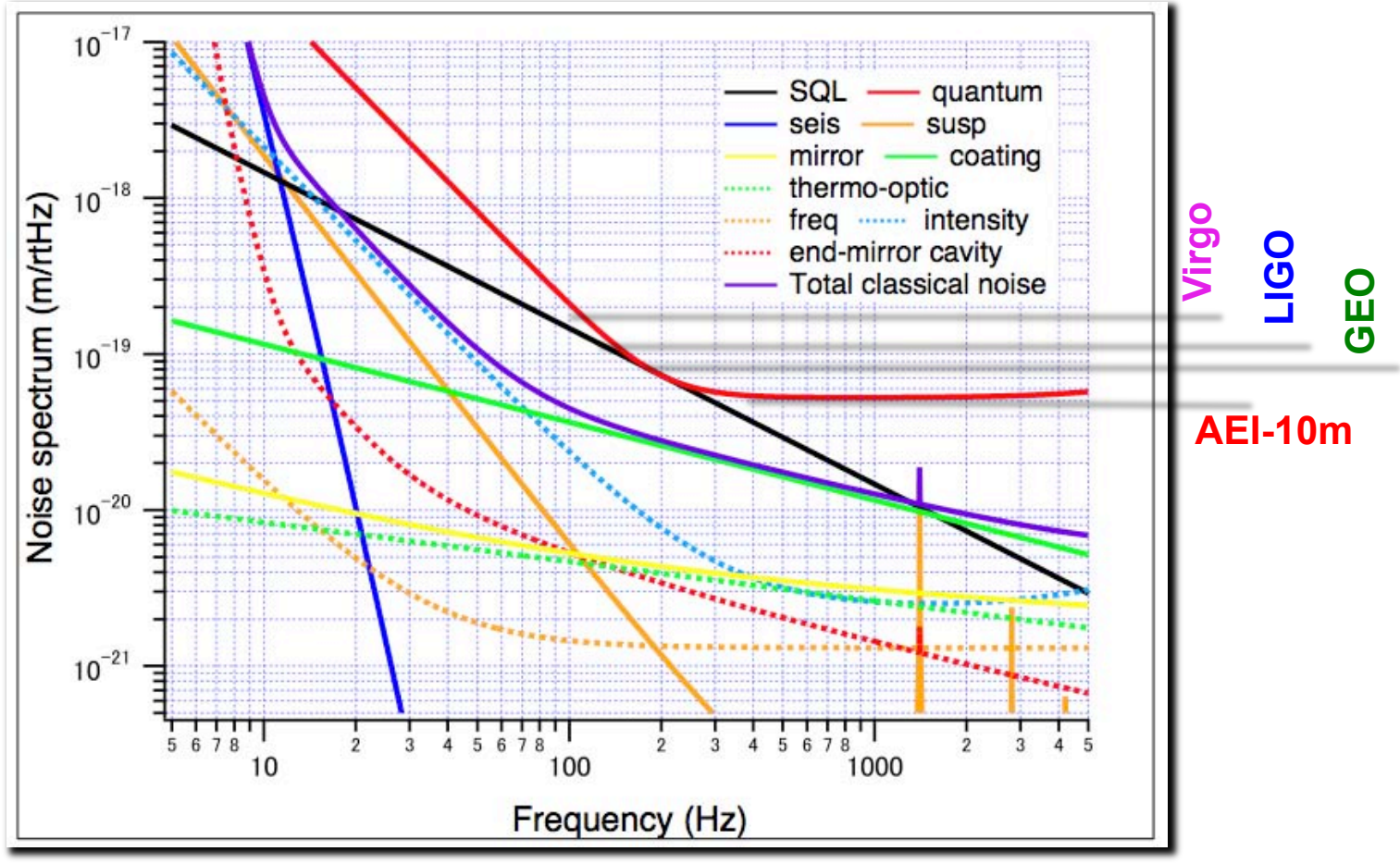
University of Glasgow

AEI-10m: **ONE BIG CHALLENGE**

- Nearly everything in the AEI-10m will be challenging!
- In these slides I will concentrate on topics within the traditional definition of "interferometric sensing and control".
- I will only give examples from the main sub-SQL interferometer. Of course there are many many challenges connected to other parts, like the **suspension platform interferometer** or the **10m reference cavity** (see Fumiko's presentation).
- Also I only give examples and my list of challenges is far from being complete. Please take the examples just as a snapshot of the whole spectrum of challenges we will have to face …

Challenge 1: overall sensitivity

- Already the first step of the AEI-10m aims for quite high sensitivity.
- Displacement better than ALL existing GWDs.

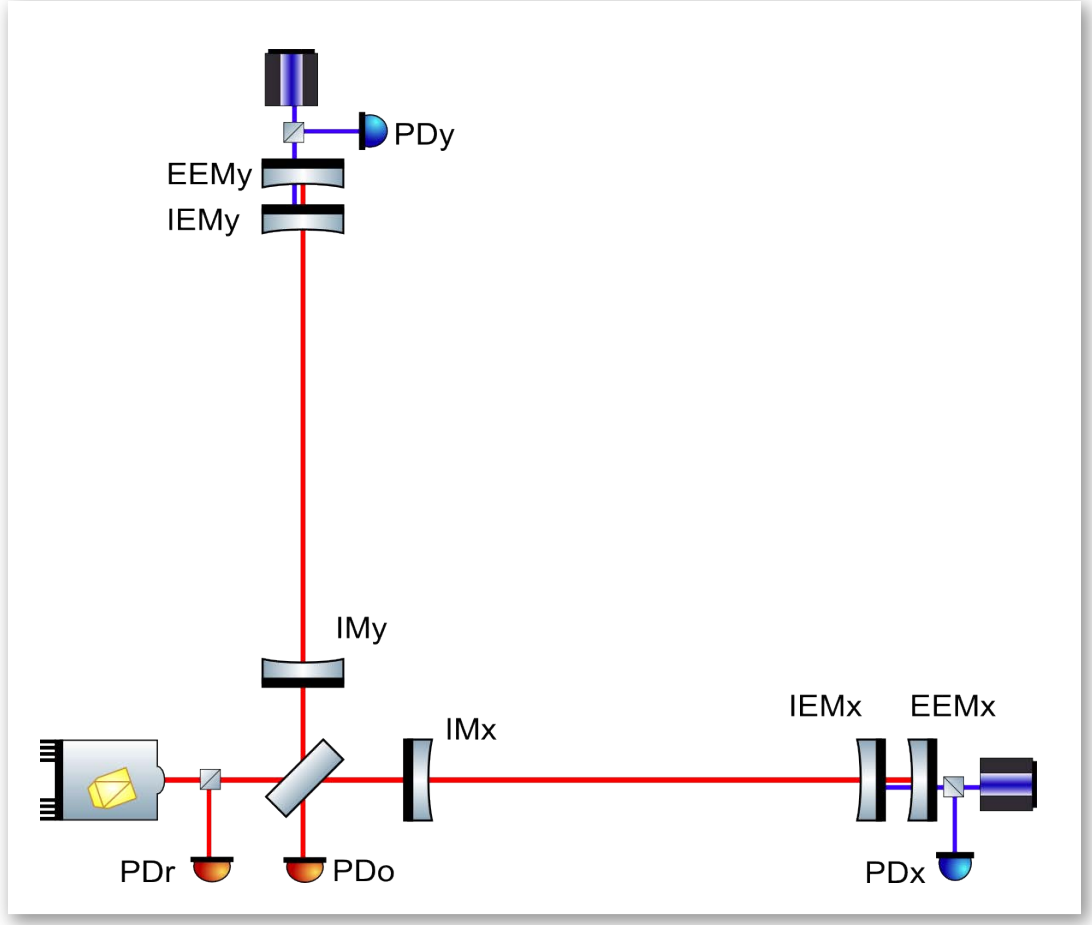


Length and alignment control

- The **AEI-10m** will have **5 coupled length degrees of freedom** in the main interferometer. (Just for comparison in GEO we have 3, in LIGO and Virgo its 4.)
- We probably also need to have fast **alignment control** for all of these degrees !!
- We need to develop proper noise and loop models. Experience from advanced detectors show:
  - It is not always easy to actually reach the desired sensitivity!
  - For simulations we probably have to use **OPTICKLE+LOOPTICKLE** (or something similar) in order to include radiation pressure as well as 'in-loop-effects'.
- I guess in the end we also need to **subtraction techniques** (e.g. like alpha beta and gamma in Virgo) to subtract MICH from DARM etc ??

Khalili-cavities

- The baseline design for the Sub-SQL-ifo features Khalili cavities at the end mirrors.
- Need to find a way to control these cavities (length & angular). Close to flat-flat cavity.
- Probably we are going for a trade-off of:
  - Locking from the back with separate lasers.
  - Locking with an additional RF modulation (resoant in arm cavities?) from the front.



Readout options

- **DC-readout ??**
- Probably the easiest to start with?
- Likely to need an OMC?

Again we need to do a trade-off and decide on a readout configuration to start with.

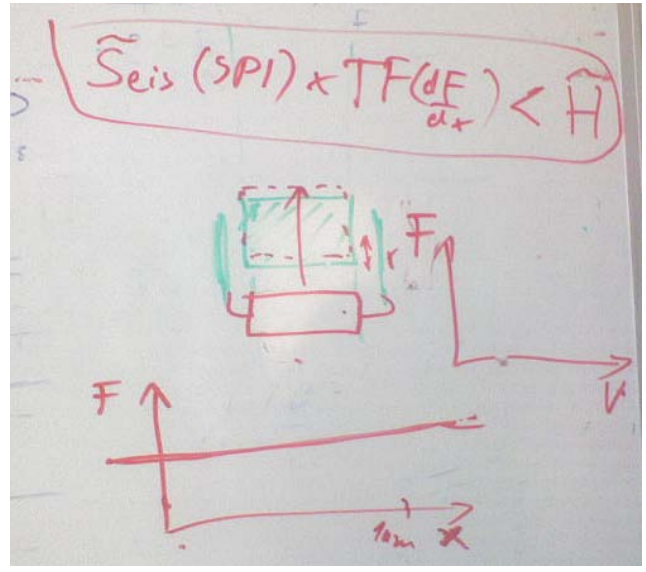
- **Variational readout / balanced homodyne ?**
- One more degree of freedom to control.
- Probably not the thing to start with, but definitely one of the easier methods to beat the SQL
- Probably also needs an OMC?

Optical layout

- Many details of the optical layout depend on the interferometric sensing and control scheme !!
- As we need to make hardware decisions (e.g. dimensions of BS, wedges in the input mirrors?) we need to hurry to define sensing and control scheme:
  - Need to decide which control ports are required?
  - Can we tolerate free running input mirror etalons? Can we control input mirror etalons?
  - Can we separate the main beam from the beam originating from the beam splitter anit-reflex coating?
  - How do we do the mode matching into the arms? Astigmatism limit? Beam jitter requirements.
- PLENTY TO DO !!

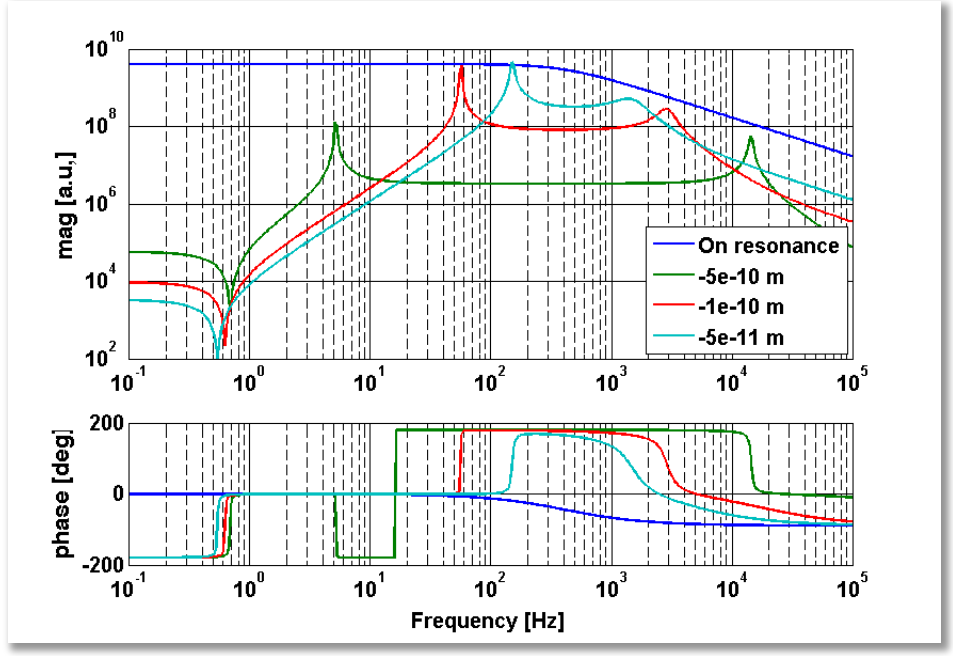
Actuators

- We need to define **required actuator ranges** in order to design them.
- For the mirror stage actuators we have a new problem**: beam size = mirror size. So now space for actuators!** We need to invent something …
- One interesting idea currently under investigation: **Use two ESD plates next to the mirror** (parallel to beam). The goal is to achieve a configuration in which the force onto the mirror just depends on the ESD voltage, but (to first order) not on the relative position of the ESD and mirror. Then ESD could be bolted directly onto the suspended tables ….



Lock-acquisition

- It seems to be likely many loops will need to have separate high-bandwidth (acquisition) and low-noise (running) stages.
- Though we won't have **optical springs** at the operation point, during lock-acquisition they will give us plenty of trouble !!
- Probably need to do lock-acquisition **simulations using time-domain methods** including radiation pressure dynamics!



Future^2

If you would like more challenges just have a look at what we write on the AEI-10m webpage…

☺