Strahlungsdruckeffekte in Interferometern mit aufgehängten Optiken

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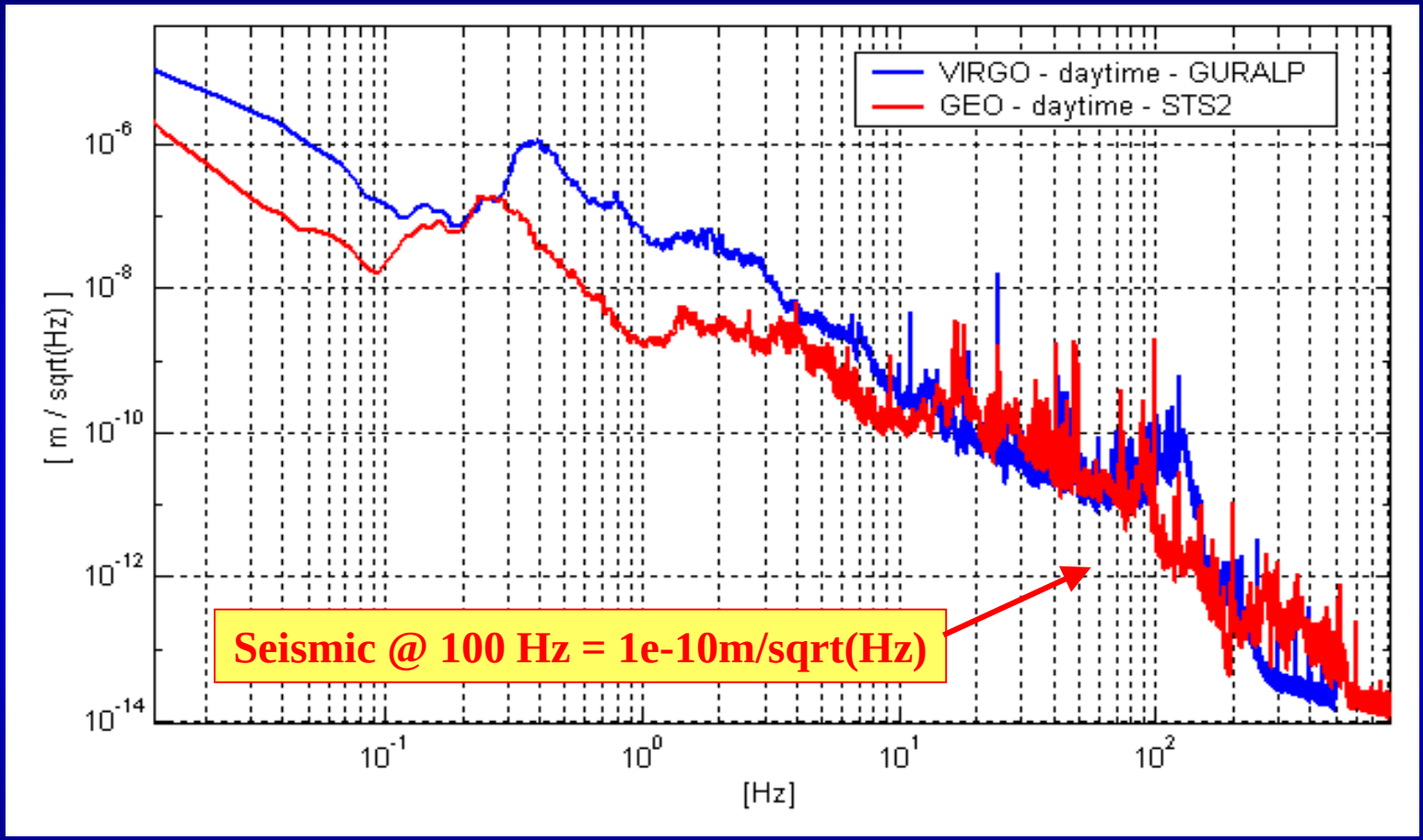
Overview

- Questions: Why suspended optics? Why high light powers?
- Examples for **problems** caused by radiation pressure effects
- Examples from **useful applications** of radiation pressure effects

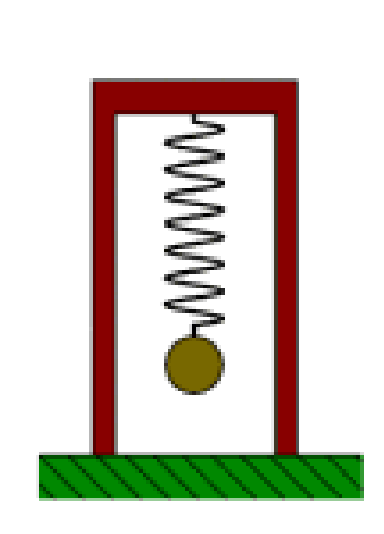
Why suspended optics?



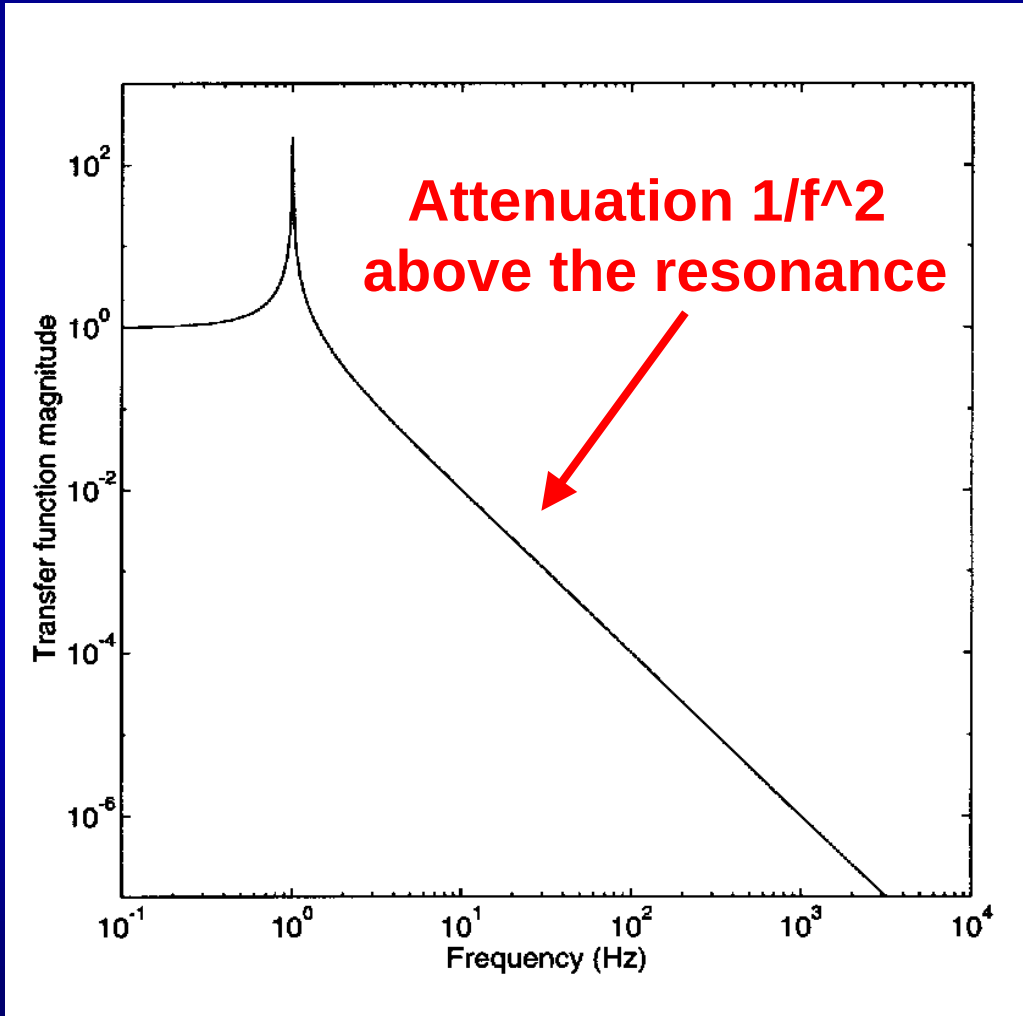
- **Ground moves about 1e-11m (at 100 Hz)**
- **We want to measure 1e-19m (at 100 Hz)**

⇒ required suppression = 8 orders of magnitude !!

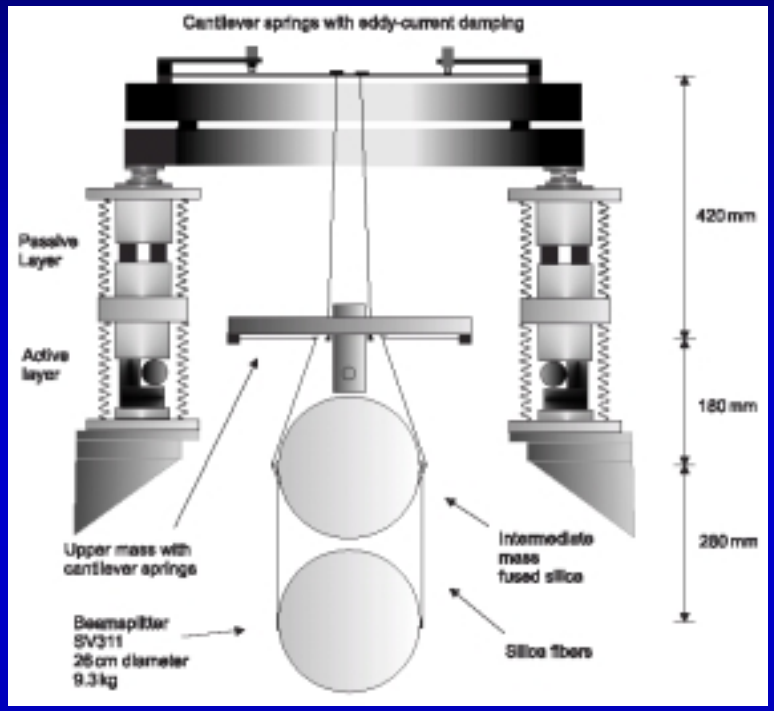
Transfer function of a single pendulum

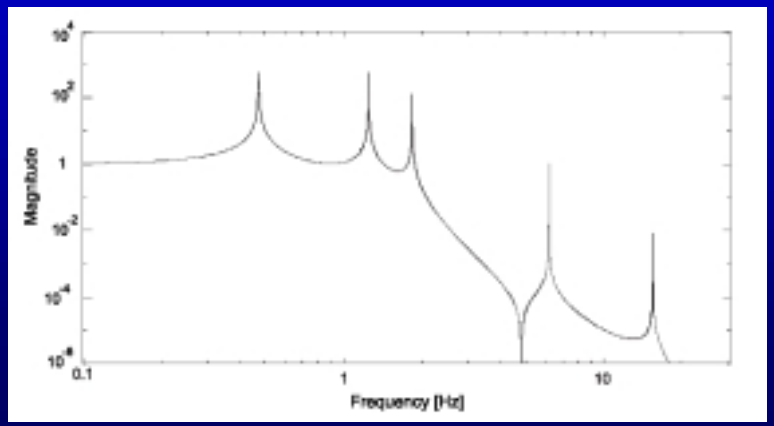


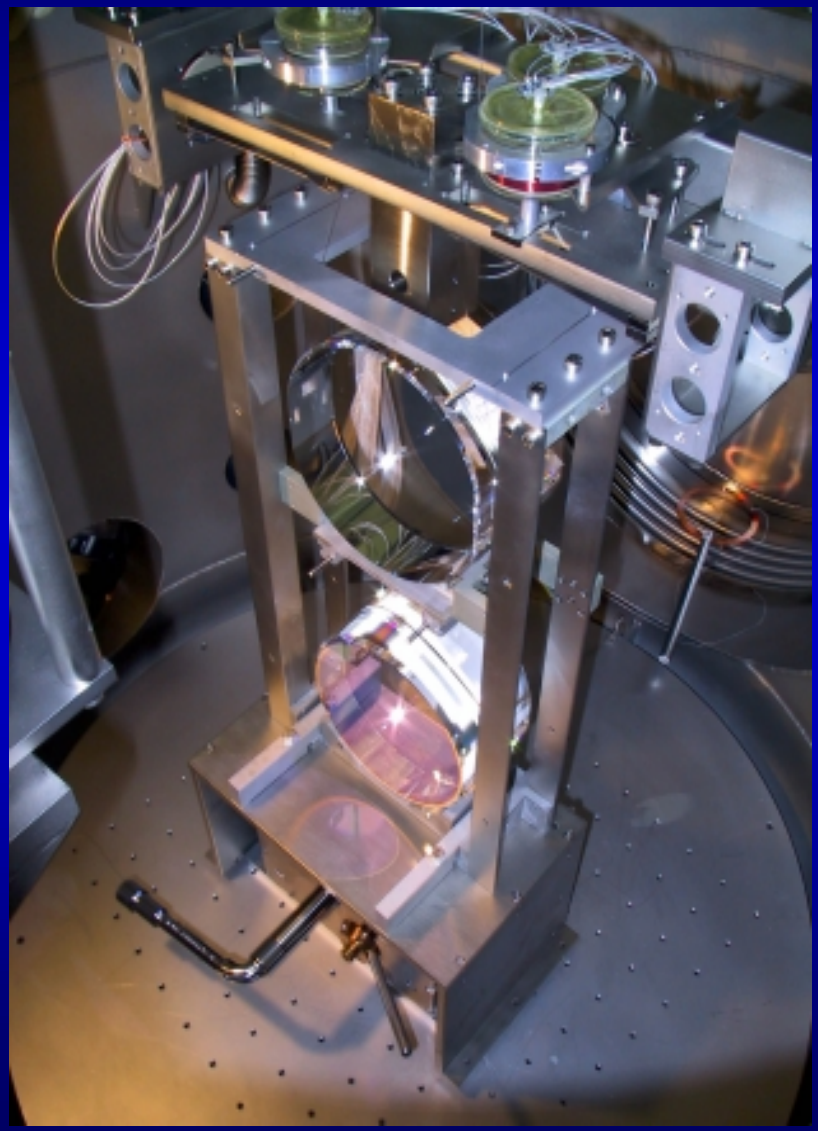
Decouple optics from seismic by suspending



A GEO600 triple suspension







Why high light powers?

- We use an optical readout (Photodiode)
- The time between two photons reaching the photodiode is not constant (Shotnoise)

$$N_{shot} \propto \sqrt{P_{opt}}$$

$$Signal_{GW} \propto P_{opt}$$

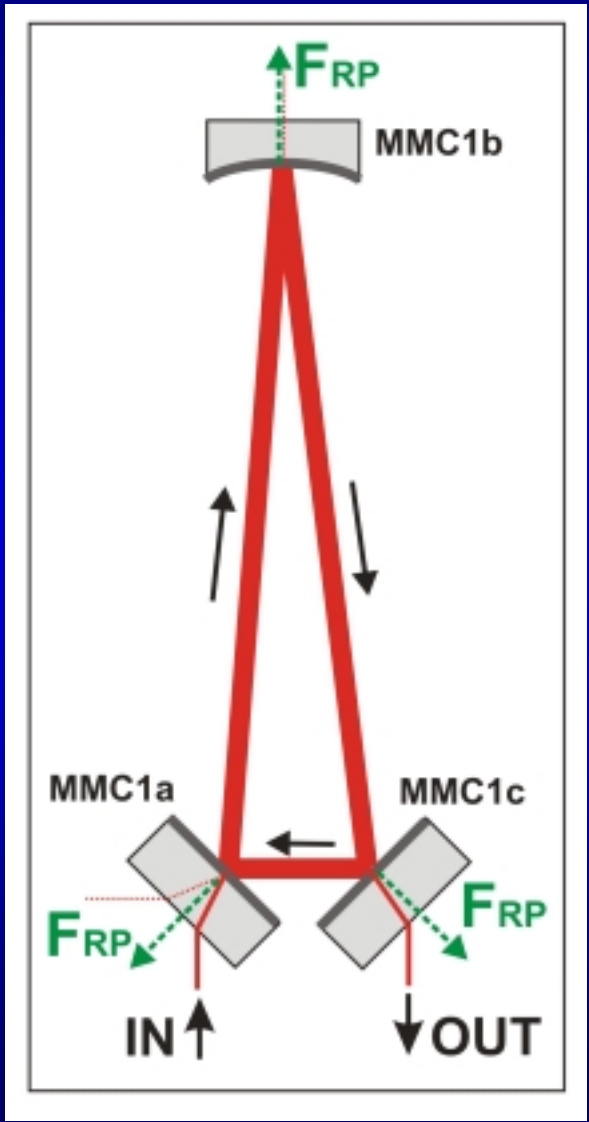
$$SNR_{GW} \propto \sqrt{P_{opt}}$$

Optical power helps !

Radition pressure effects onto MC1

- Suspended ring cavity of about 8m round-trip length
- intracavity power = 6kW (10 kW)
- low weight mirrors = 0.86 kg
- Force F_{RP} = 35 uN (60 uN) per mirror
- total lenght change during power buildup caused by radiation pressure = **5.2 um (8.5 um)**

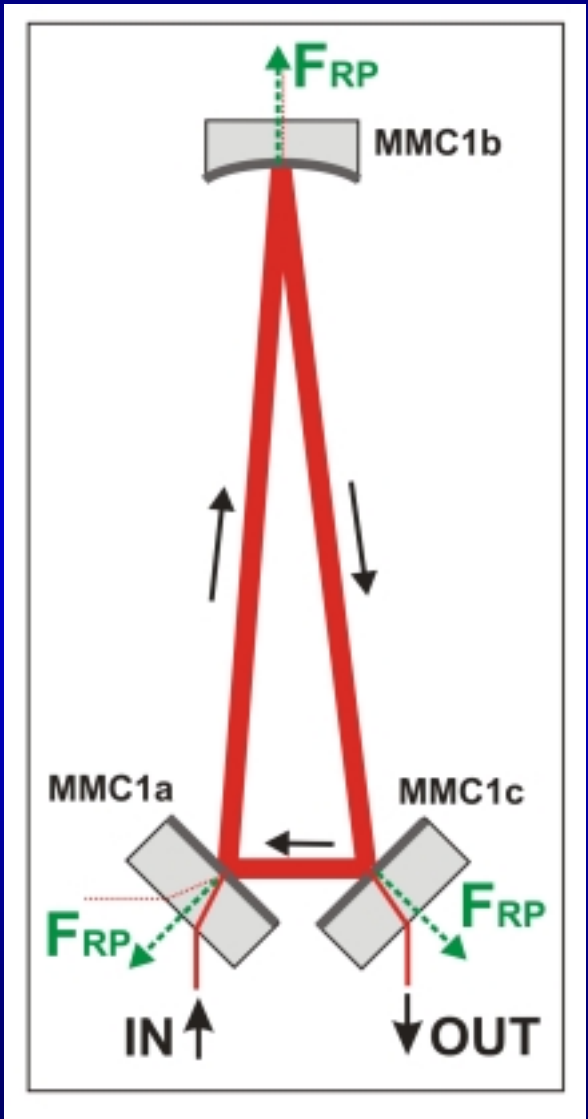
Macroscopic effect !



Radition pressure effects onto MC1

Problem:
Saturation of the limited actuator range prevents lock acquisition.

Solution:
Apply a bias force to the mirrors for acquisition and reduce this force in lock corresponding to the power build-up.
(nearly zero force when cavity a operating point = low noise)



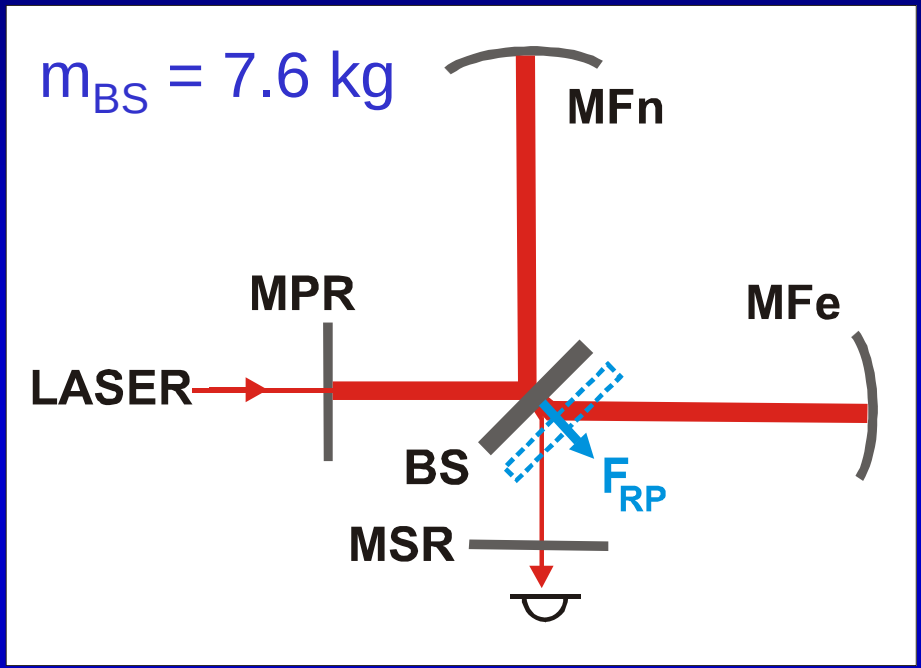
Radiation pressure on beamsplitter (BS)

Problem:
Power fluctuations in the power-recycling cavity at frequencies in the detection band.

⇒ Change of the radiation pressure ⇒ BS is shifted

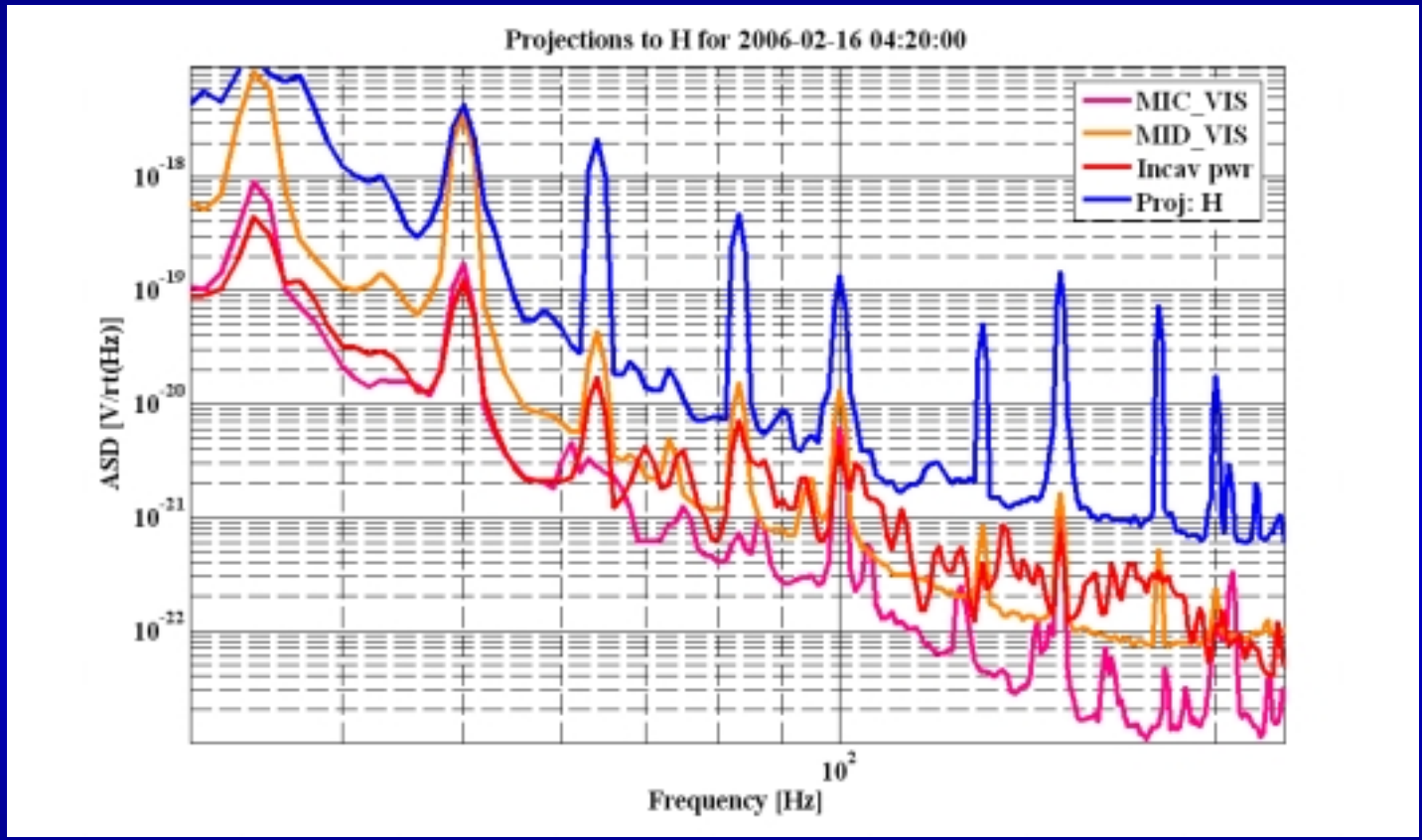
⇒ east arm gets shorter
⇒ north arm gets longer

⇒ Indistinguishable from gravitational wave.



$$\frac{\widetilde{\delta L}}{L} = \frac{\widetilde{P_0}}{m_{BS} c \ell \omega^2}$$

Radiation pressure on beamsplitter 2

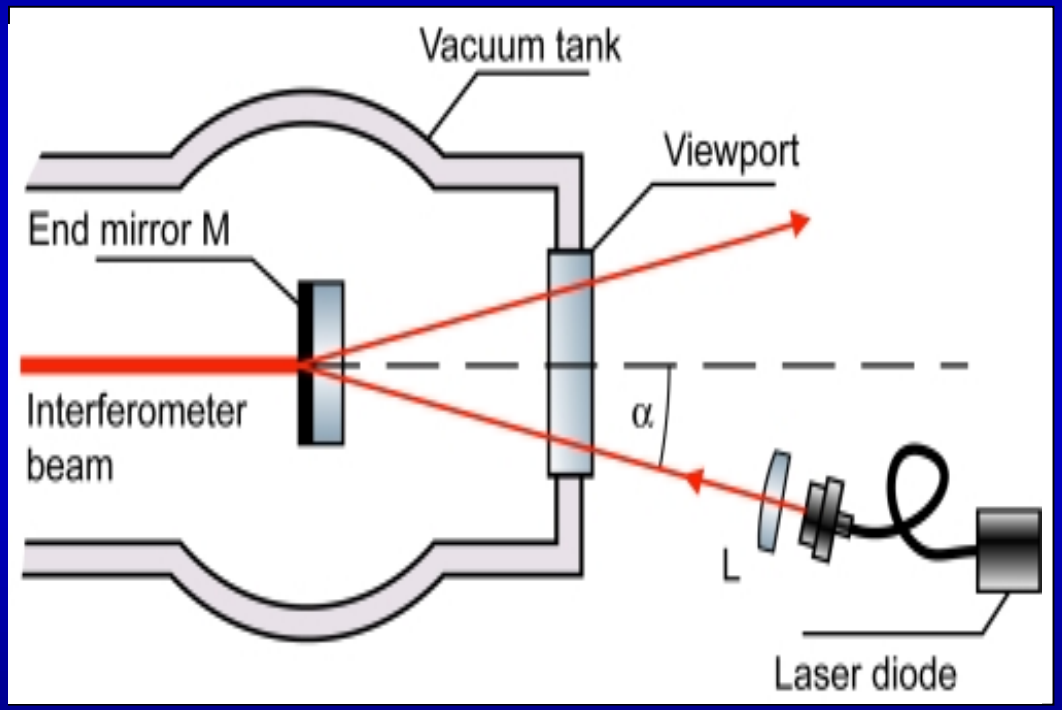


No problem at the moment due to active power stabilisation

Photon pressure calibrator

Using photon pressure effect to calibrate GEO600 sensitivity

(From Volts/sqrt(Hz) at photodiode to mirror displacement in meter/sqrt(Hz))

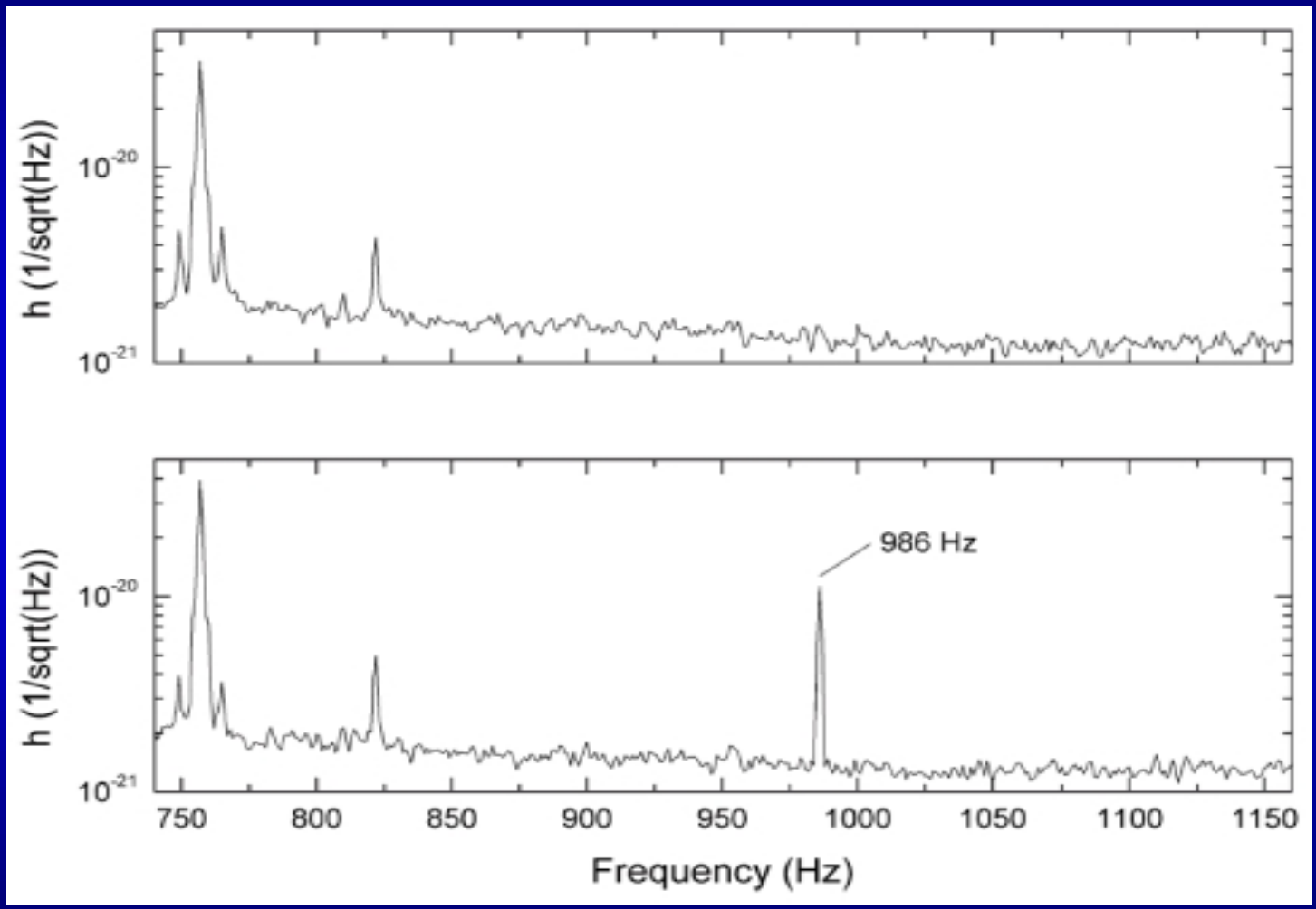


Wavelength: 1035 nm
Max. power: 1.4 W
Weight of mirror: 5.6 kg

A photon pressure drive can (in principle) very easily be calibrated using:

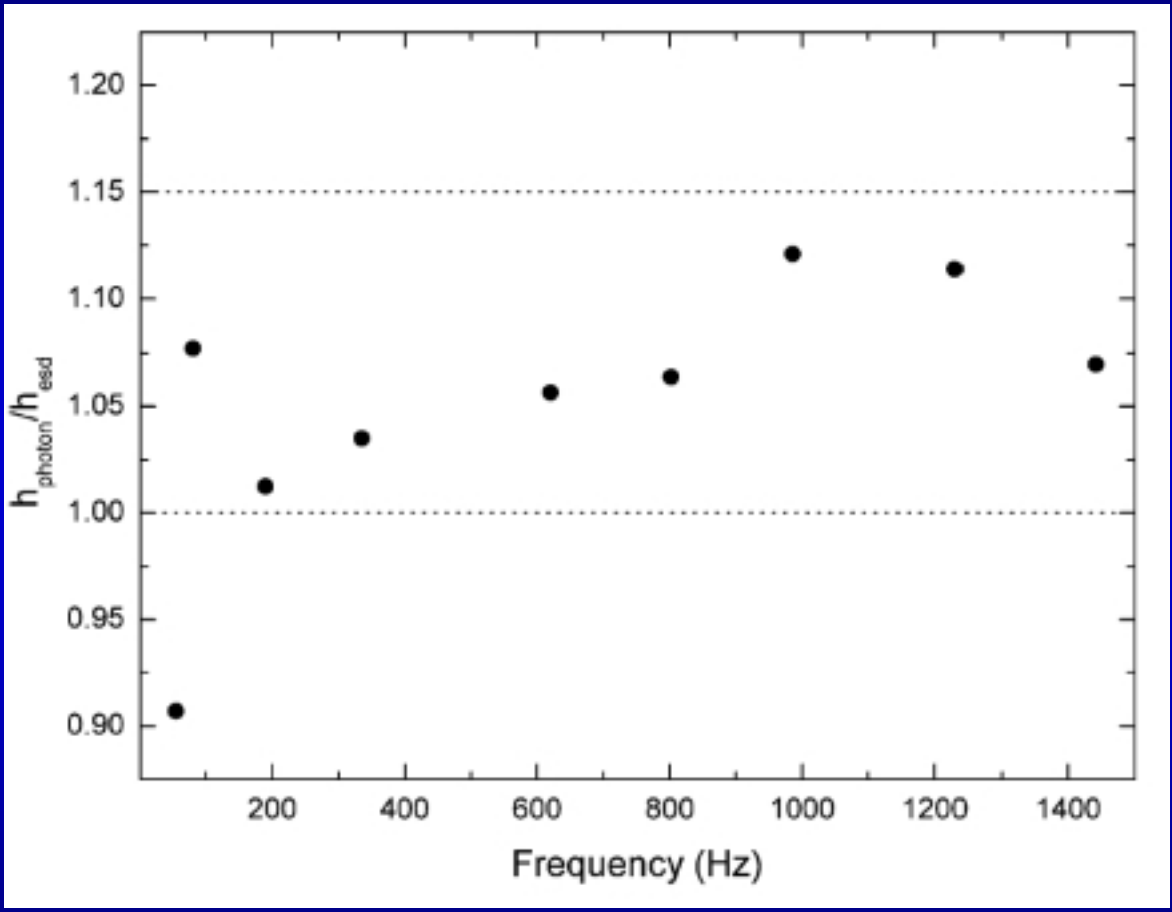
$$F = 2\,\frac{P}{c}$$

Injecting a photon pressure line



Can measure the effect of 1mW modulated light at f=100 Hz.

Independent check of GEO600 calibration



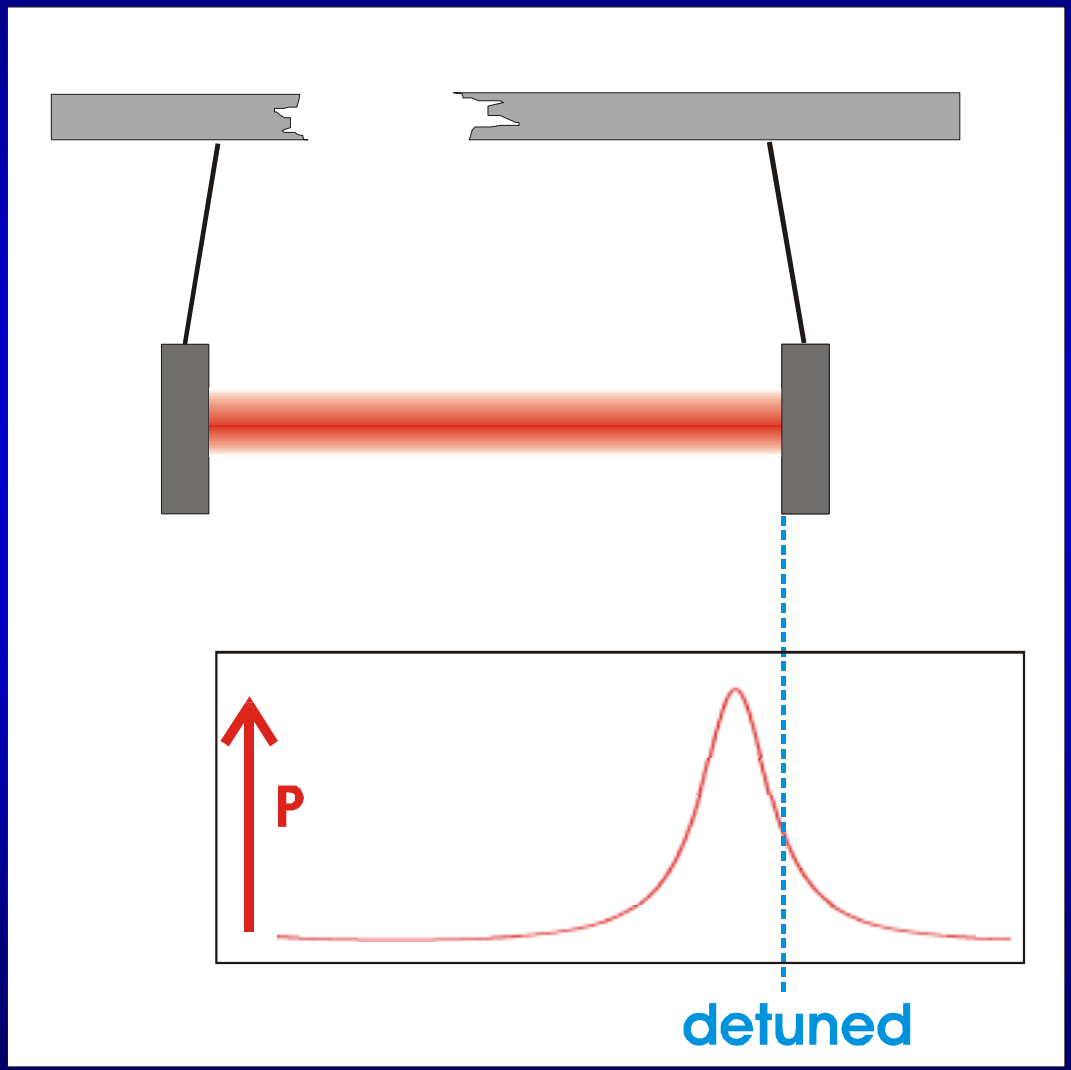
Good agreement of photon pressure calibration and the usually used calibration scheme based on electrostatic actuators.

Optical spring resonance

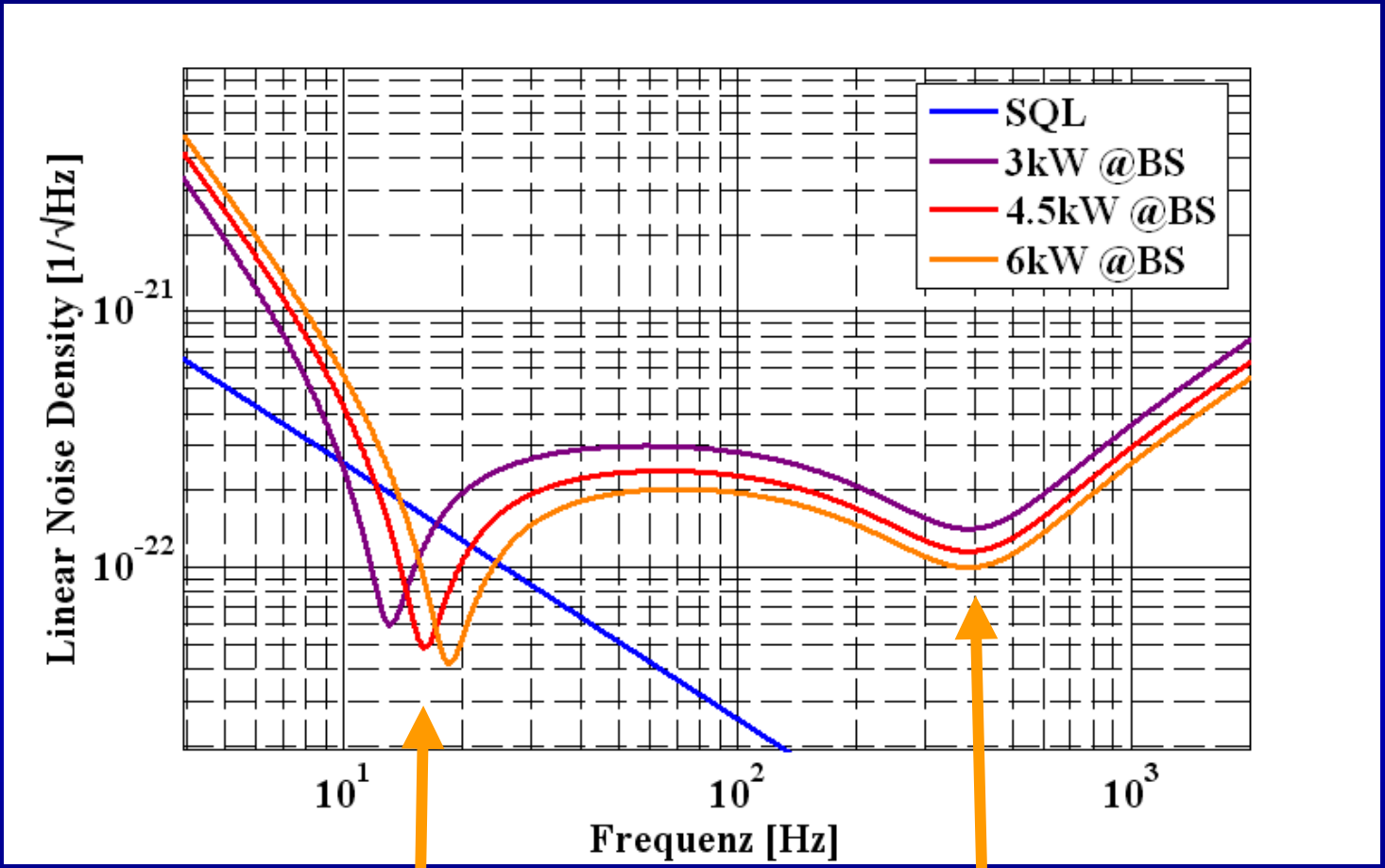
In a detuned suspended cavity the radiation pressure depends on the position of the mirror.

⇒ Opto-mechanical coupling.

⇒ Resonance frequency can be influenced by tuning and optical power.



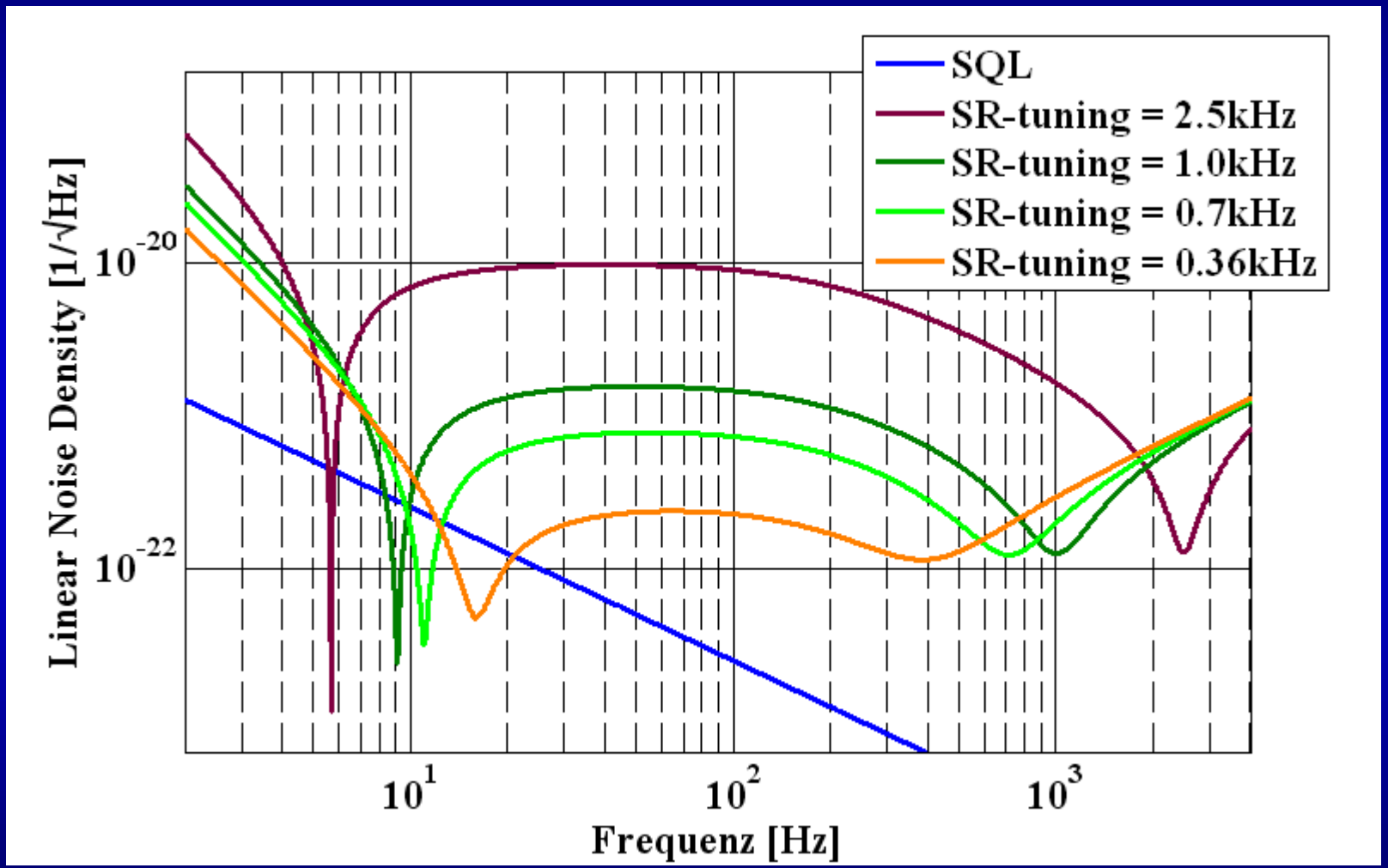
Optical spring in GEO for different powers



Opto-mechanical resonance

Optical resonance (Signal-recycling)

Optical spring in GEO for different tunings



So far we haven‘t been able to measure the effect.

Summary

- Radiation pressure is an import player in GEO600 !!

- Radiation pressure effects cause **problems** :
  - Macroscopic mirror movement
  - Displacement noise due to power fluctuations

- But we can also **profit** from radiation pressure effects:
  - Photon pressure calibrator
  - Opto-mechanical resonance (‘optical spring’)

End