Opto-mechanics with a 50 ng membrane

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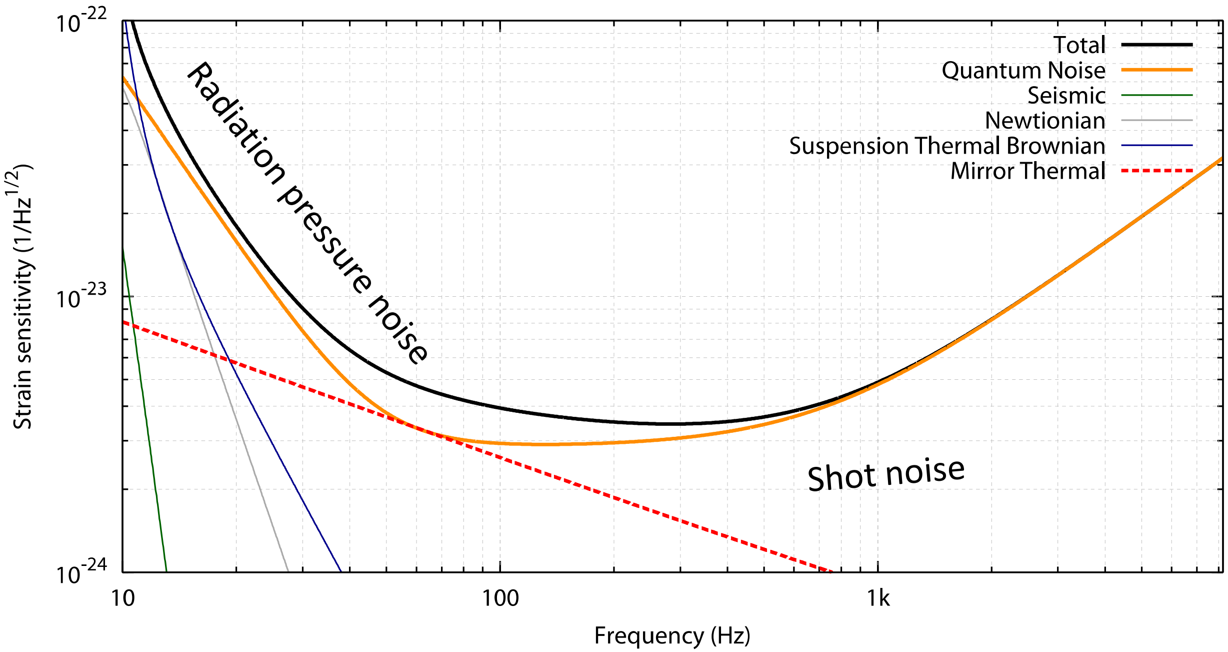
Radiation pressure noise

A limiting factor for low frequencies

Often referred to as back-action noise

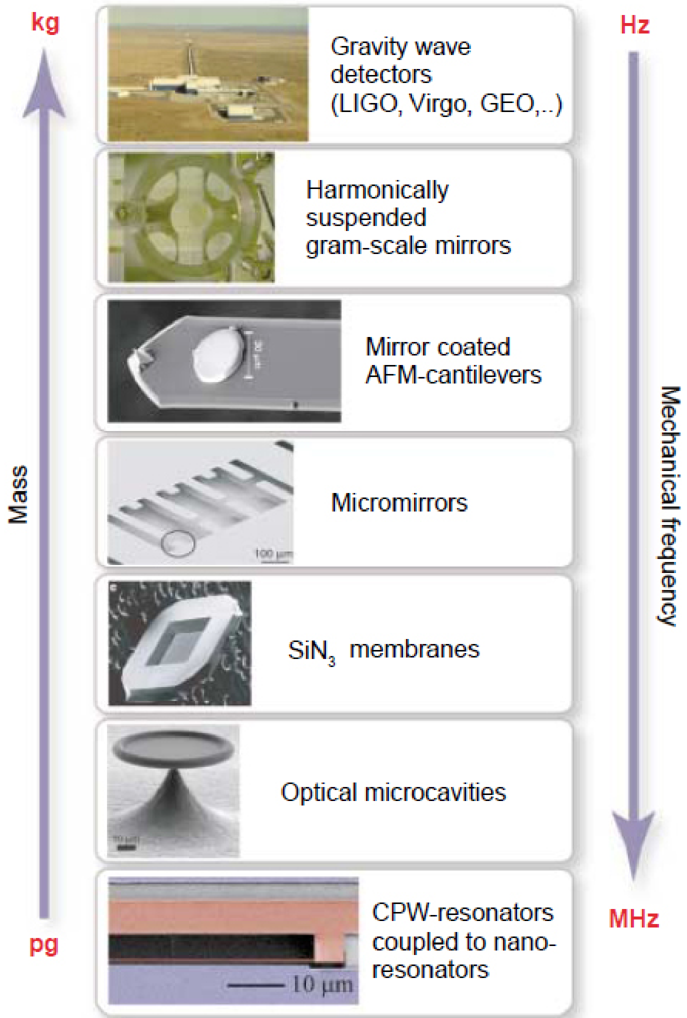
Next generation detectors will observe back-action noise

Is it observeable with tabletop experiments?



Advanced LIGO anticipated strain sensitivty

Opto-mechanics

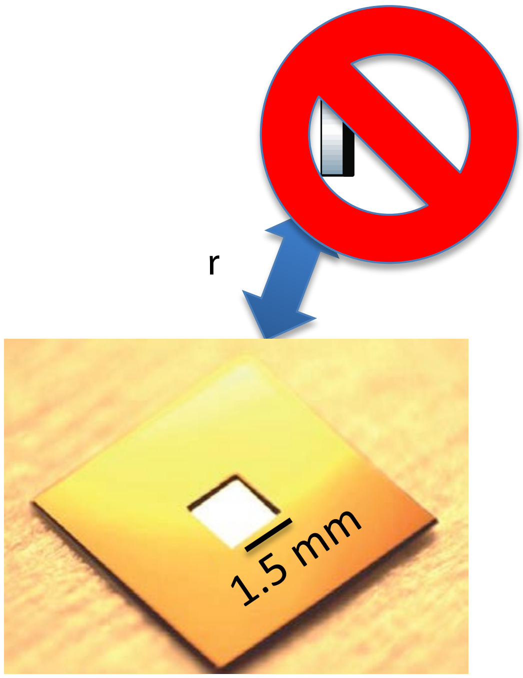


T.J. Kippenberg and K.J. Vahala, Science 321, 1172 (2008)

Transfer of photon momentum

$$F = \frac{2p}{c} \qquad p = \hbar k$$

Standard approach:
Build Cavity



40 nm thickness
m_{eff} = 80 ng
Q factor = 500.000
f_{res} = 100 kHz

R = 17 % @ 1064 nm

(refractive index + ethalon effect)

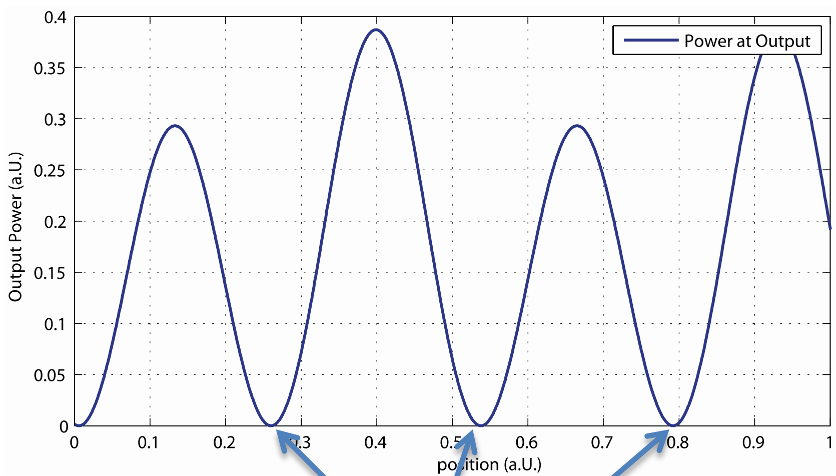
Michelson-Sagnac interferometer

%

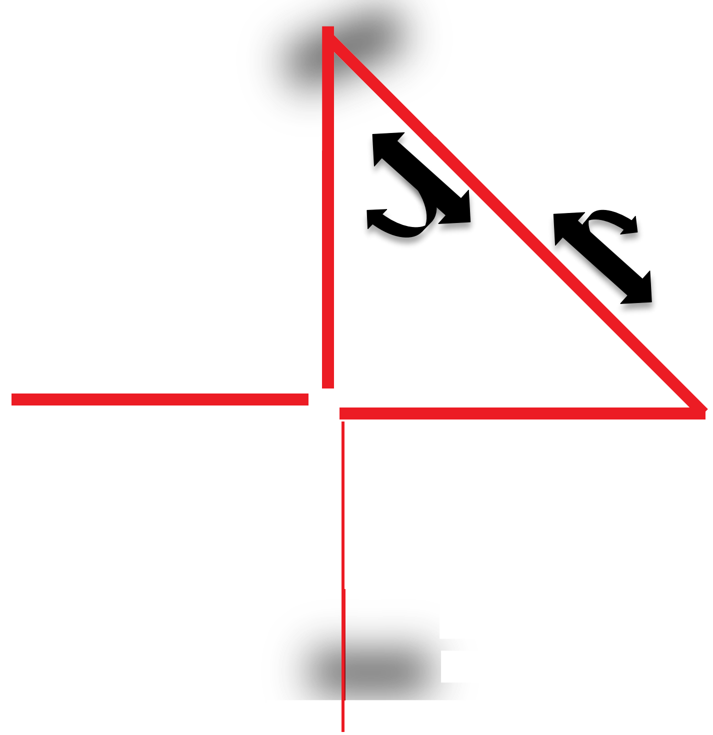
SIN membrane used as common end-mirror

Recycling mirror in interferometer output

No drawback from low power reflectivity



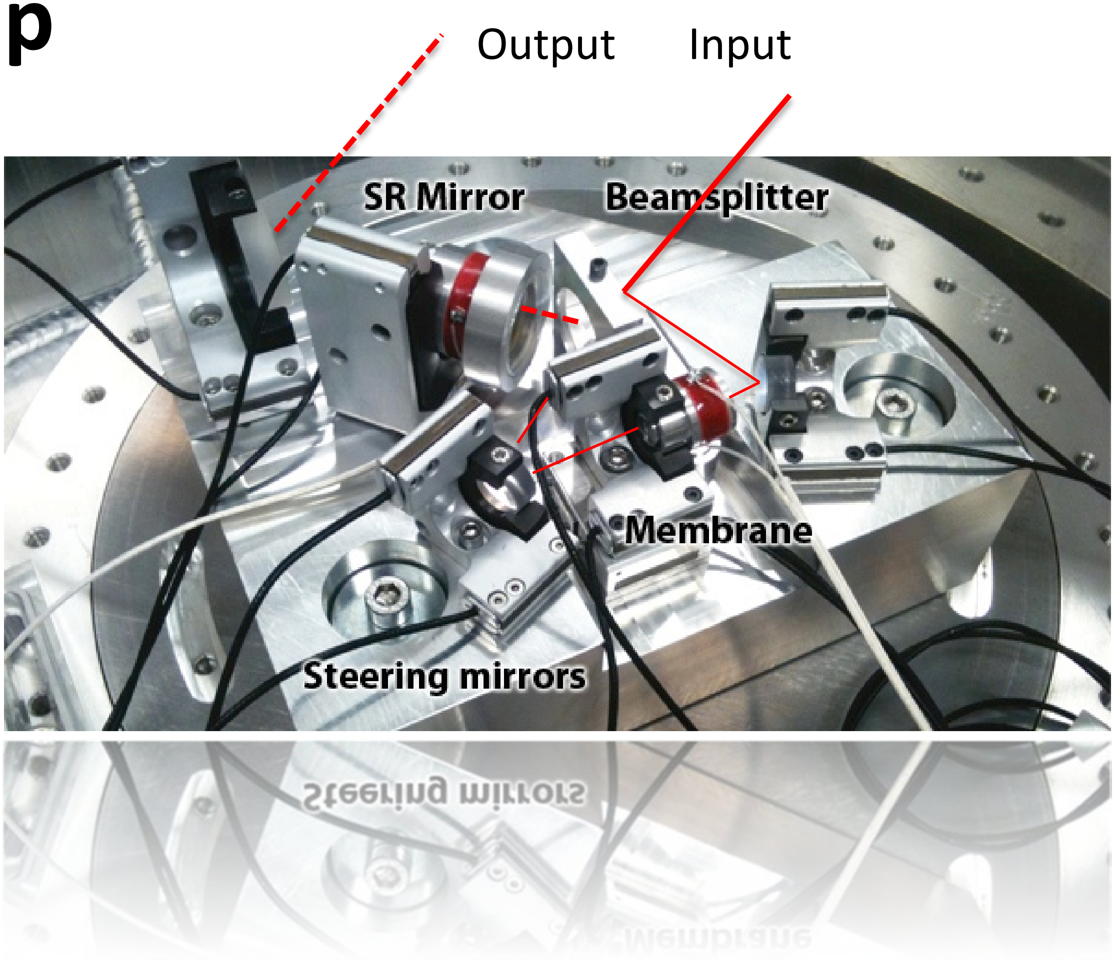
Laser noise rejection

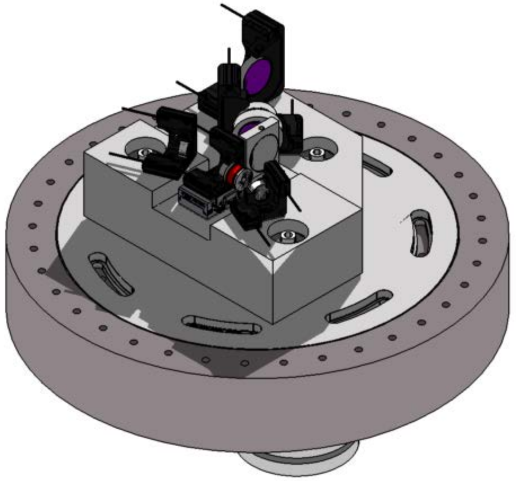


Experimental setup

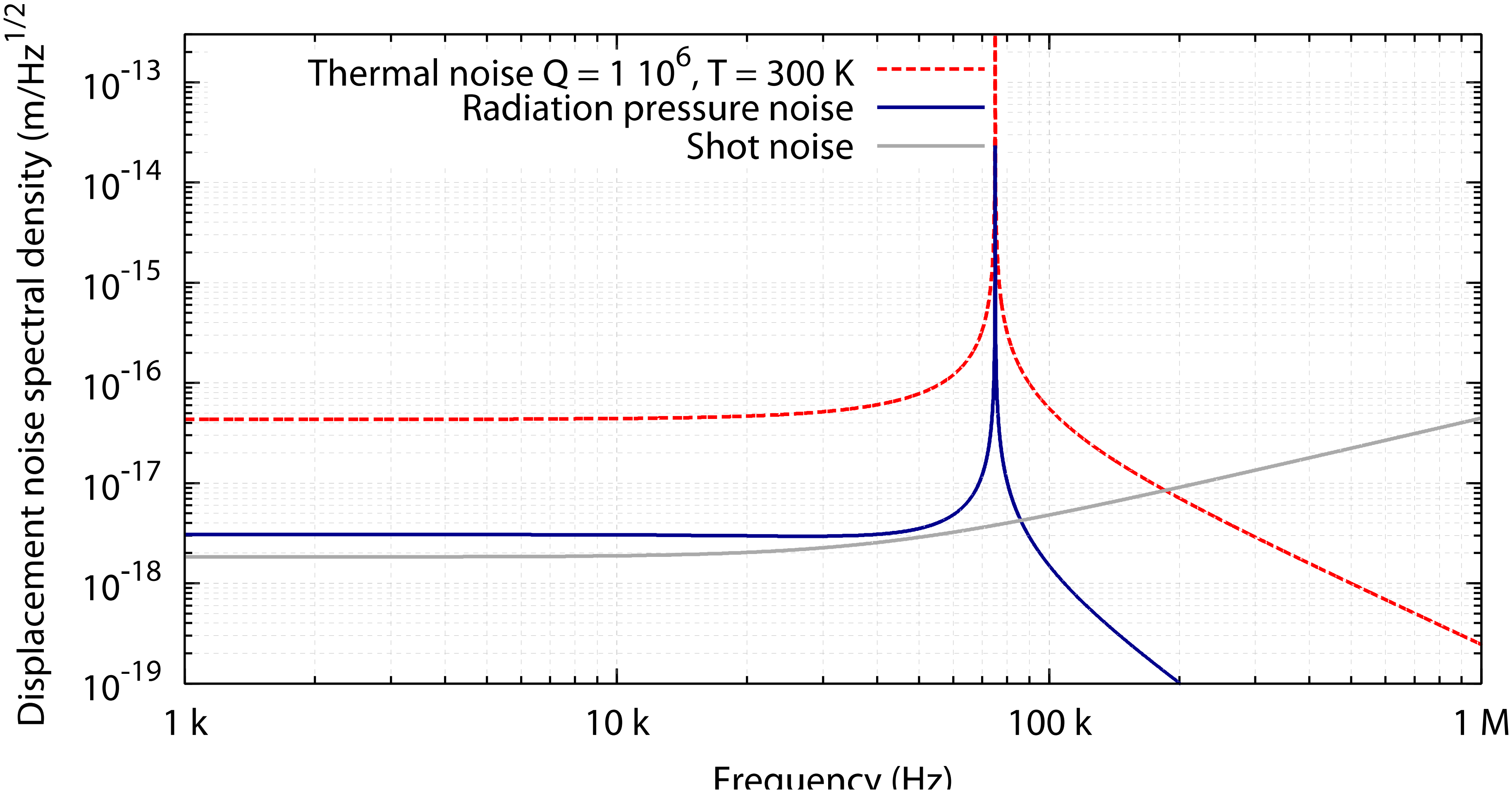
Setup features

- Arm length = 6 cm
- 0.5 " Optics and piezos
- Double seismic isolation
- Operated at 10^{-6} mbar
- Remote control for alignment



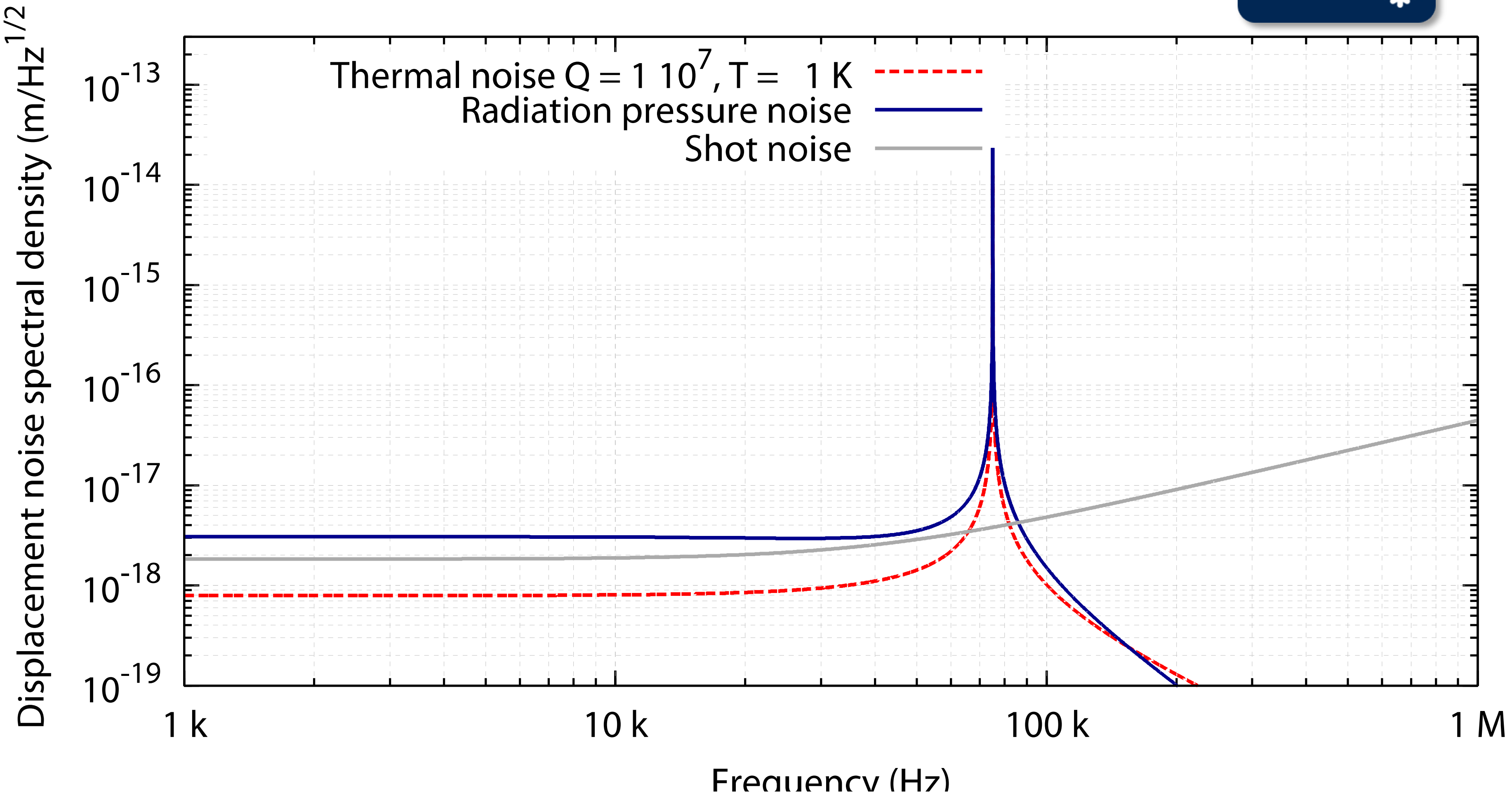


Currently limited by thermal noise



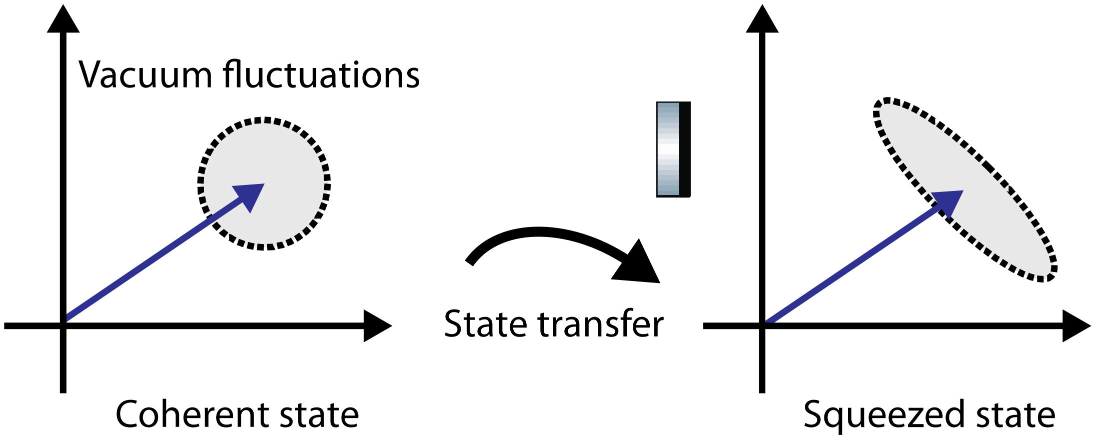
Quantum noise

Cryogenic cooling and signal recycling R_{sr} = 99,97 %



K. Yamamoto et al, Phys. Rev. A 81 , 033849 (2010)

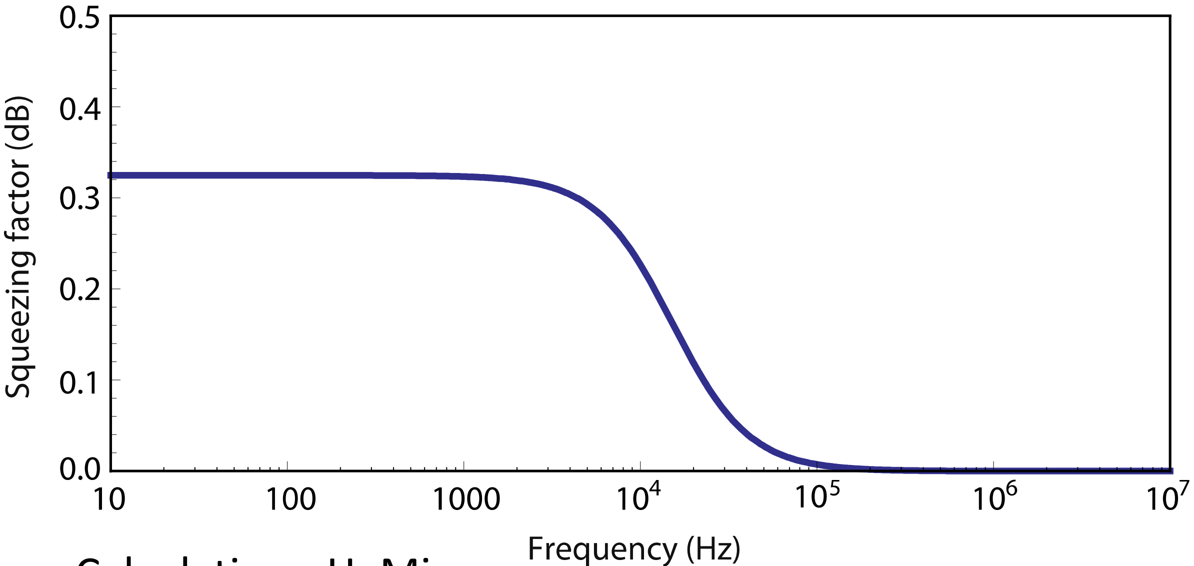
Ponderomotive squeezing



Amplitude <-> Phase fluctuation
Membrane acts as coupling device

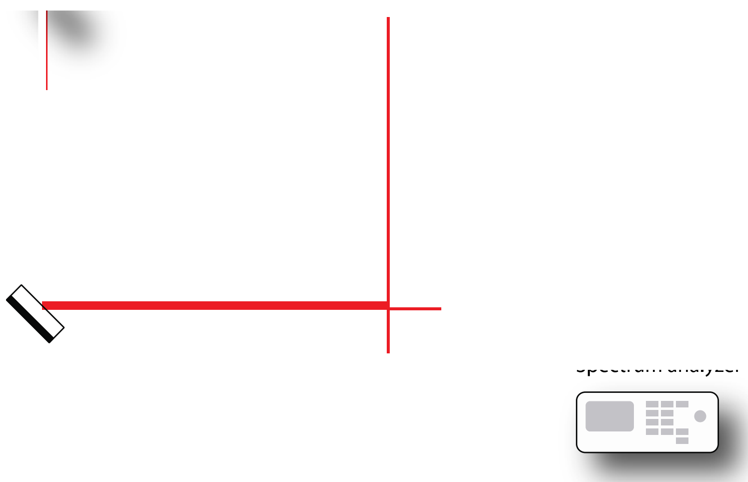
Requires homodyne readout
(Read out phase quadrature)

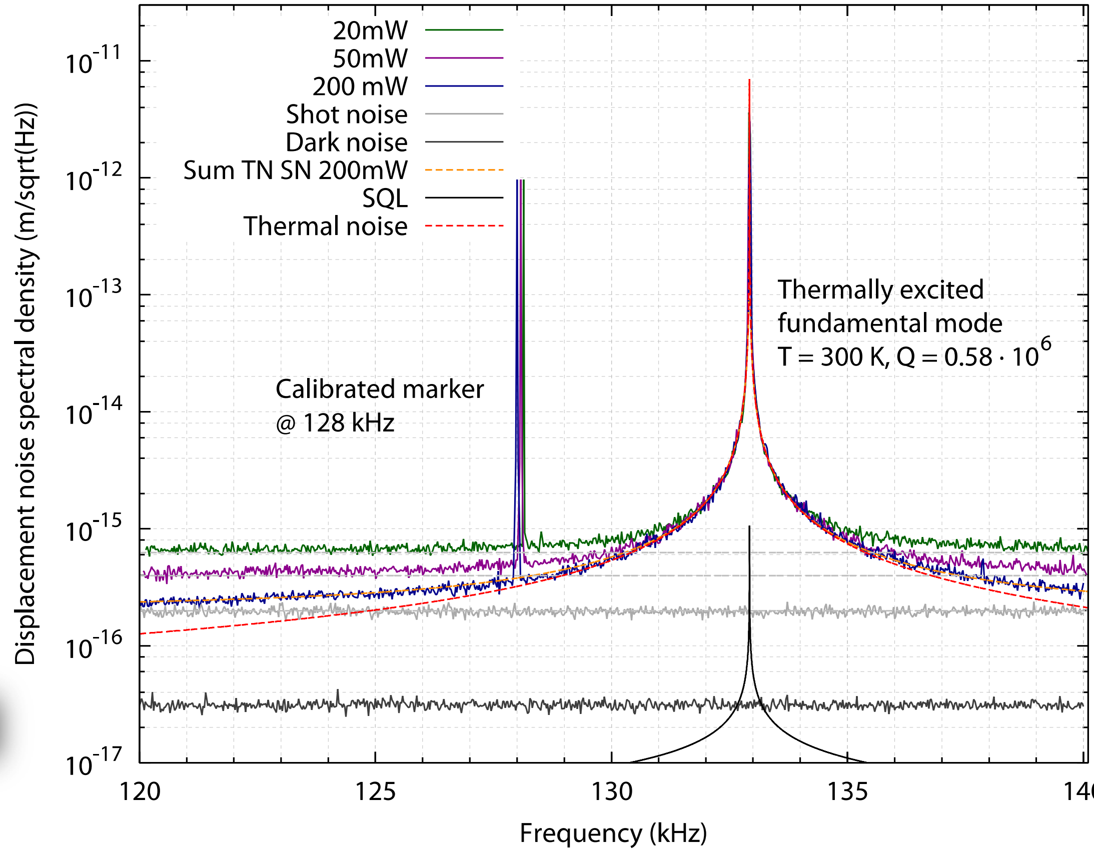
0.3 dB @ 500 mW input power



Calculation : H. Miao

Balanced homodyne read out (no recycling)



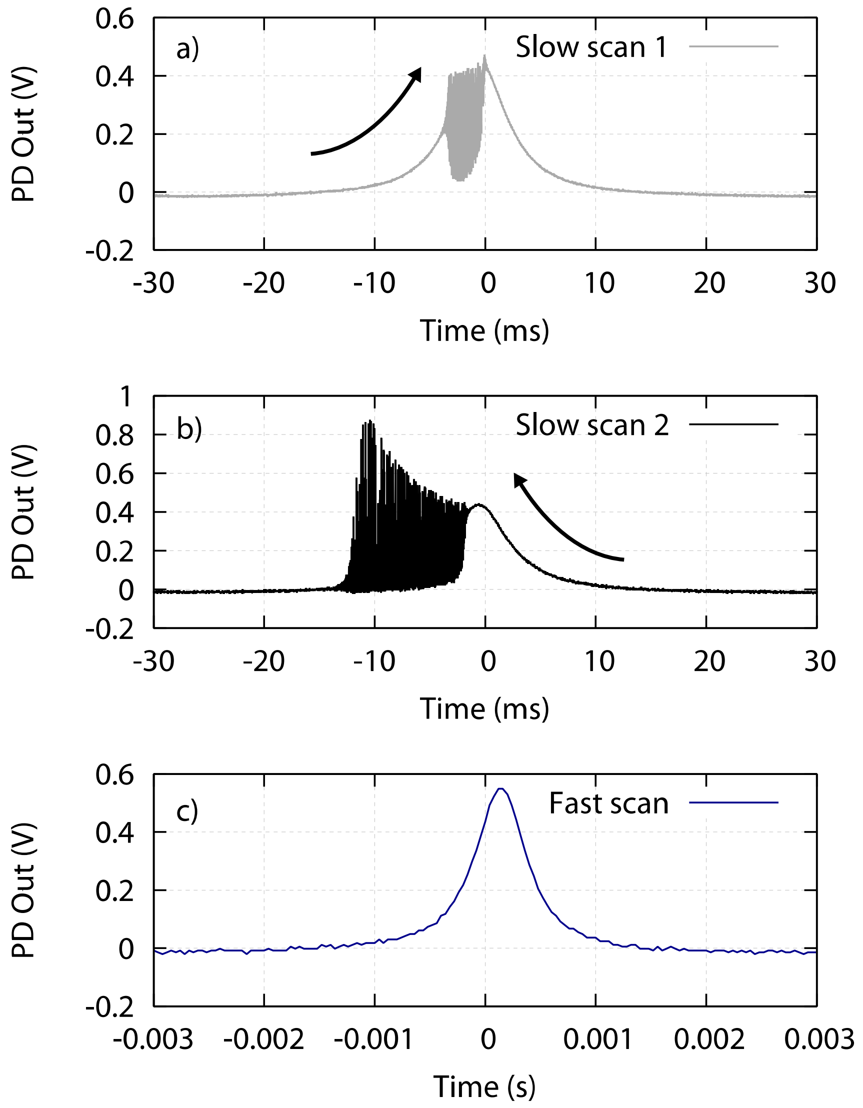


With recycling mirror : Induced oscillations

Cavity operated with R_{sr} = 99,97 %
Optical linewidth = 30 kHz

Stable and Anti-stable behavior

Induced parametric (de-) amplification of Membrane motion



Optical cooling

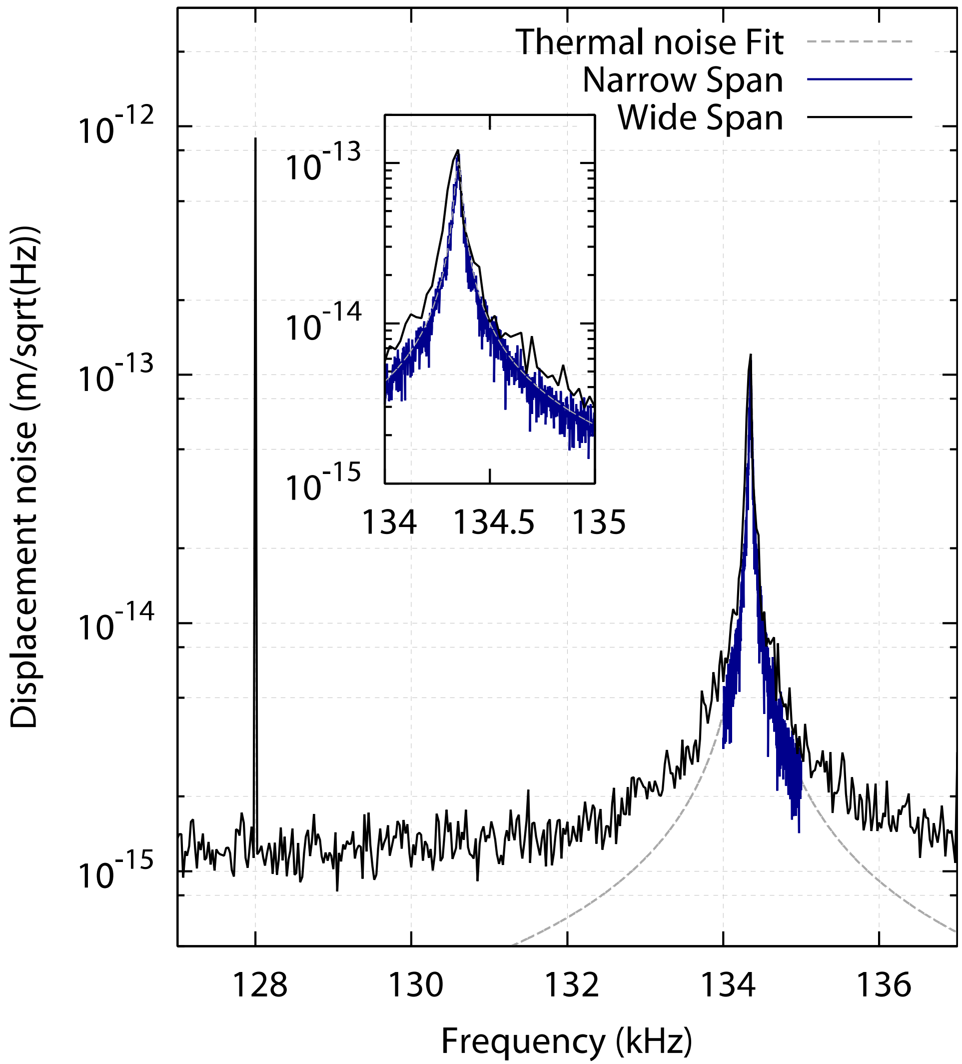
Spectra obtained with DC read out

Only slightly improved displacement sensitivty

Unknown noise background
(most propably laser frequency noise)

Changed oscillator parameters,
Calculated T_{eff} = 7 K and Q_{eff} = 4500

With R_{sr} = 99 % and P_{in} = 100 mW



Thank you for your attention

Questions?

Dissipative opto-mechanics

Usual idea: use cavity and detune

Supress lower sideband

$E_{ph} = hf$

Require : $l_{opt} << f_{mech}$
For strong cooling

Dissipative cooling
Require system with