

Optomechanical Instability in the KAGRA Gravitational Wave Telescope

KAGRA

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Abstract

KAGRA is a 3-km interferometric gravitational wave telescope which started construction in 2010 at Kamioka, Japan [1]. We reduce seismic noise by constructing the interferometer in the quiet underground site, and we reduce thermal noise by cooling down the test mass mirrors to 20 K. These advanced technologies help KAGRA detect gravitational waves from binary neutron stars 150 Mpc away.

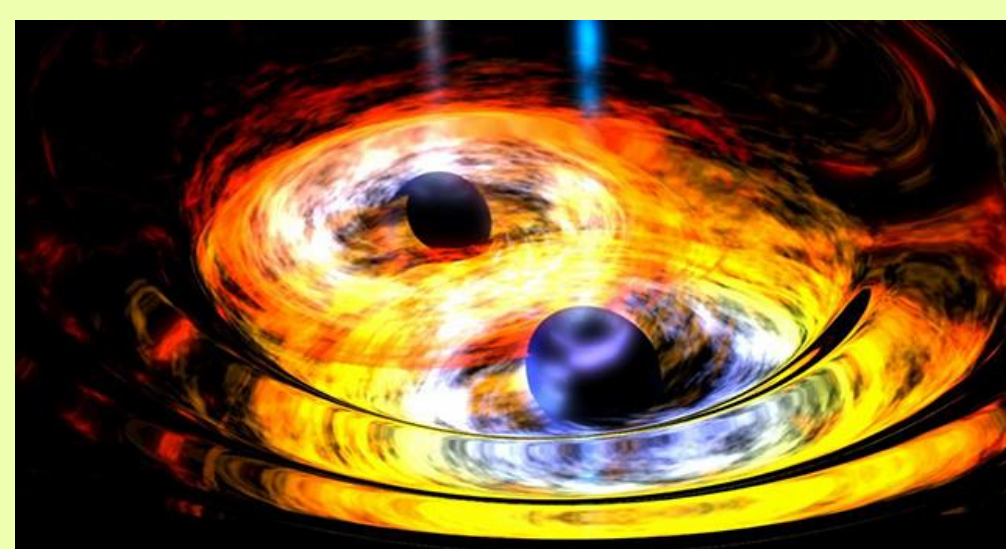
In order to achieve such a high sensitivity, longitudinal and angular motions of the mirrors must be finely controlled. However, the alignment control will be one of the most challenging issue because of the optomechanical angular instability of the arm cavities [2,3].

Here, we present our interferometer design to reduce this instability, and show angular noise estimate from the interferometer modeling.

1. Gravitational wave and its detection



binary neutron star



binary black hole



supernova

Gravitational wave

- ripples in spacetime
- quadrupole
- propagates at the speed of light

GW telescope

= Dual Recycled Fabry-Pérot Michelson Interferometer

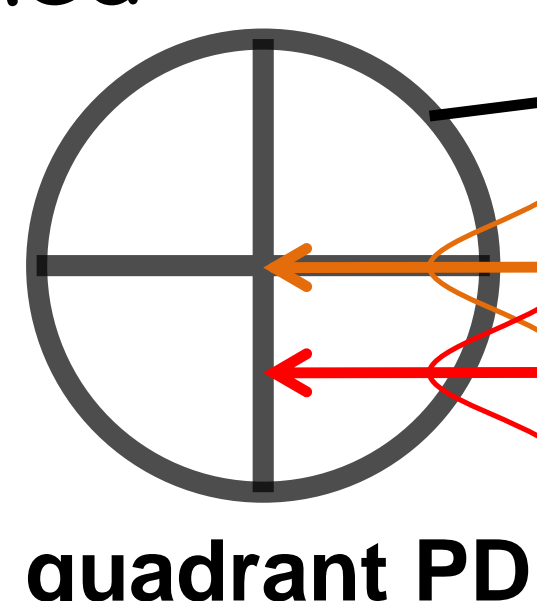
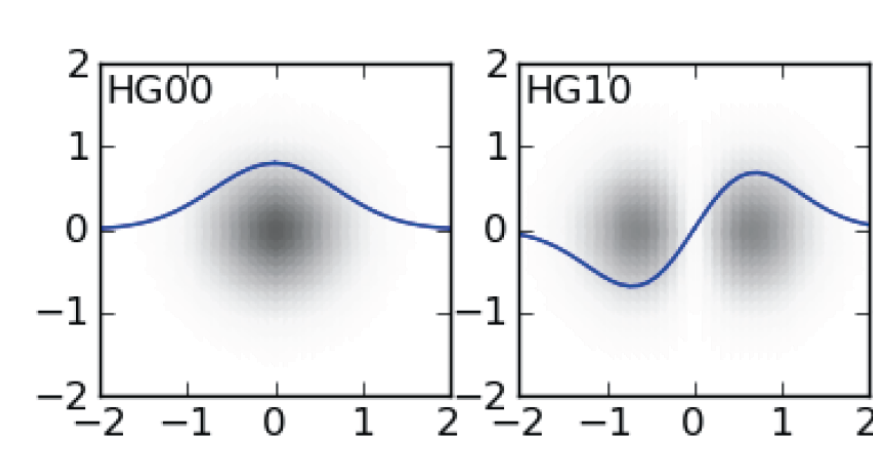
2. Optomechanical angular instability

Angular instability of the arm cavities

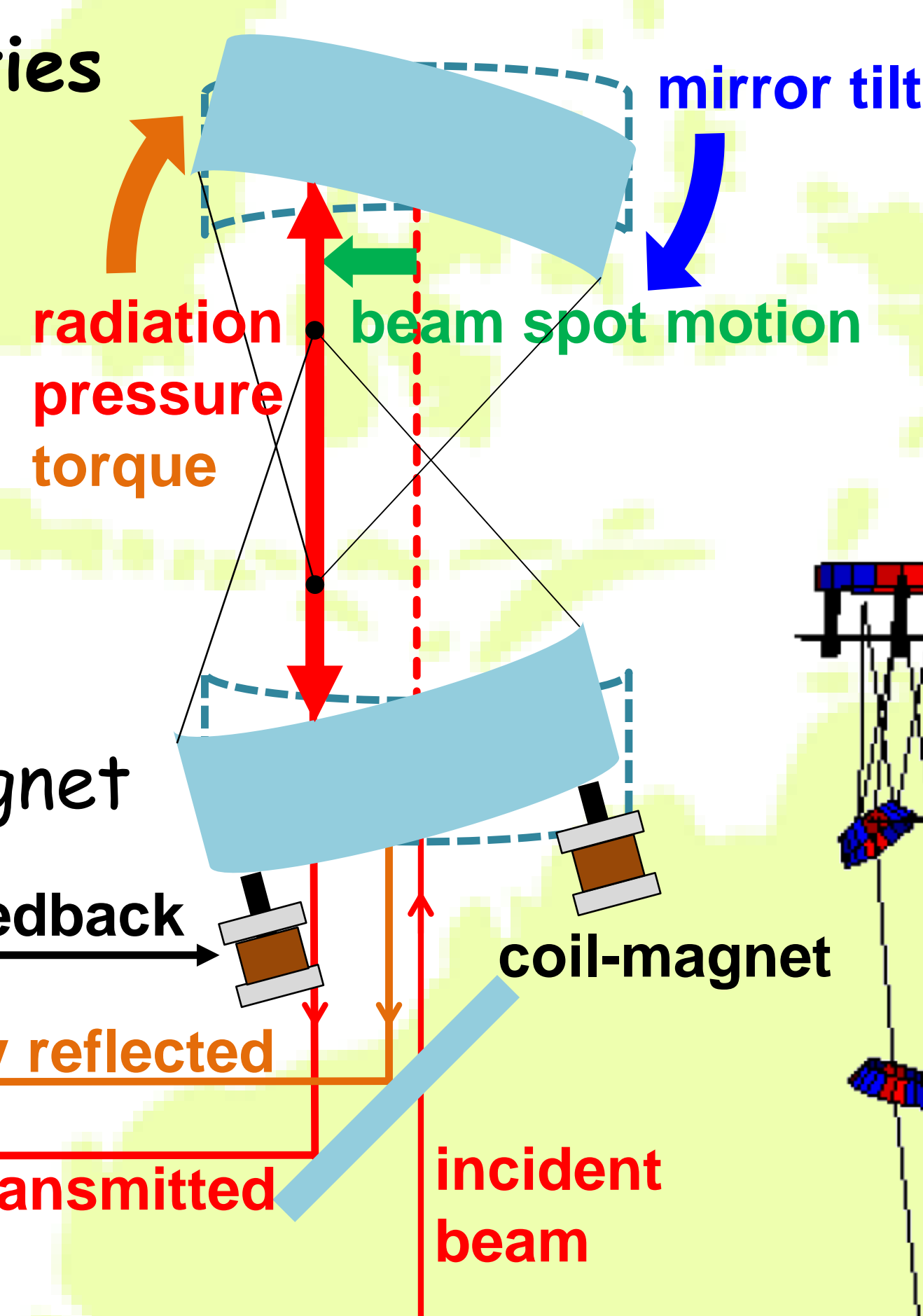
- high intra cavity power (400 kW)
- radiation pressure torque works as torsional anti-spring (or spring) [2]
- smaller RoC (negative g-factor), less anti-spring

Alignment sensing and control

- wavefront sensing technique [4]
- feedback the signal to the coil-magnet actuators attached on mirrors



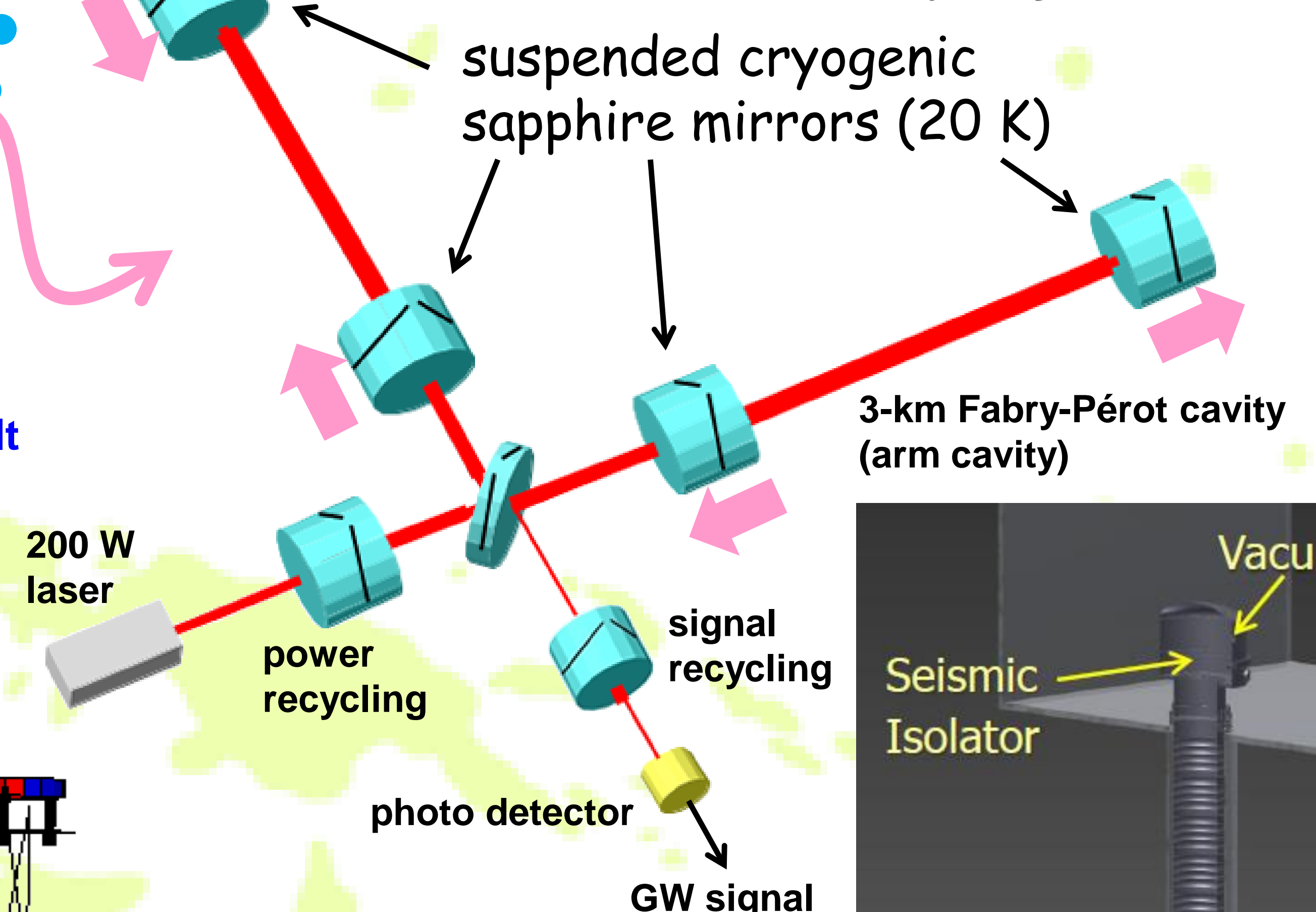
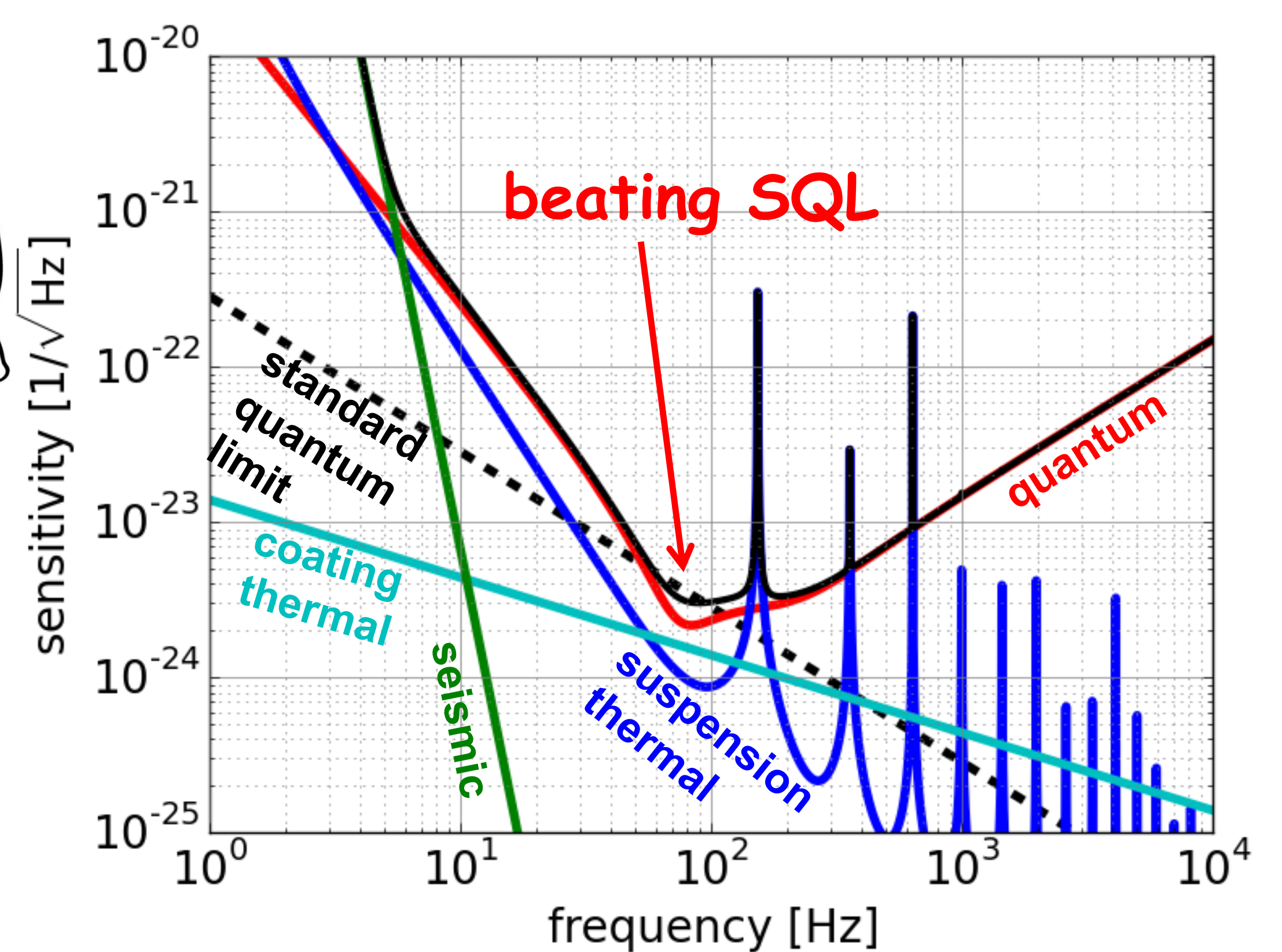
quadrant PD



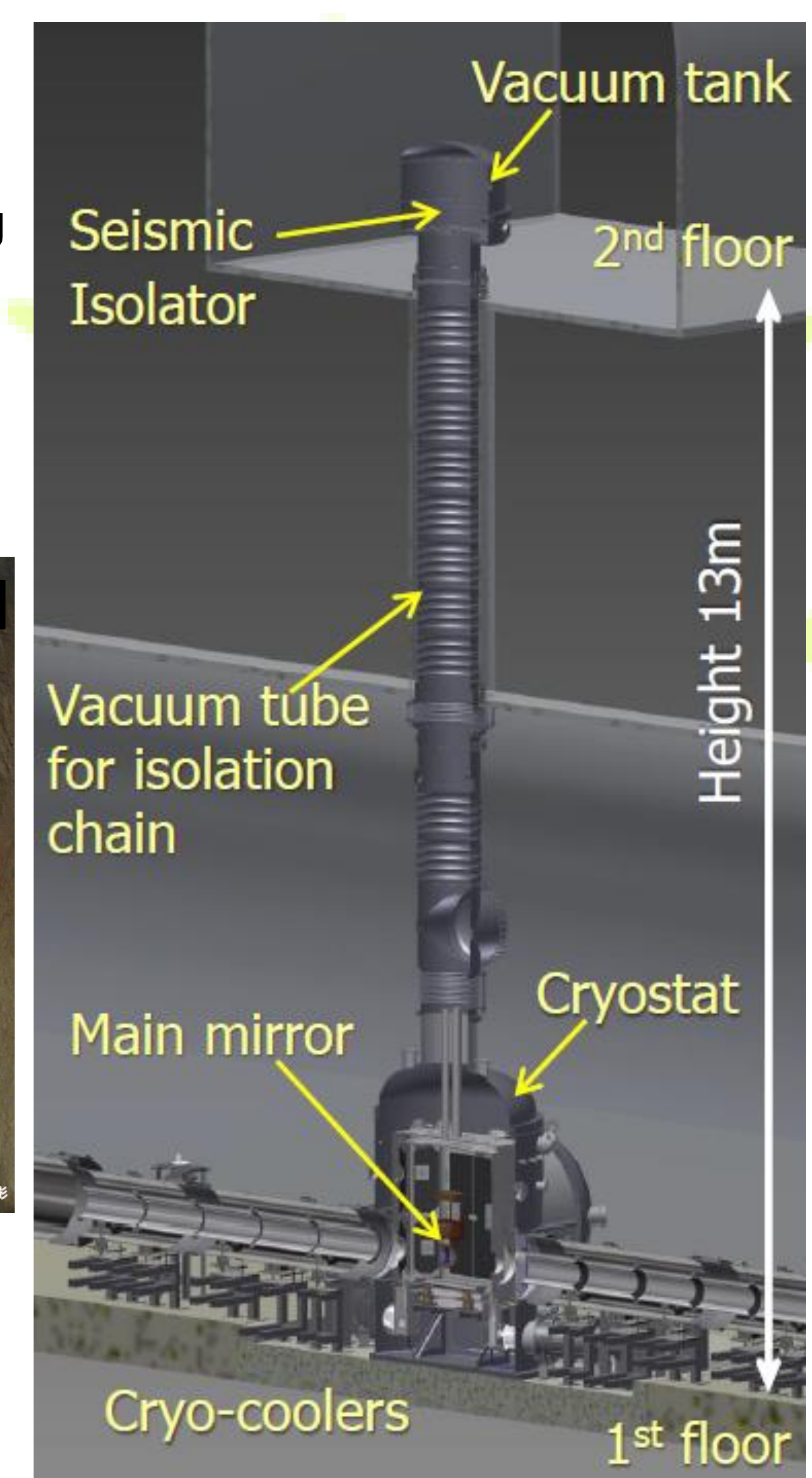
Kamioka
神岡



Φ 22 cm
23 kg



underground tunnel and 3-km vacuum pipe (2015.2.13)



3. Angular noise estimate

Interferometer modeling

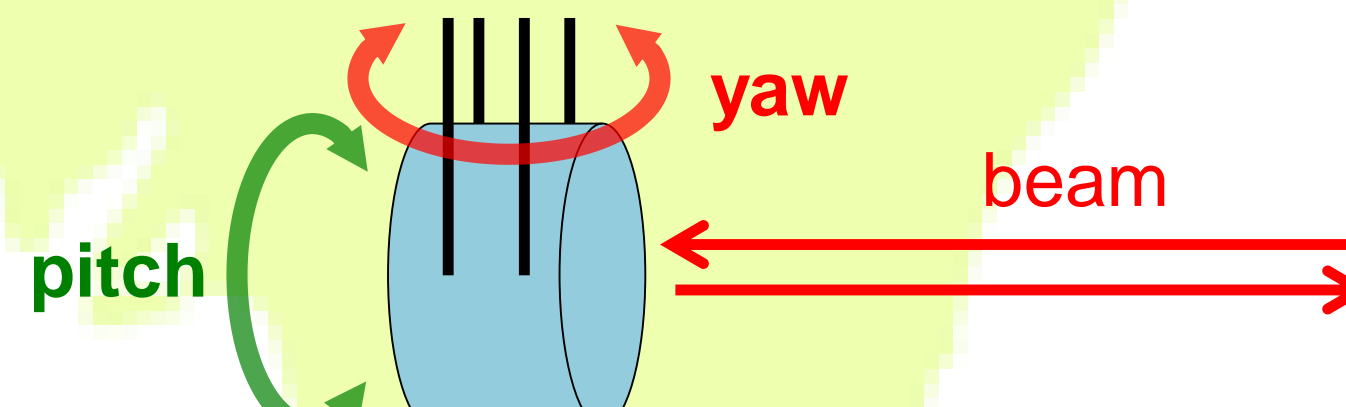
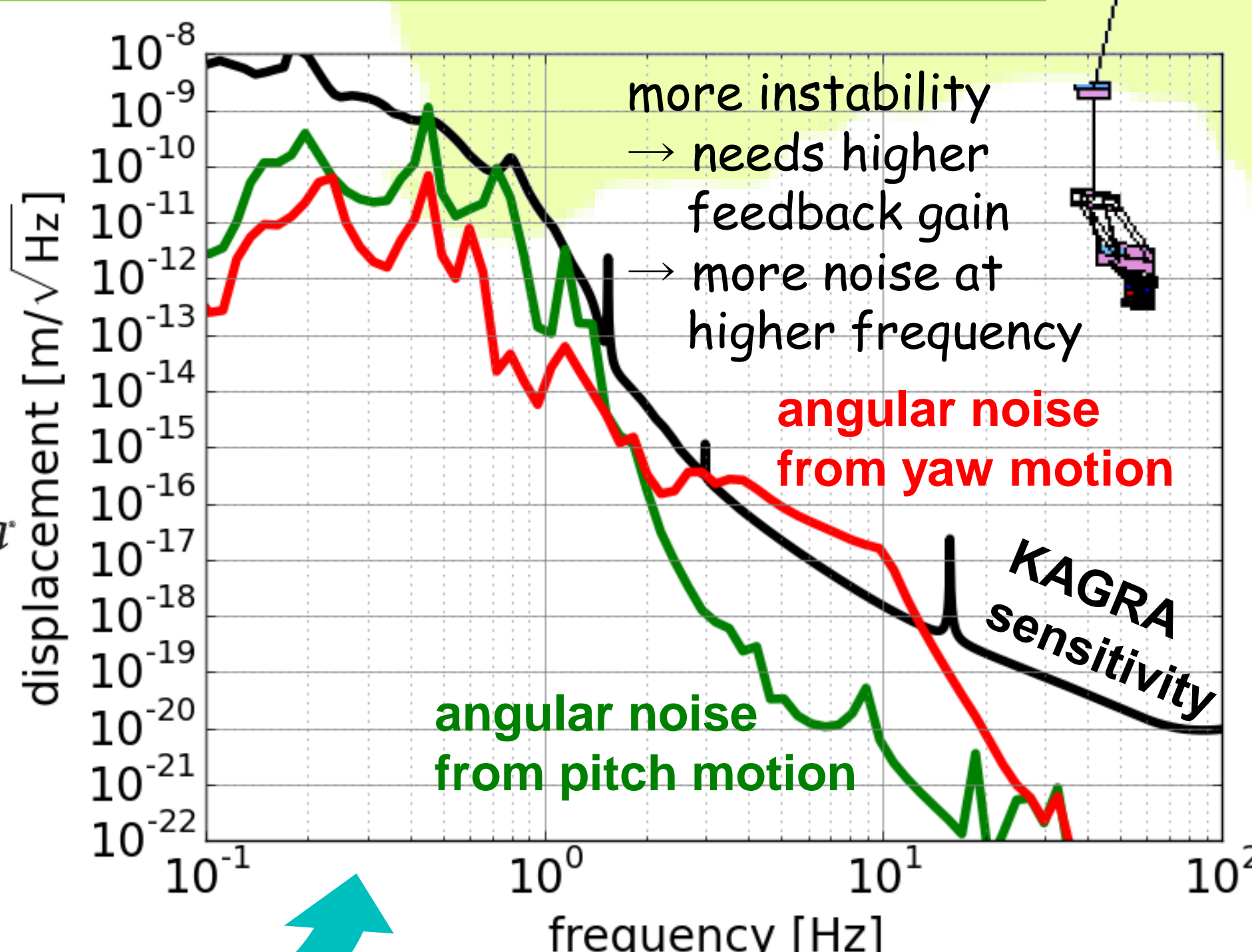
- 3D rigid body model [5] for simulating mechanical responses of test mass mirror suspensions



Wolfram
Mathematica

- Optickle [6] frequency domain quantum-optomechanics simulation tool

MATLAB



References

- [1] Y. Aso, Y. Michimura, K. Somiya et al., Phys. Rev. D **88**, 043007 (2013)
- [2] J. A. Sidles and D. Sigg, Phys. Lett. A **354**, 167 (2006)
- [3] L. Barsotti et al., Class. Quantum Grav. **27**, 084026 (2010)
- [4] E. Morrison et al., Appl. Opt. **33**, 5041 (1994)
- [5] T. Sekiguchi, JGW-T1100416 (2011), JGW-T1302090 (2013)
- [6] M. Evans et al., <https://github.com/Optickle/Optickle>

KAGRA drawings and photos are taken from JGW-G1503311 by S. Kawamura and JGW-G1402288 by M. Ando
Drawings of GW sources are from <http://youtu.be/g8s81MzzJ5c>
http://www.astroarts.co.jp/news/2013/12/04binary_bh/
<http://en.wikipedia.org/wiki/Supernova>