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Beam Jitter Requirements for PSL Beam

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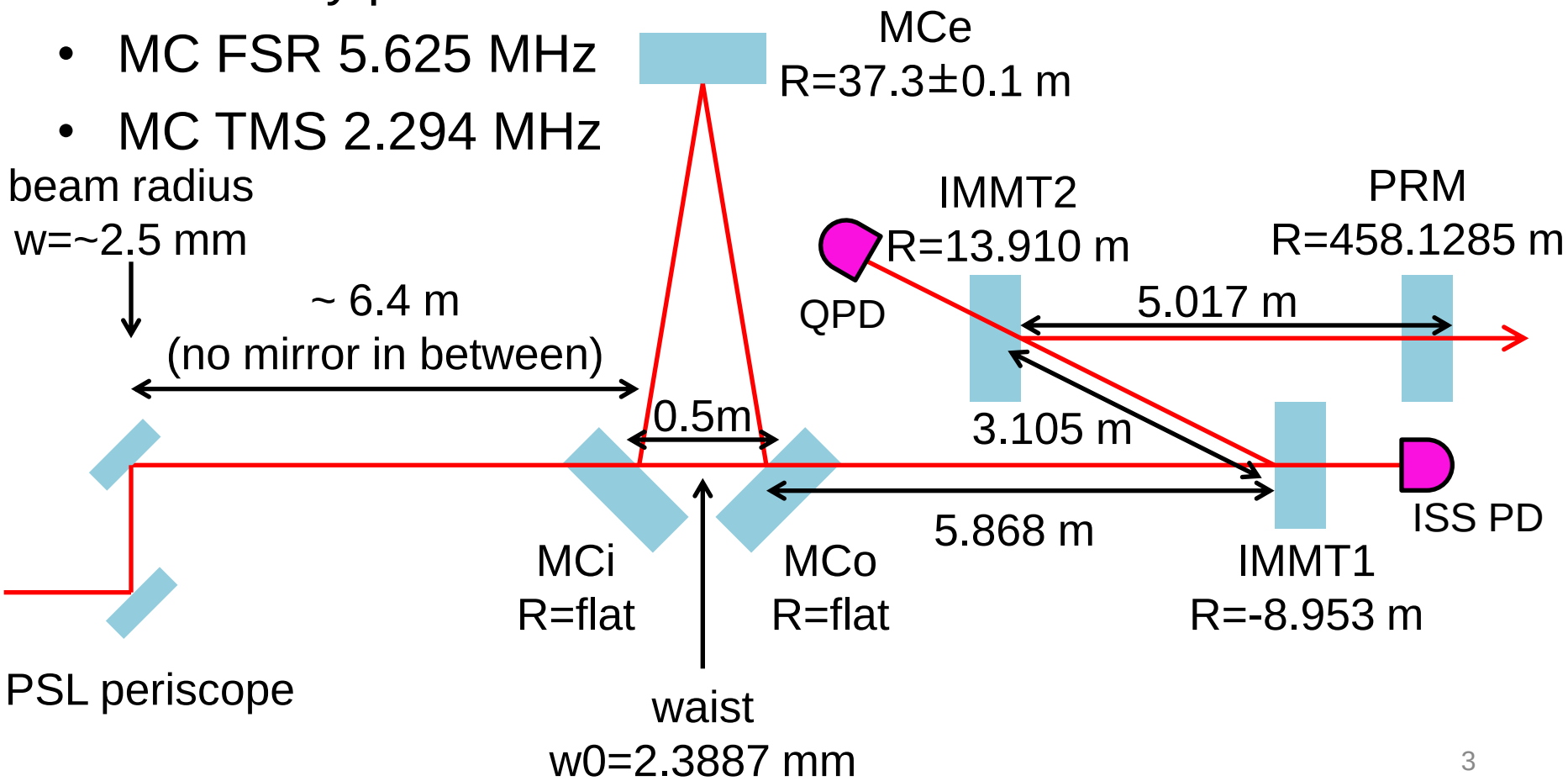
Purpose

- Derive beam jitter/drift requirements for PSL output beam to design PSL periscope etc.

- Related documents:
  - http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/MIFIOOInterfaces
  - https://granite.phys.s.u-tokyo.ac.jp/svn/LCGT/trunk/mif/OptLayout/Layout/ (IMC, MMT, MIF layout)
  - JGW-G1301747 (jitter requirements from MIF)
  - JGW-T1402324 (periscope study)
  - JGW-T1302068 (IMC, MMT layout)
  - JGW-T1200913 (MIF design)
  - JGW-D1100774 (PSL table, chamber layout)
  - JGW-G1402290 (IOO External Review)

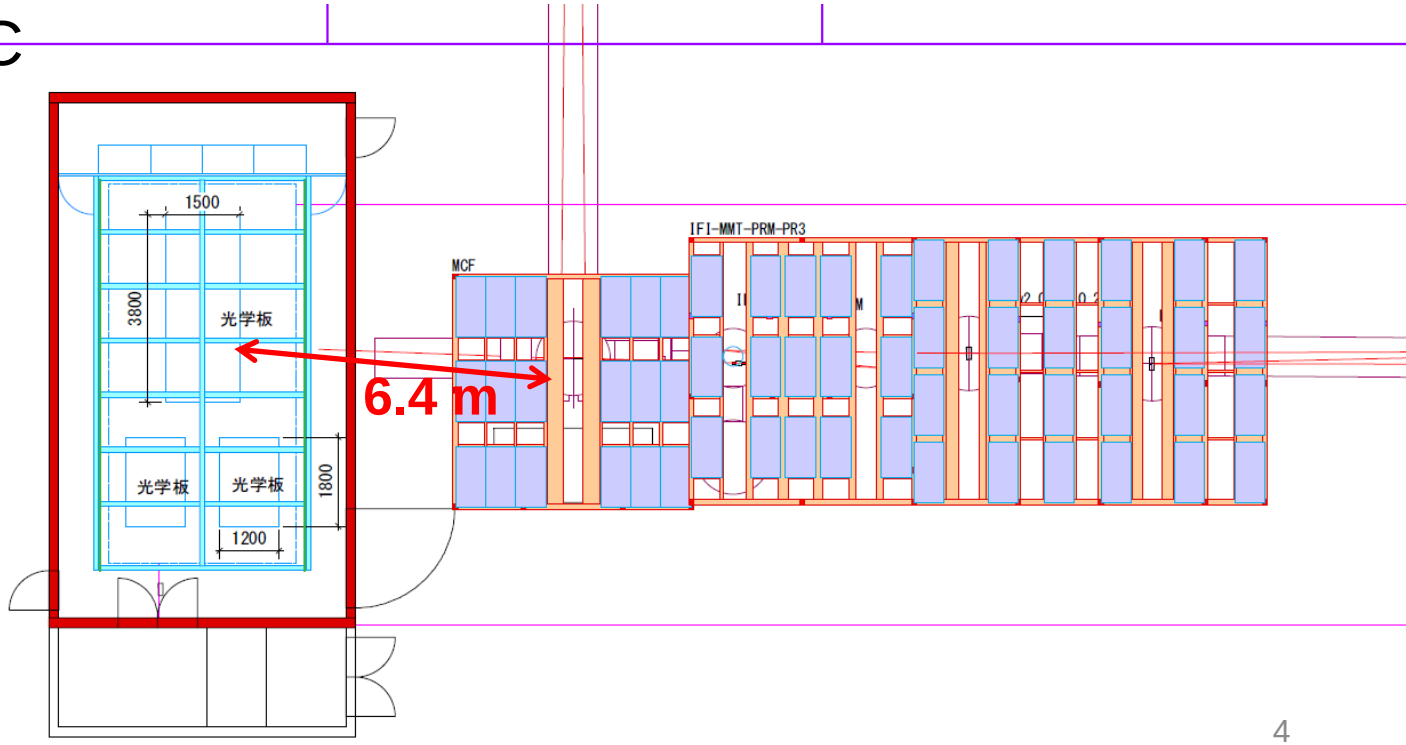
Optical Layout from PSL to PRM

- MC round-trip 2*26.65 m
- MC finesse 500
- MC cavity pole 5.625 kHz
- MC FSR 5.625 MHz
- MC TMS 2.294 MHz



Optical Layout from PSL to IMC

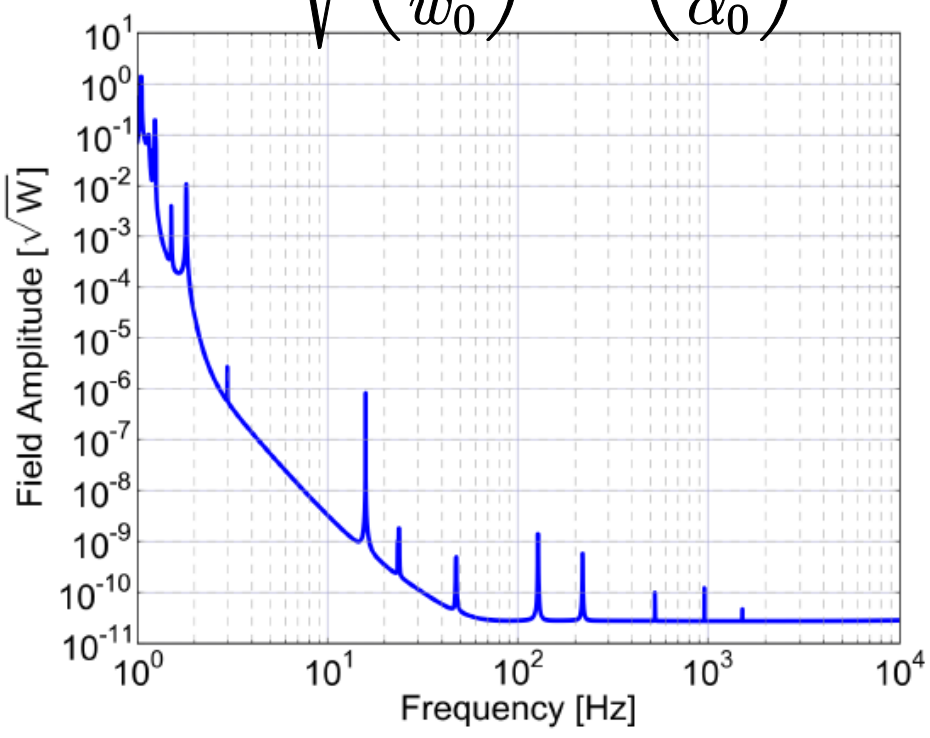
- Detailed design not fixed yet
- Drawing from Miyoki-san (JGW-D1100774) gives rough estimate of the distance from PSL table to IMC (~6.4 m)
- This gives beam radius of ~2.5 mm at the PSL periscope
  → 1-inch mirror may not be sufficient for periscope mirror
- MMT to IMC should be put on the PSL table



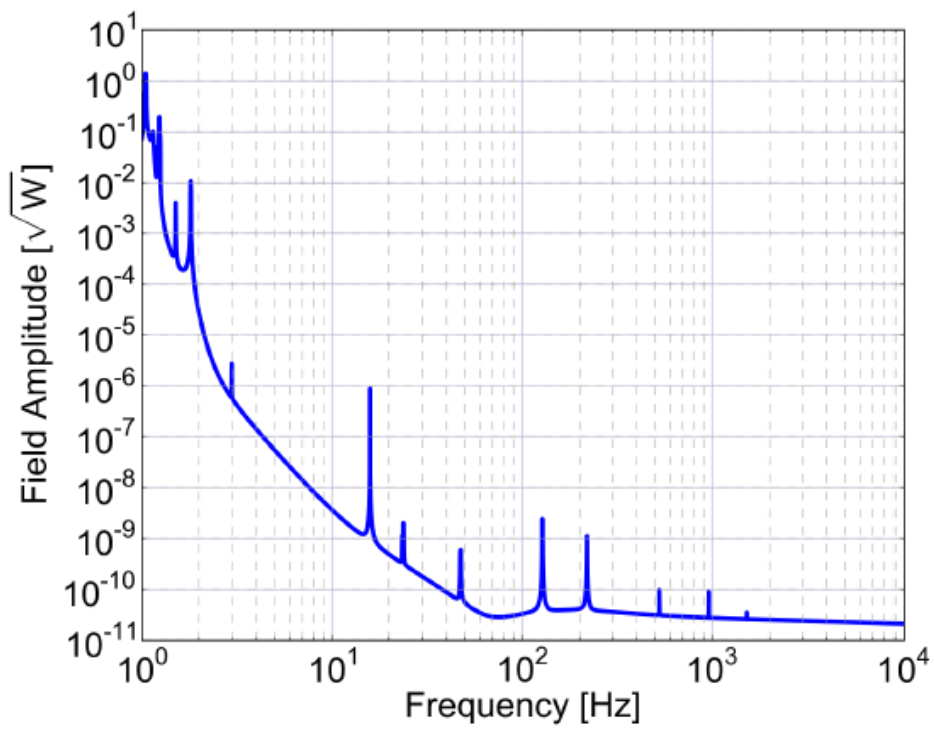
MIF Requirement (bKAGRA)

- Requirement for TEM01 amplitude per 1W at PRM incident is plotted (for both BRSE/DRSE cases)
- Roughly

$$\varepsilon = \sqrt{\left(\frac{\delta x}{w_0}\right)^2 + \left(\frac{\delta \theta}{\alpha_0}\right)^2} < \left(3 \times 10^{-11} + 3 \times 10^{-5}\,\mathrm{Hz}/f^4\right)/\sqrt{\mathrm{Hz}}$$



BRSE



DRSE

JGW-G1301747

Requirement Derivation 1

- Beam waist radius at PRM is ~4.4 mm, at IMC is ~2.4 mm
- ABCD matrix from PRM to IMC is

  1.59 15.2

  -0.0201 0.435
- TEM01 by translation will be multiplied by

  A/(w0_IMC/w0_PRM) = 2.9
- TEM01 by tilt will be multiplied by

  B/(α0_IMC/α0_PRM) = B/(w0_PRM/w0_IMC) = 8.3
- Thus, TEM01 requirement at IMC is requirement at PRM times 2.9 $\varepsilon < \left(9 \times 10^{-11} + 9 \times 10^{-5}\,\mathrm{Hz}/f^4\right)/\sqrt{\mathrm{Hz}}$
- IMC TEM01 amplitude transmissivity is

$$t_{01} = \sqrt{\frac{1}{1 + [(f_{\mathrm{TMS}} - f)/f_{\mathrm{cp}}]^2}}$$

- t01 is constant (~2.5e-3) below TMS = 2.2 MHz

Requirement Derivation 2

- Thus, beam jitter requirement at IMC incident is

$$\varepsilon < \left(4 \times 10^{-8} + 4 \times 10^{-2}\,\mathrm{Hz}/f^4\right)/\sqrt{\mathrm{Hz}}$$

- ABCD matrix from IMC to PSL is

1	6.2
0	1

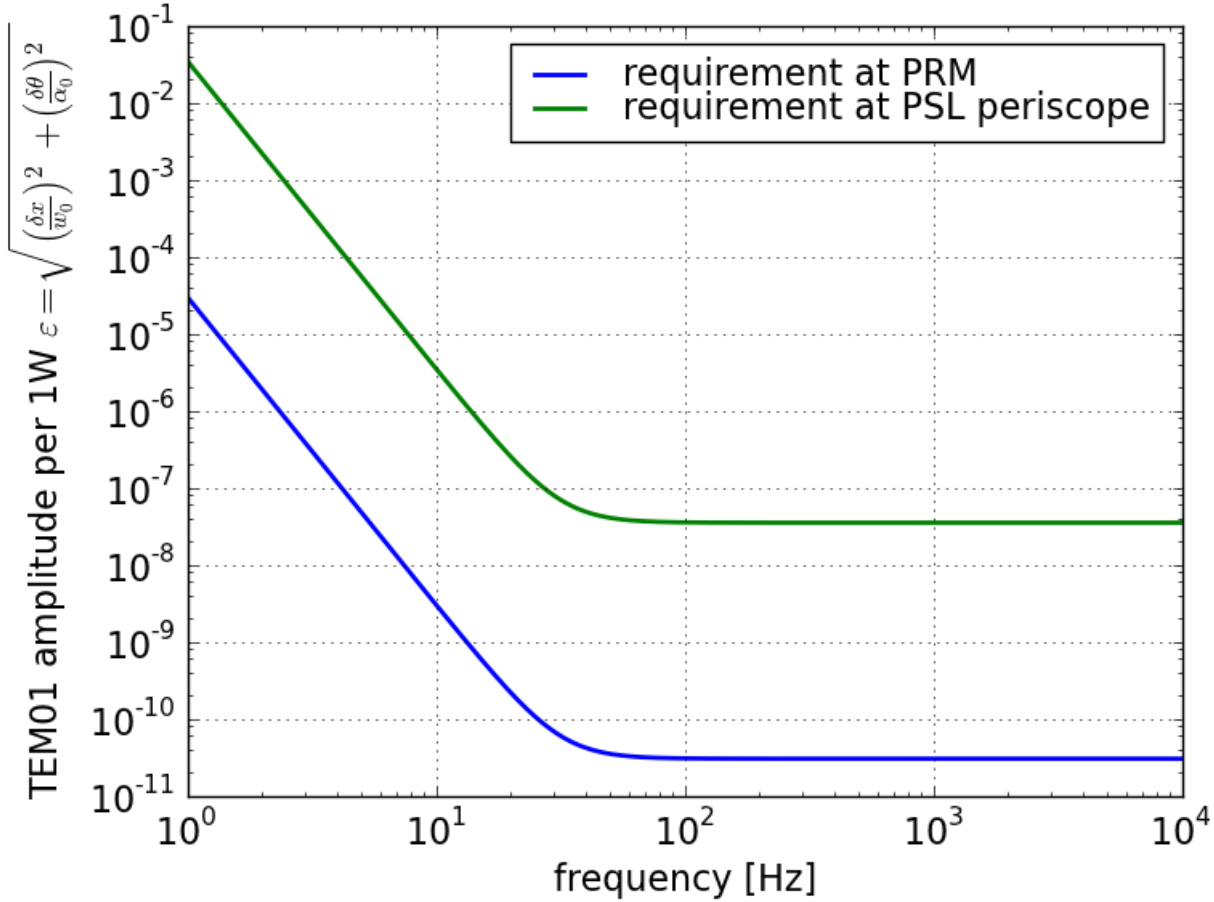
- TEM01 by translation will be multiplied by
  A = 1
- TEM01 by tilt will be multiplied by
  B = 6.2
- Thus, beam jitter requirement at PSL periscope is the same as requirement at IMC incident

PSL Beam Jitter Requirement

- Approximately

$$\varepsilon < \left(4 \times 10^{-8} + 4 \times 10^{-2}\,\mathrm{Hz}/f^4\right)/\sqrt{\mathrm{Hz}}$$

(1.2e3 larger than the requirement at PRM)



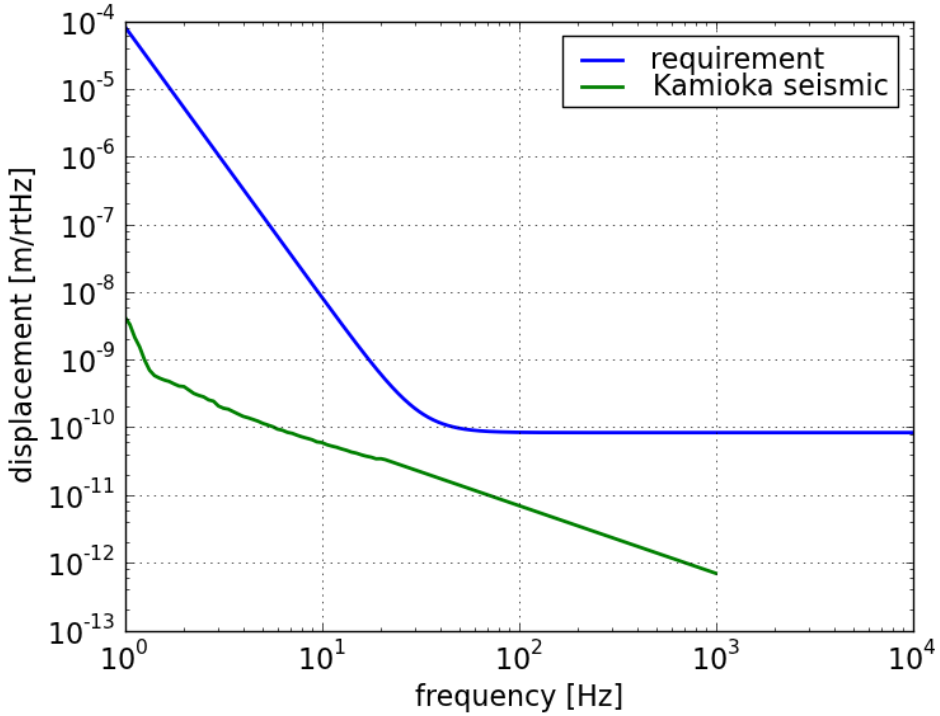
In Terms of Periscope Displacement

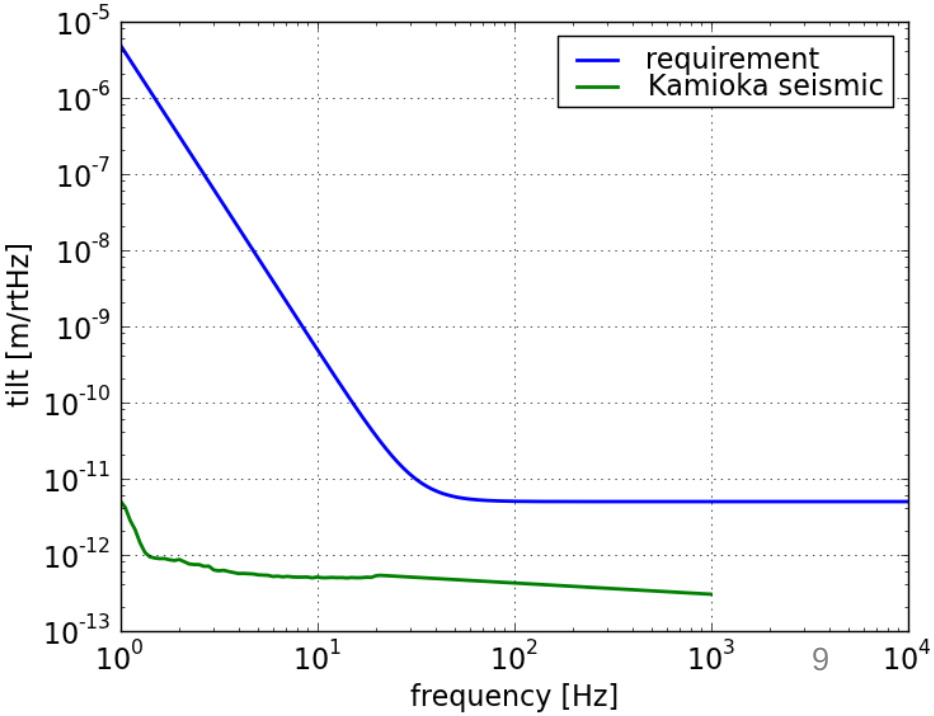
- Beam waist radius at the periscope is ~2.4 mm
- Thus, in terms of periscope mirror displacement/tilt, the requirements are

$$\delta x < (1 \times 10^{-10} + 1 \times 10^{-4}\ \mathrm{Hz}/f^4)\,\mathrm{m}/\sqrt{\mathrm{Hz}}$$

$$\delta\theta < (3 \times 10^{-12} + 3 \times 10^{-6}\ \mathrm{Hz}/f^4)\,\mathrm{rad}/\sqrt{\mathrm{Hz}}$$

- Kamioka seismic noise is smaller by more than x10





PSL Beam Drift Requirement

- PSL beam drift will be compensated by PZT mirror on the PSL periscope (by IMC WFS servo)
- So, PSL beam drift should be smaller than PZT range

Requirements for iKAGRA

- Jitter requirement
  ???
  (Since bKAGRA requirements are not so severe, I recommend setting same requirement for iKAGRA)
- Drift requirement is the same with bKAGRA