

Beam Jitter Requirements for PSL Beam

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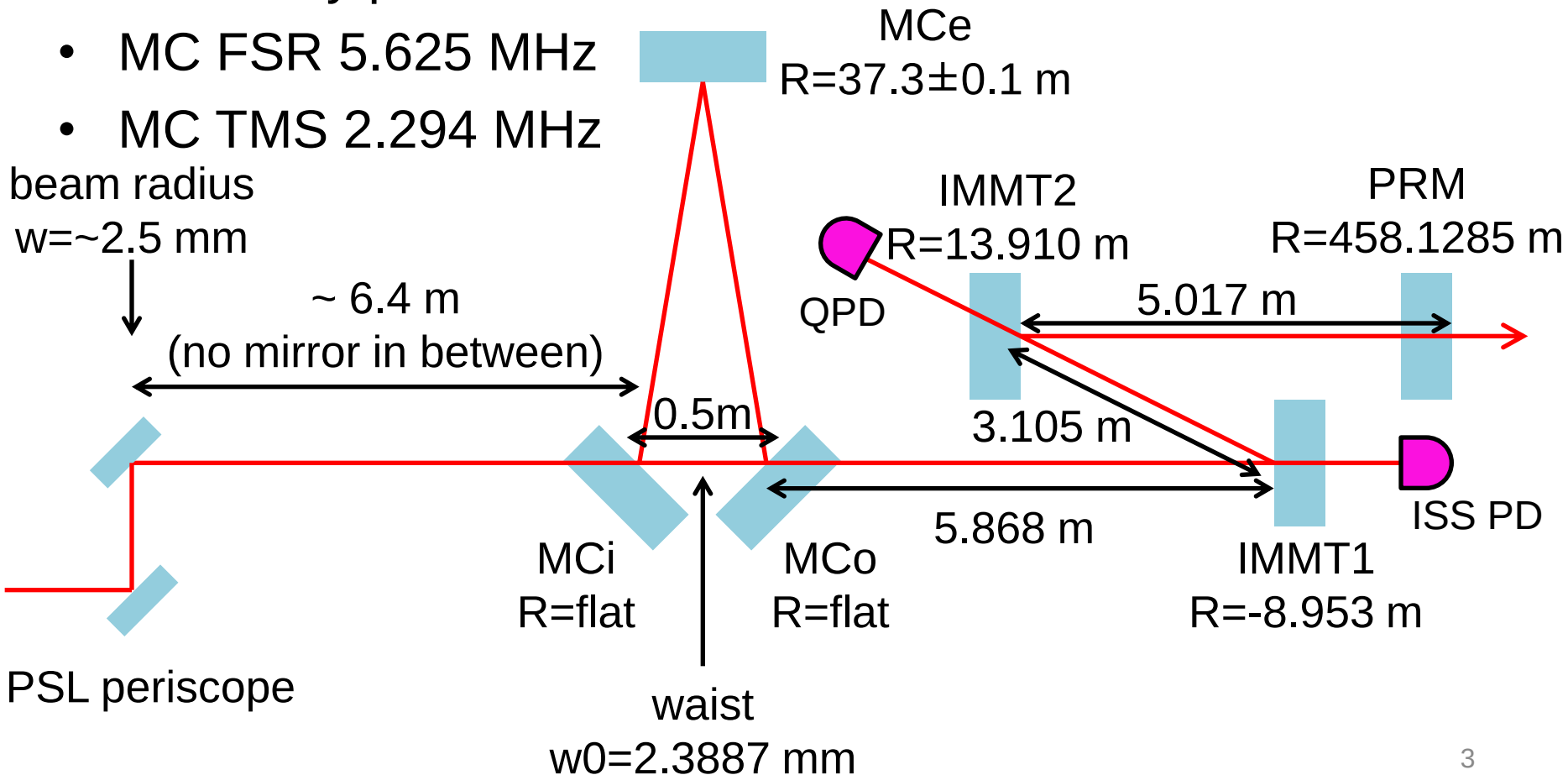
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Scope

- Derive beam jitter/drift requirements for PSL output beam to design PSL periscope etc.
- Related documents, references:
 - <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)
 - [LIGO-T0900142](#) (aLIGO beam jitter requirements)

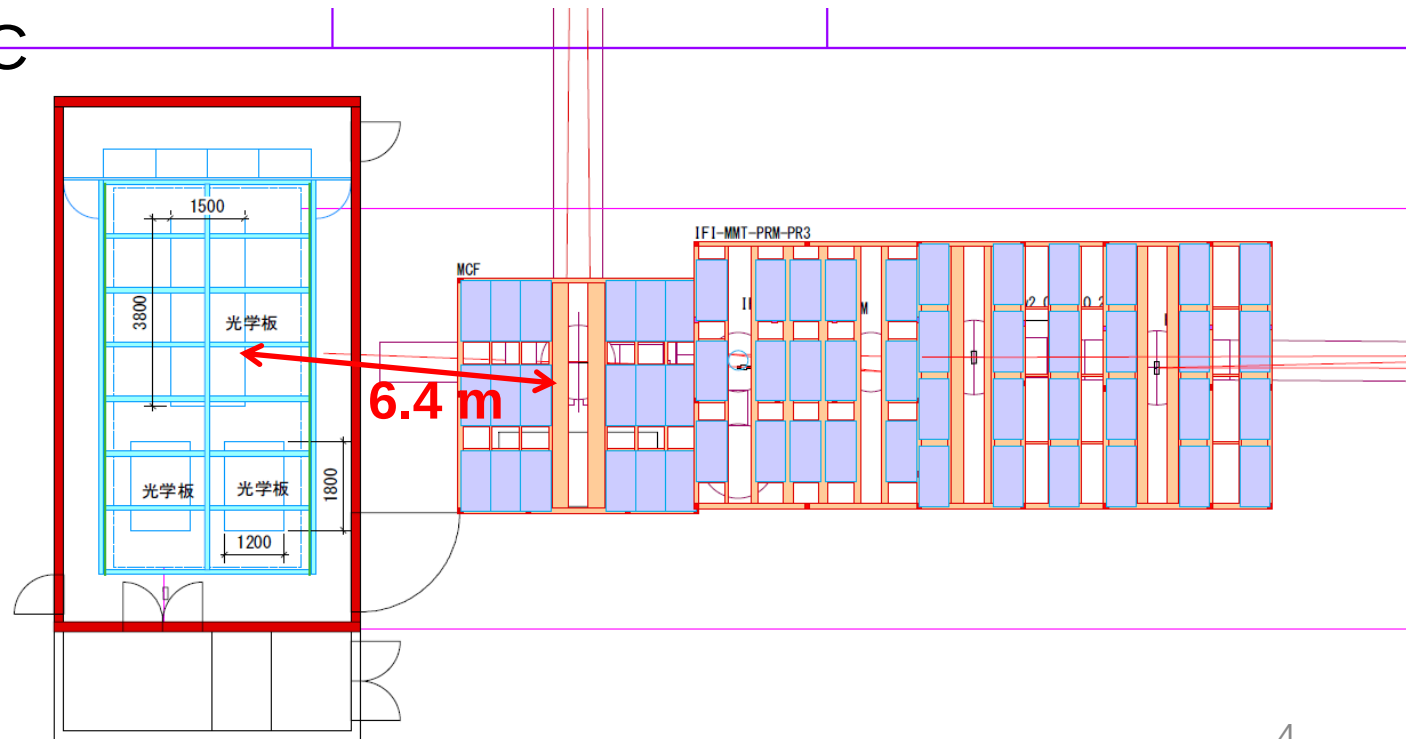
Optical Layout from PSL to PRM

- 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

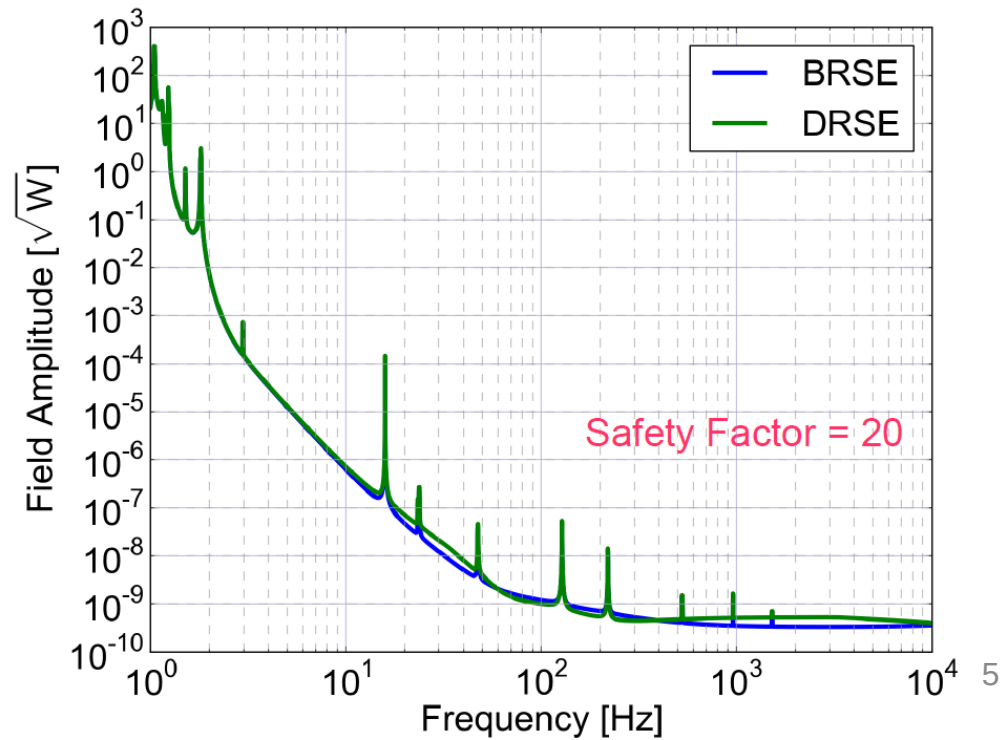


MIF Requirement (bKAGRA)

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

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

入射TEM01振幅への要求値(入射パワー1W)



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

$$\begin{pmatrix} 1.59 & 15.2 \\ -0.0201 & 0.435 \end{pmatrix} \begin{pmatrix} \delta x_2 \\ \theta_2 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} \delta x_1 \\ \theta_1 \end{pmatrix}$$

- Normalized ABCD matrix from PRM to IMC is

$$\begin{pmatrix} 0.869 & 0.488 \\ -0.627 & 0.798 \end{pmatrix} \begin{pmatrix} \delta x_2/w_{02} \\ \theta_2/\alpha_{02} \end{pmatrix} = \begin{pmatrix} A' & B' \\ C' & D' \end{pmatrix} \begin{pmatrix} \delta x_1/w_{01} \\ \theta_1/\alpha_{01} \end{pmatrix}$$

- Thus, TEM01 requirement at IMC is the requirement at PRM times 1.4 $\varepsilon < (4 \times 10^{-10} + 4 \times 10^{-3} \text{ Hz}/f^4) / \sqrt{\text{Hz}}$
- IMC TEM01 amplitude transmissivity is

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

- t_{01} is constant ($\sim 2.5\text{e-}3$) below TMS = 2.2 MHz

Requirement Derivation 2

- Thus, beam jitter requirement at IMC incident is

$$\varepsilon < (2 \times 10^{-7} + 2 \times 10^0 \text{ Hz}/f^4) / \sqrt{\text{Hz}}$$

- ABCD matrix from IMC to PSL is

$$\begin{array}{cc} 1 & 6.2 \\ 0 & 1 \end{array}$$

- Normalized ABCD matrix from PRM to IMC is

$$\begin{array}{cc} 1 & 0.365 \\ 0 & 1 \end{array}$$

- Thus, beam jitter requirement at PSL periscope is the requirement at IMC incident times 1.4

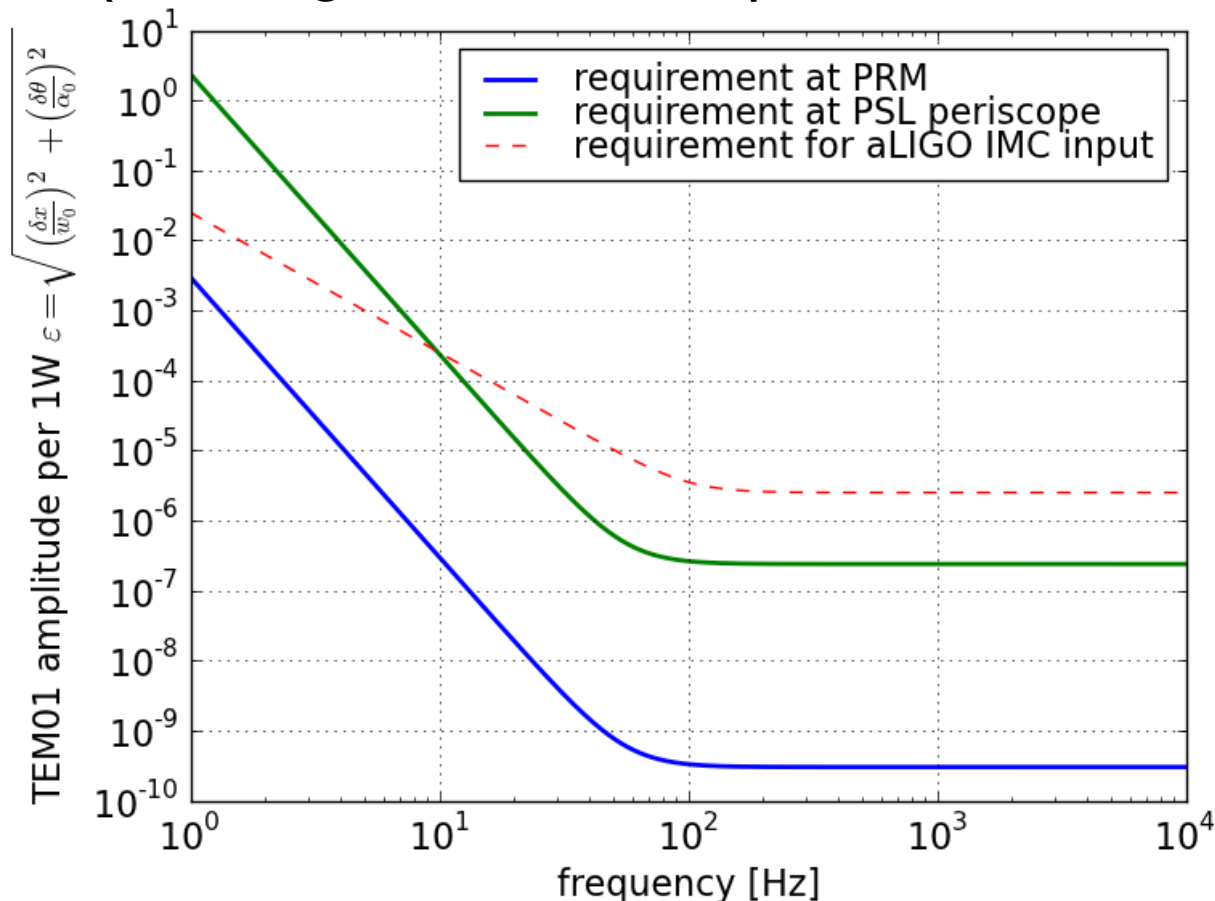
$$\varepsilon < (2 \times 10^{-7} + 2 \times 10^0 \text{ Hz}/f^4) / \sqrt{\text{Hz}}$$

PSL Beam Jitter Requirement

- Roughly

$$\varepsilon < (2 \times 10^{-7} + 2 \times 10^0 \text{ Hz}/f^4) / \sqrt{\text{Hz}}$$

(8e2 larger than the requirement at PRM)



aLIGO
requirement
is also plotted as
a reference
([LIGO-T0900142](#))

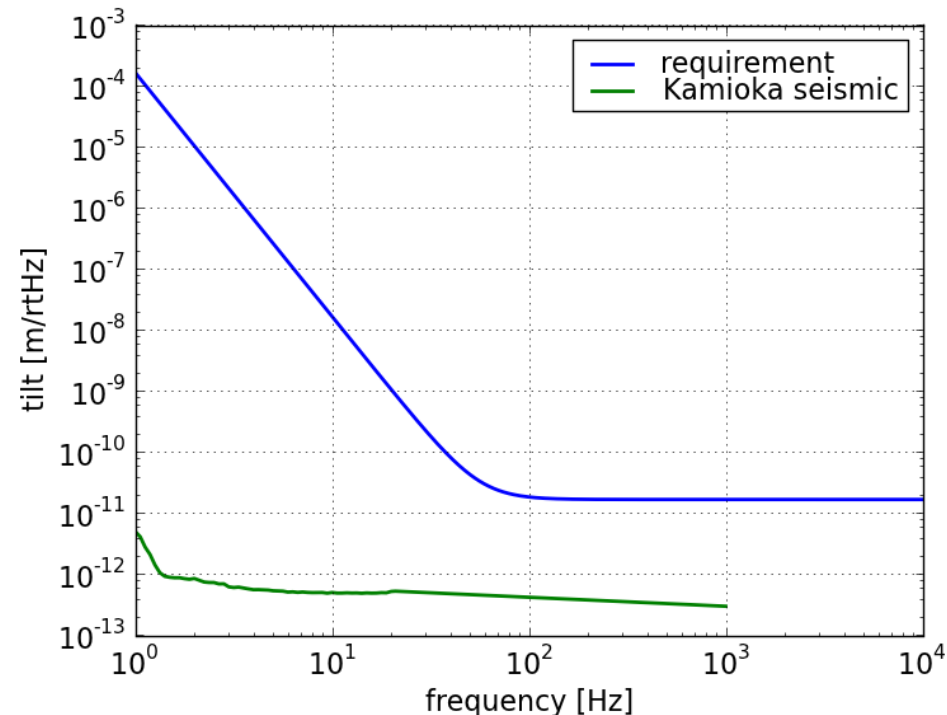
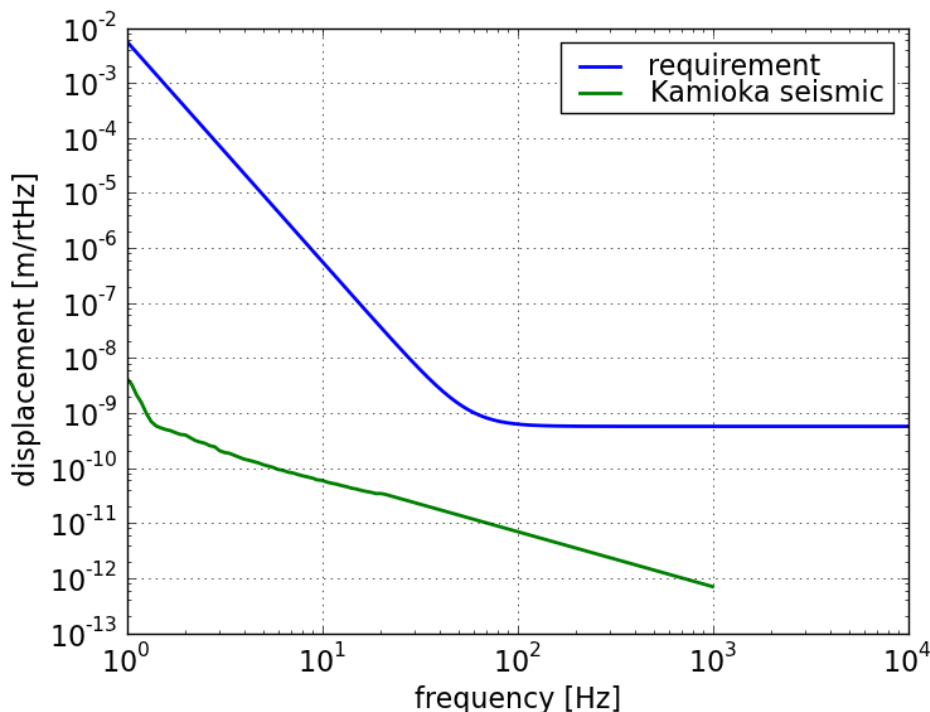
In Terms of Periscope Displacement

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

$$\delta x < (5 \times 10^{-10} + 5 \times 10^{-3} \text{ Hz}/f^4) \text{ m}/\sqrt{\text{Hz}}$$

$$\delta \theta < (2 \times 10^{-11} + 2 \times 10^{-4} \text{ Hz}/f^4) \text{ rad}/\sqrt{\text{Hz}}$$

- Kamioka seismic noise is smaller by more than x100



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 the same requirement for iKAGRA)

- Drift requirement is the same with bKAGRA