Current Status of Main Interferometer Subsystem

2012/2/3

Yoichi Aso

Overview: Definition and scope of the subsystem

MIF includes: Arm cavities, Recycling cavities, Michelson part

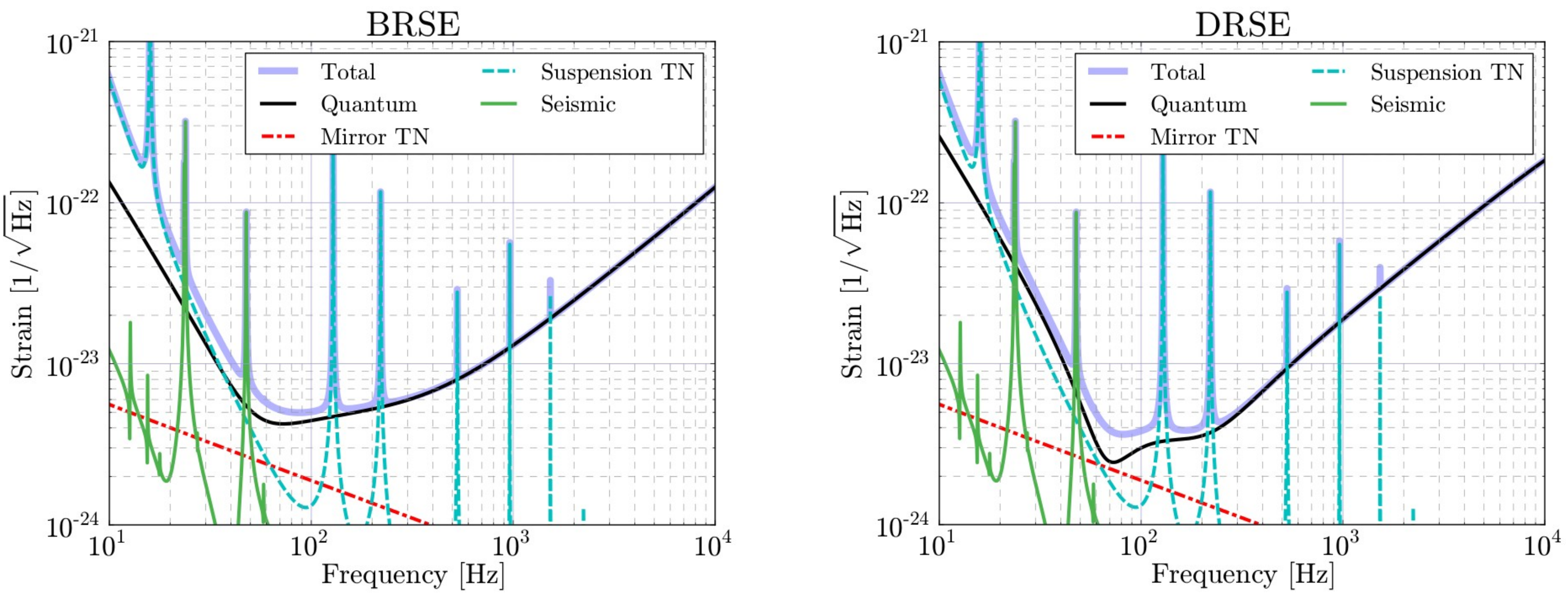
Assigned tasks

- Parameter selection of the MIF
  - Length, ROC, etc
  - Optical layout
- Design of the control scheme
  - LSC, ASC
- Lock acquisition scheme
- Commissioning

For some reason, detector characterization is a part of MIF
Maybe the Instrument Control will be too

Requirements

Operate the interferometer with the following noise level
Duty cycle > 90%(?)



Recap of the MIF design

Interferometer Parameter

Arm Finesse	1550	Arm Length	3km	PRG	10
SRM Reflectivity	85%	Input Laser Power	51W	PRC Length	66.6m
SRC Detuning	3.5°	SRC Length	66.6m	MICH Asym.	3.33m
g1	-0.786	g2	-0.602	g1・g2	0.473
R1	1.68km	R2	1.87km		

For details:
http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/LCGT/subgroup/ifo/MIF/OptParam

Sideband Resonant Conditions for Signal Extraction

Signal Ports

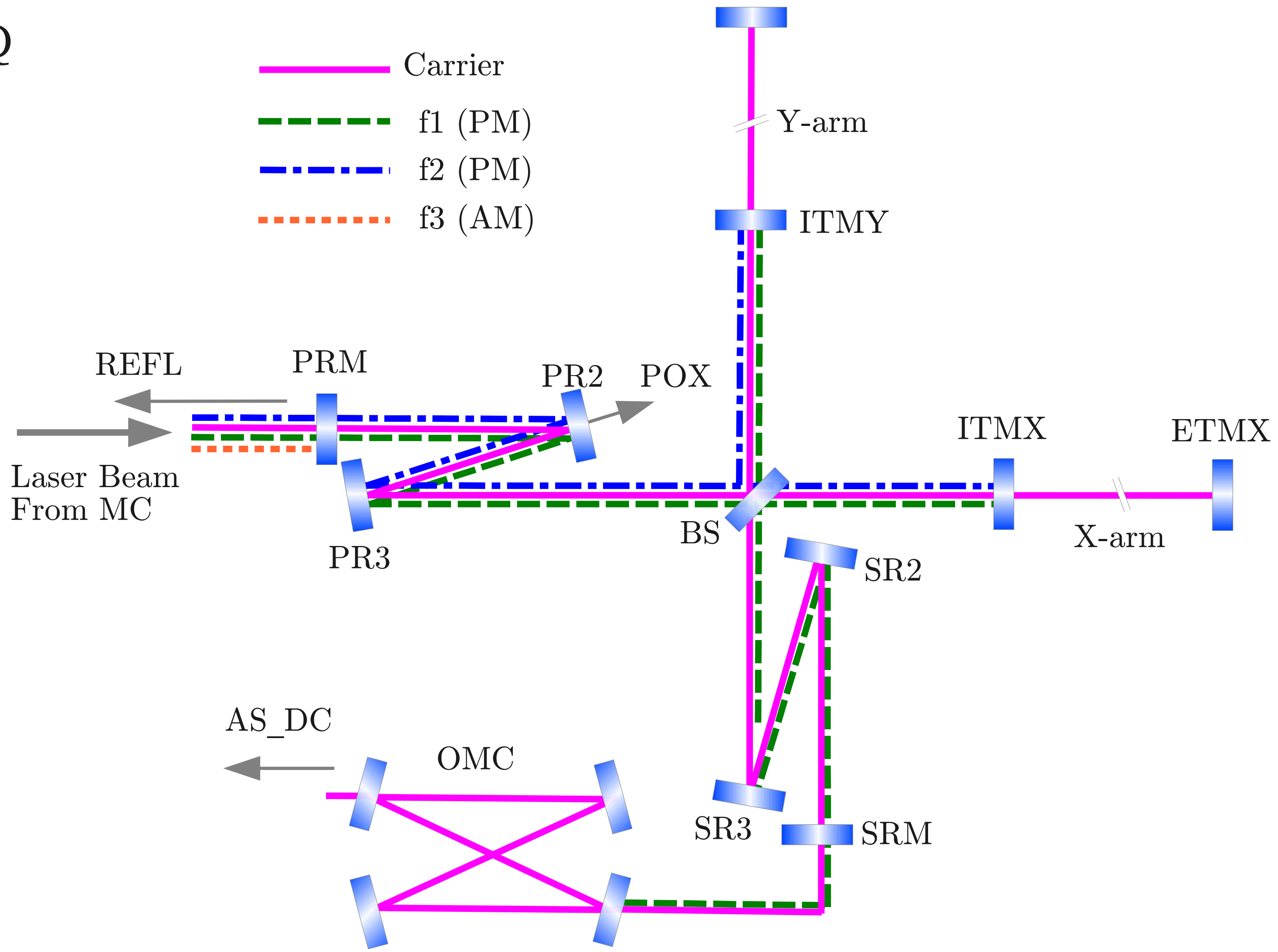
DARM: AS_DC

CARM: REFL_1I

MICH: REFL_1Q

PRCL: POP_2I

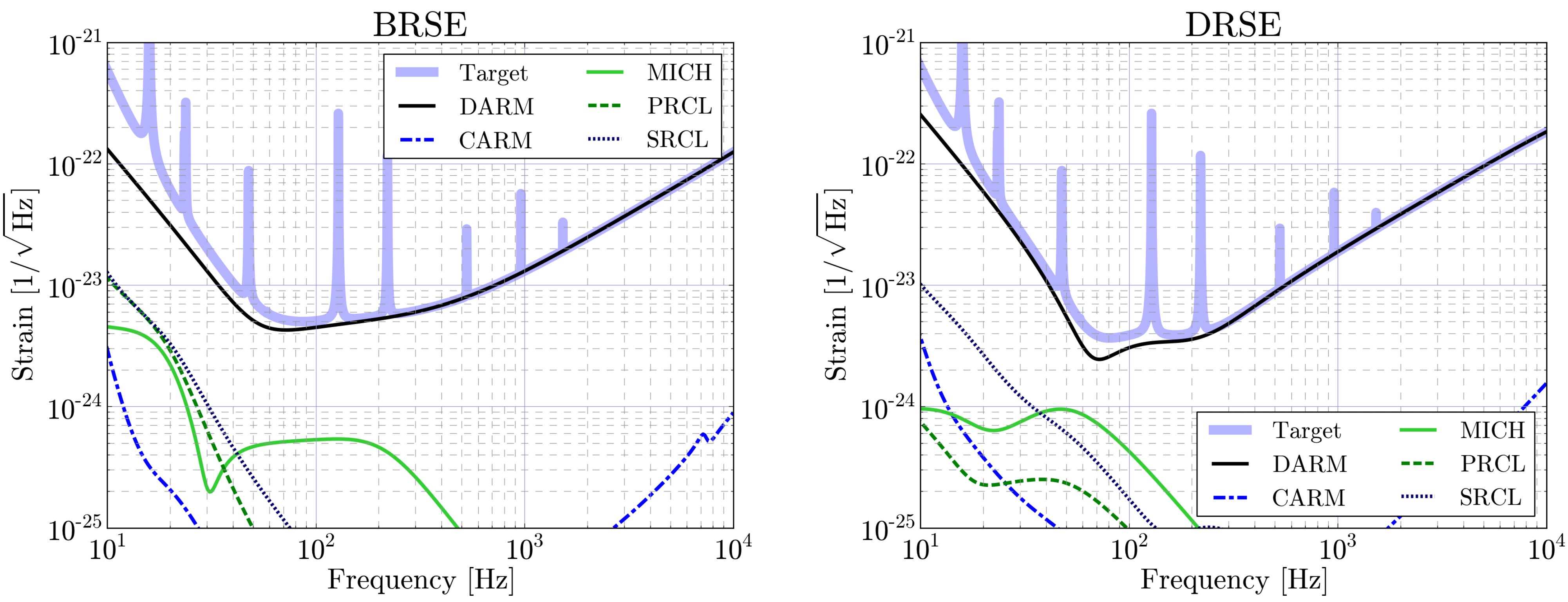
SRCL: POP_1I



LSC Loop Noise Couplings

UGF DARM: 200Hz, CARM: 10kHz, Others: 50Hz

Feed Forward Gain: 100



Recent updates

- g-factor determined
- Some updates to the LSC Optickle model
- Laser noise requirements
- Scattered light noise requirements
- Green lock servo simulation
- iKAGRA Layout

g-factor selection

Beam Size

ITM: 3.5cm, ETM:4.0cm

- 4.0cm is the maximum spot size for 22cm mirror.
- 3.5cm beam at the central part is easier to handle.
- Since ITMs have less coating layers, the thermal noise is not compromised by 3.5cm beam size on ITMs.

Decided: $g_1 \cdot g_2 = 0.473$

Candidates

- g1=0.786, g2=0.602 (R1=14km, R2=7.5km)
- g1=-0.786, g2=-0.602 (R1=1.68km, R2=1.87km)

Arm Cavity HOM Resonances

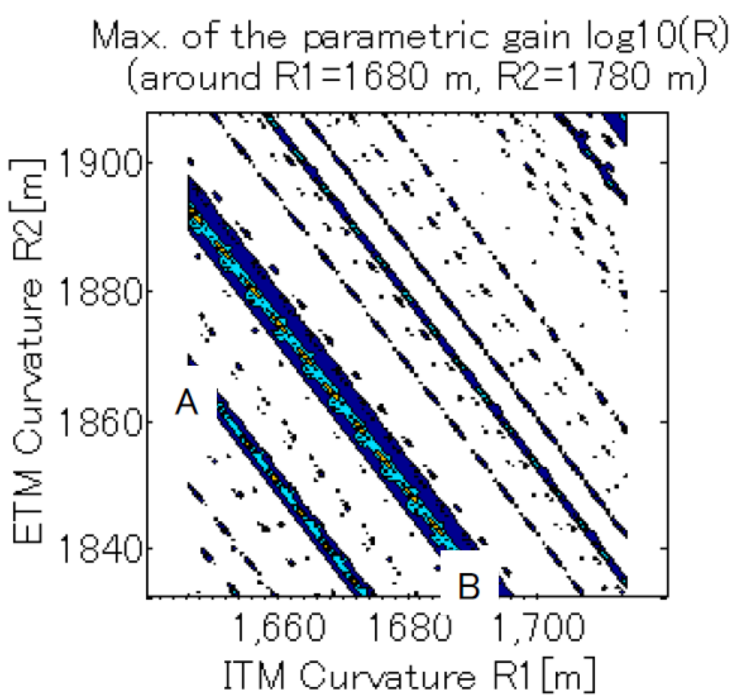
No significant difference between Positive and Negative

See JGW-G1200789

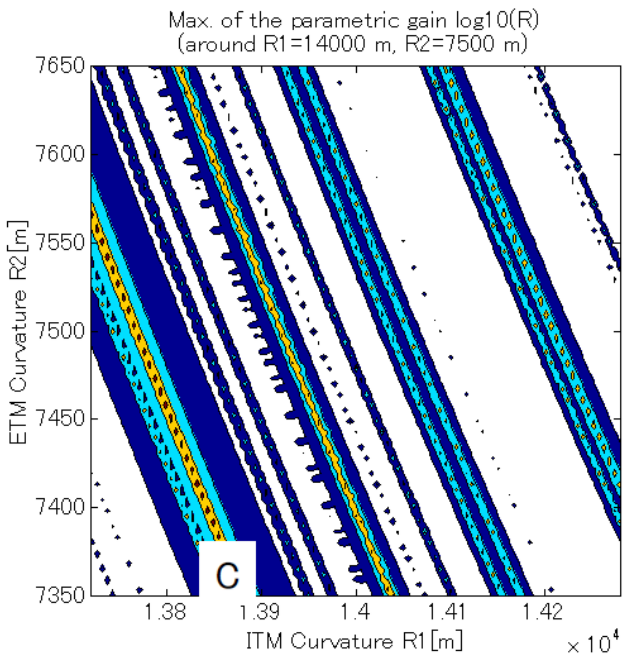
Parametric Instability

Colored area = Unstable mode exists

Negative g



Positive g



See JGW-T1200787

Sidles-Sigg Instability (ASC)

- WFS UFG for Pitch has to be lower than 1Hz
- For arm power > 330kW, Pitch instability frequency > 1Hz for positive g-factor
- Negative g-factor never makes Pitch unstable
- Current arm power (compromised to deal with high sapphire absorption) = 250kW --> even positive g-factor is OK
- Original (desirable) arm power = 376kW
  --> positive g-factor is not an option

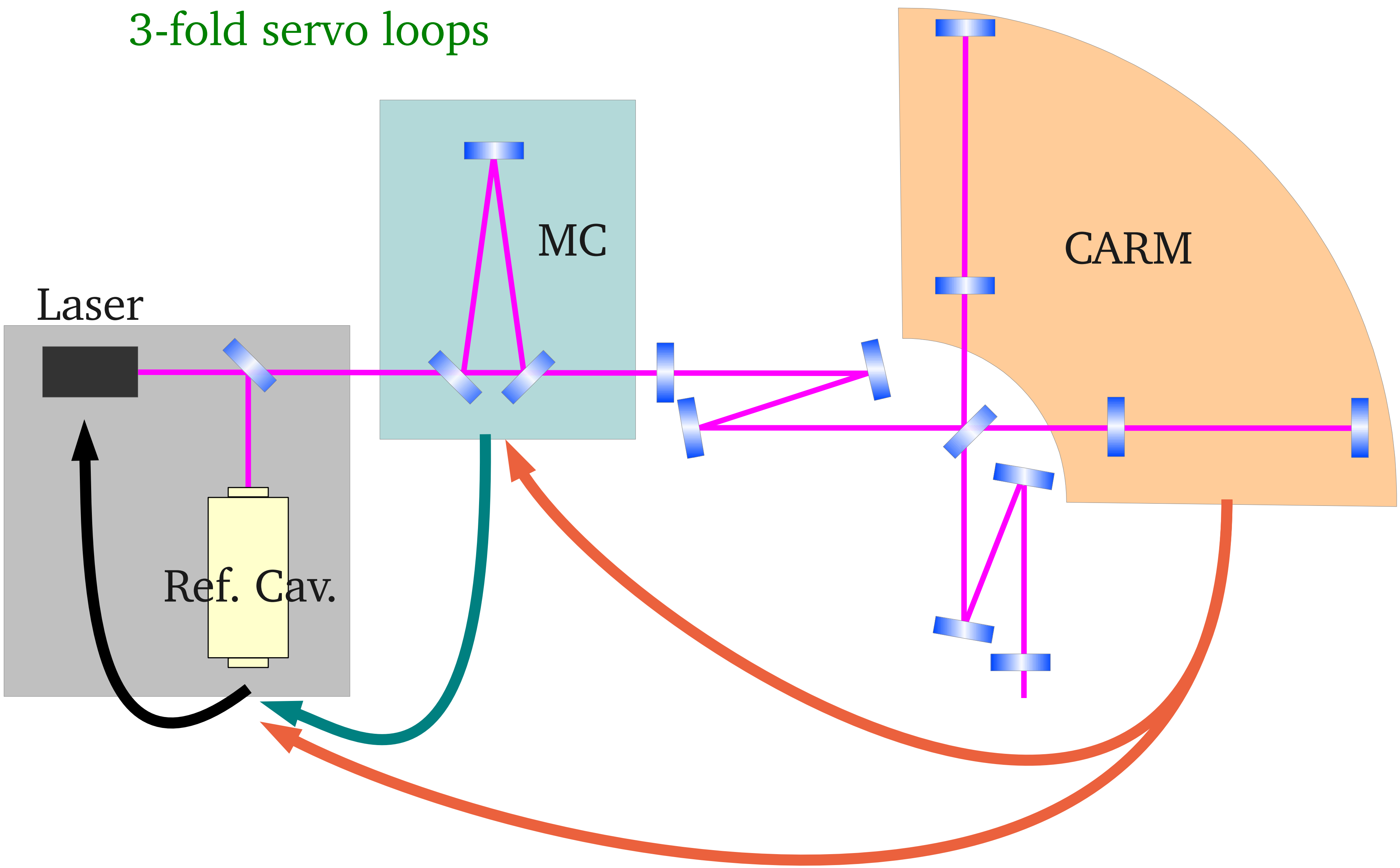
Conclusion

Negative g-factor is better

Positive g-factor limits us to operate only with low power

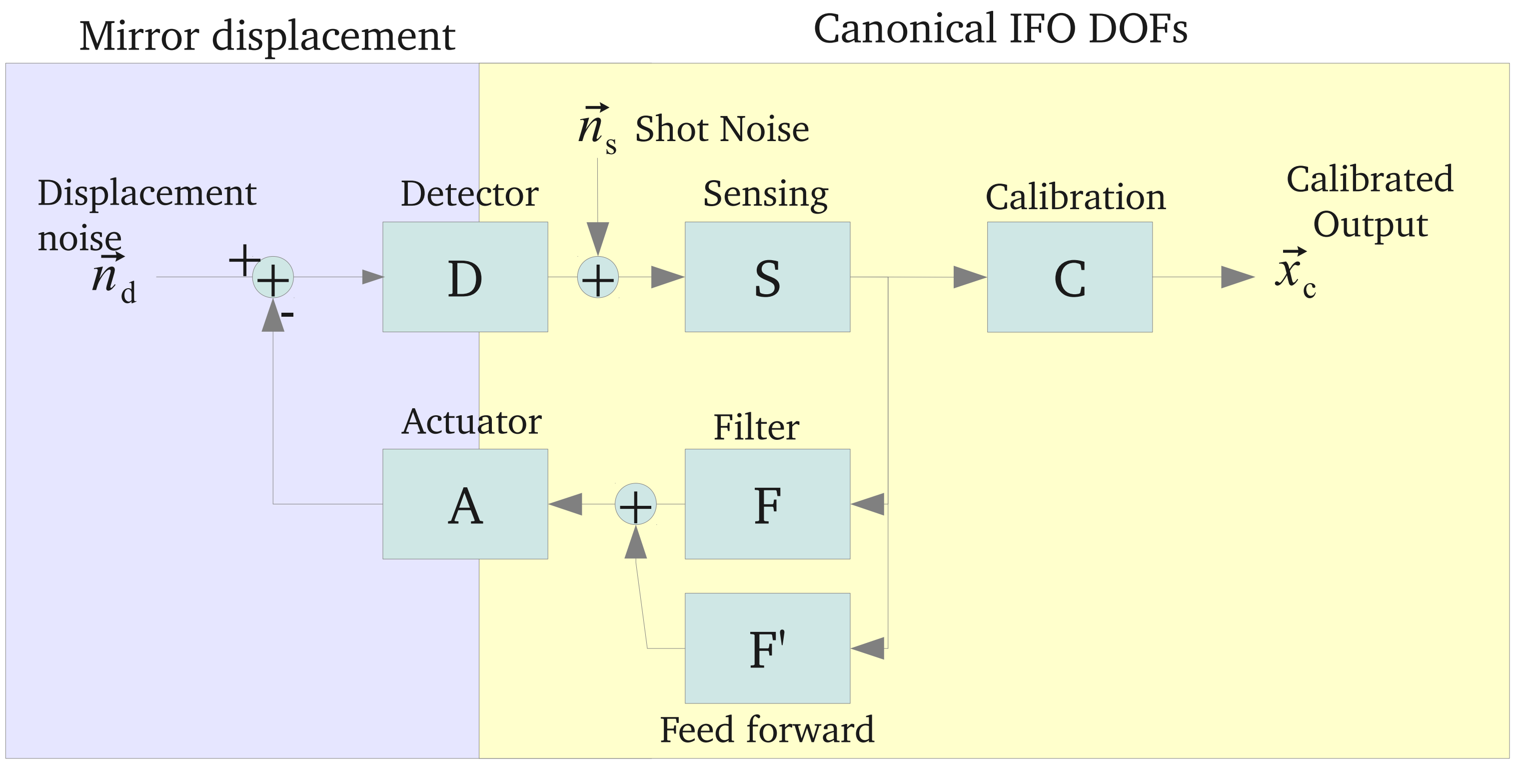
Laser Frequency Noise Requirement

Frequency Stabilization Servo Topology



Optickle Simulation

Formulation used here:



$$\vec{x}_c = (I+G)^{-1} \cdot S \cdot \vec{n}_s + (I+G)^{-1} \cdot SD \cdot \vec{n}_d$$

$$G \equiv S \cdot D \cdot A \cdot (F + F')$$

D: Optical Gain Transfer Function calculated by Optickle

A: Mechanical TFs of the mirror suspensions + optical spring stiffness

F: Feedback filters

F': Feed forward matrix

S: Sensing matrix (here I just used identity matrix)

Laser Frequency Noise Requirement

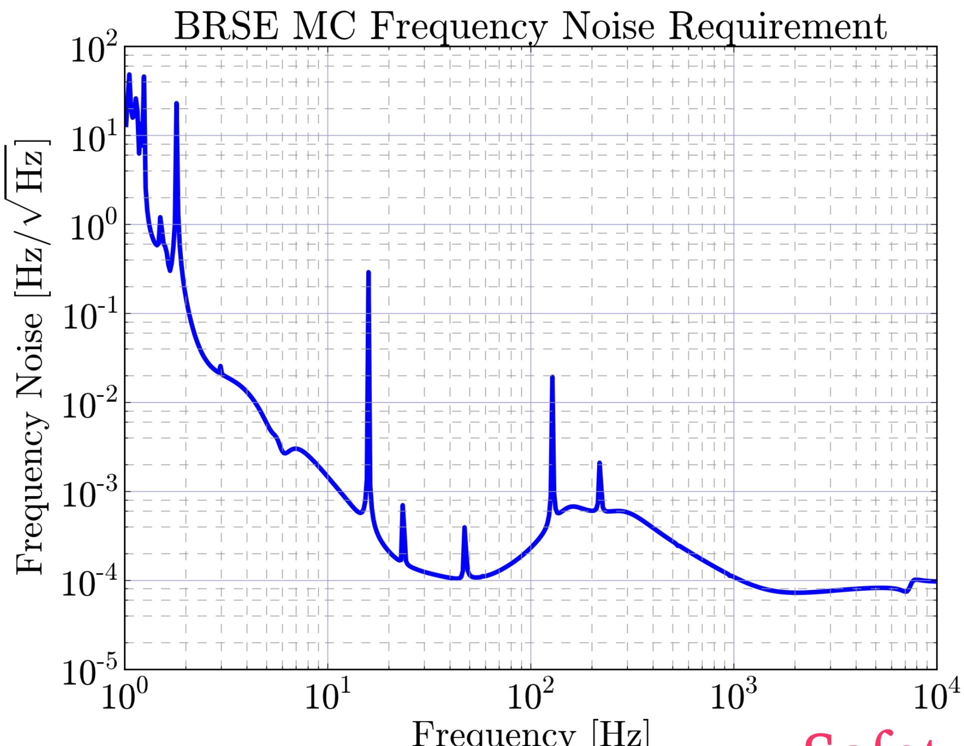
Assumption:

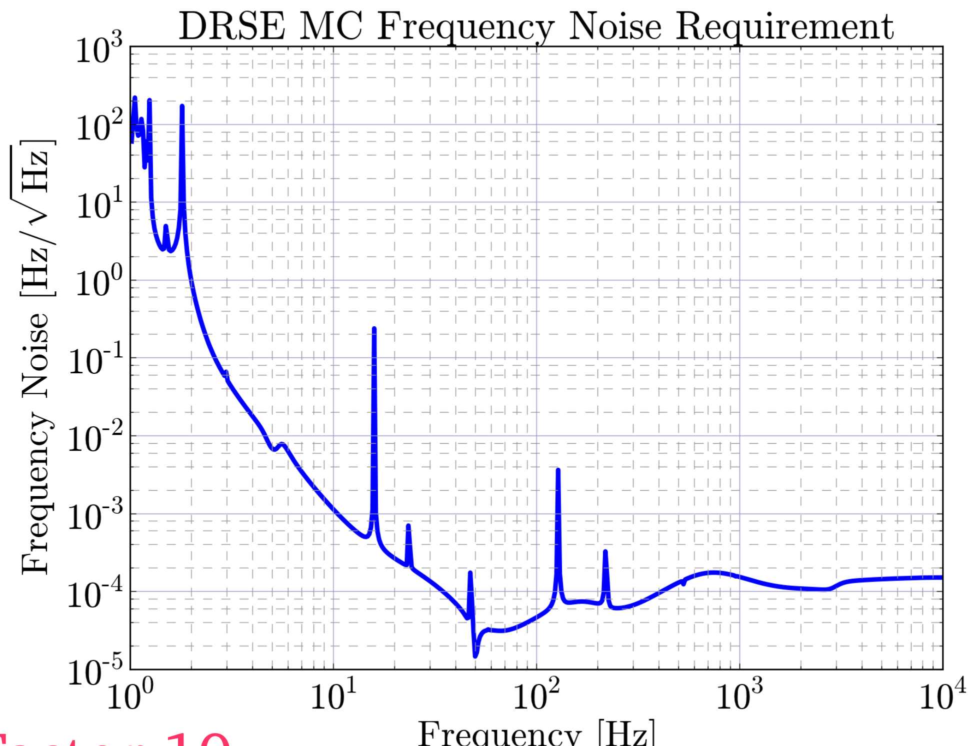
- CARM UGF=10kHz fed back to the MC and Reference Cavity error point.

Method:

- Add a PM actuator after the laser in the Optickle model.
- Measure the transfer function from the PM actuator to DARM

Frequency noise requirement without CARM feedback





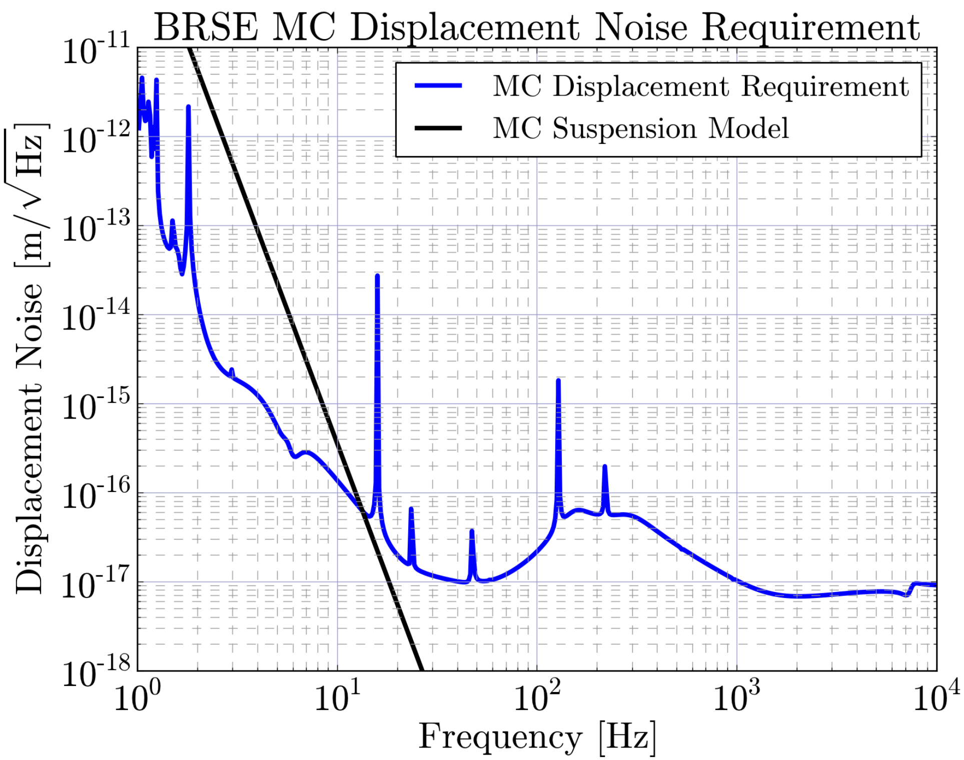
Safety Factor 10

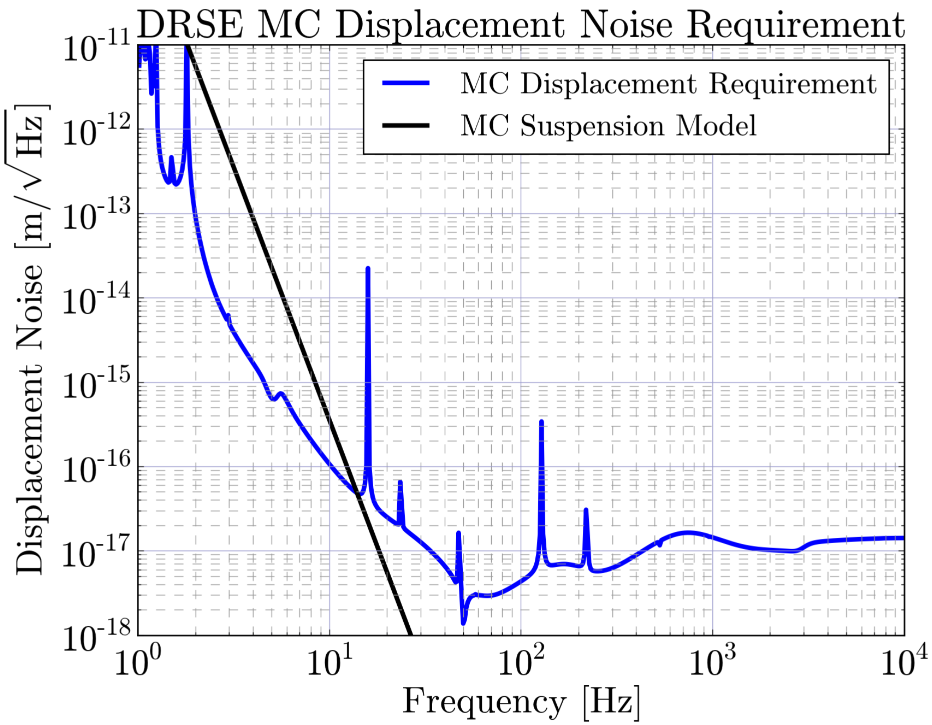
Laser Frequency Noise Requirement

Translate the frequency noise requirements into equivalent MC displacement noise.

MC suspension: (Kamioka seismic) * $(0.7/f)^4$

50cm double pendulum



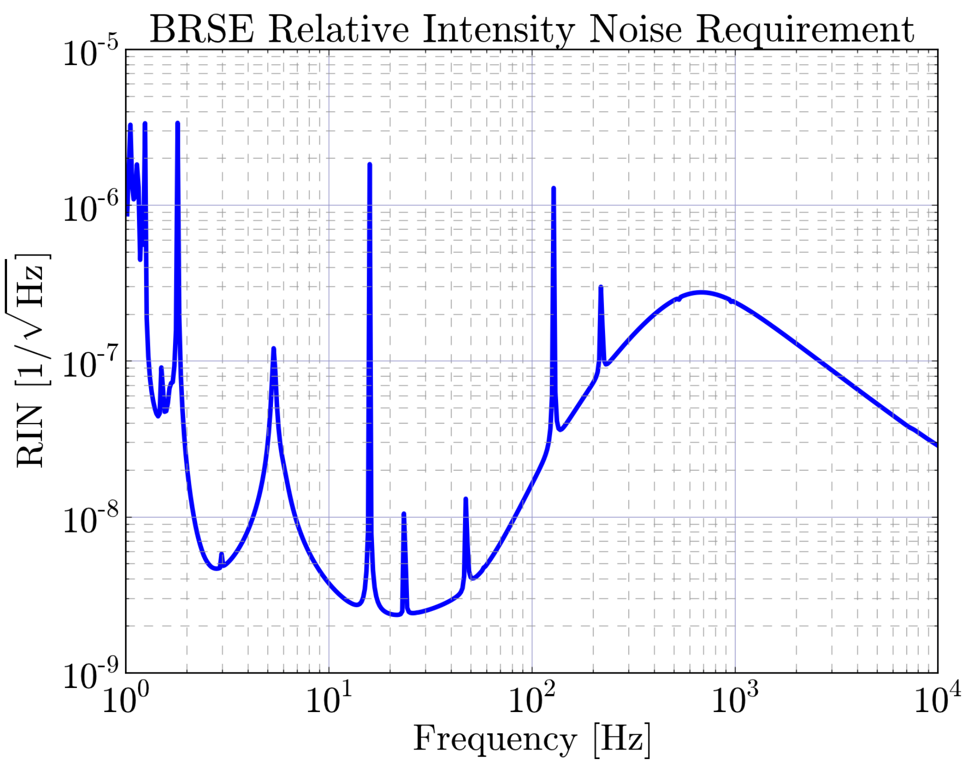


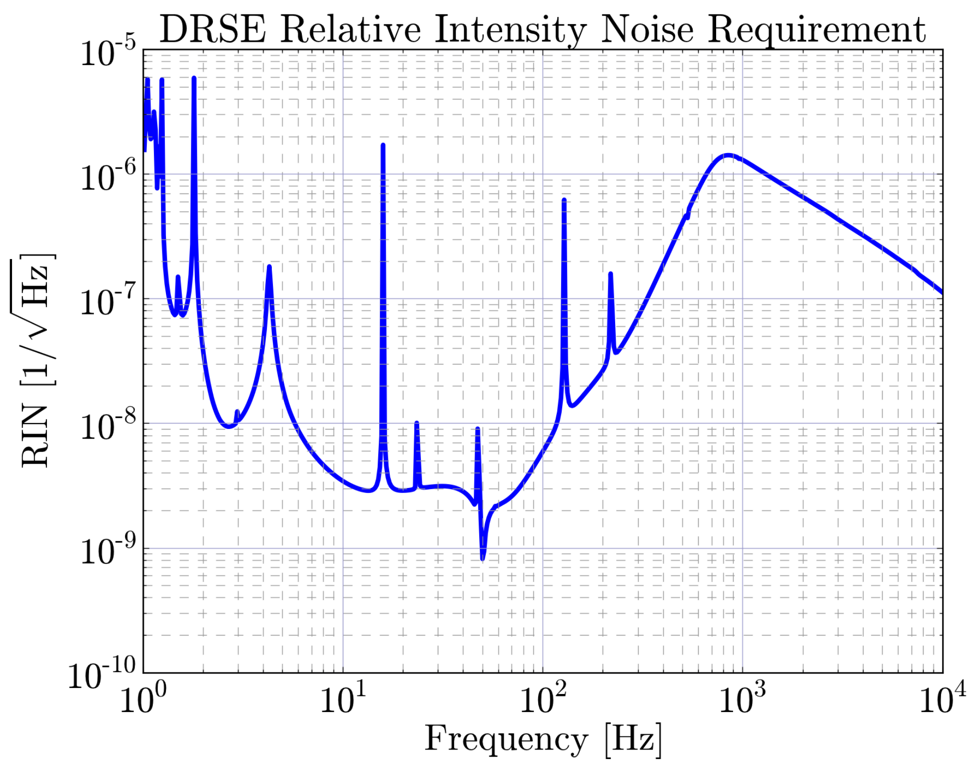
Safety Factor 10

Laser Intensity Noise Requirement

Method:

- Add an AM actuator after the laser in the Optickle model.
- Measure the transfer function from the AM actuator to DARM

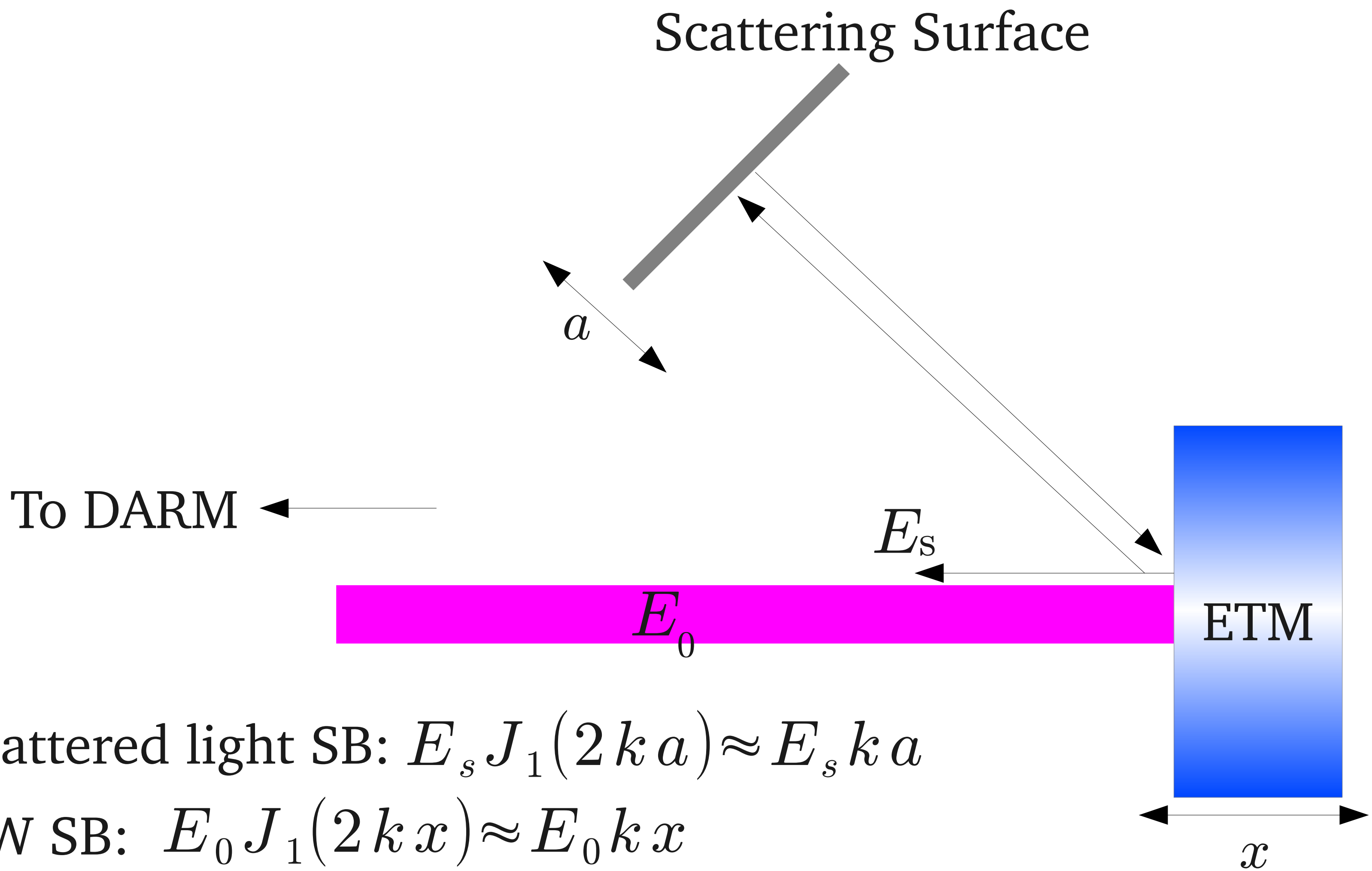




Safety Factor 10

Scattered Light Noise Requirement

Scattering Light Model



Scattered light SB: $E_s J_1(2ka) \approx E_s k a$

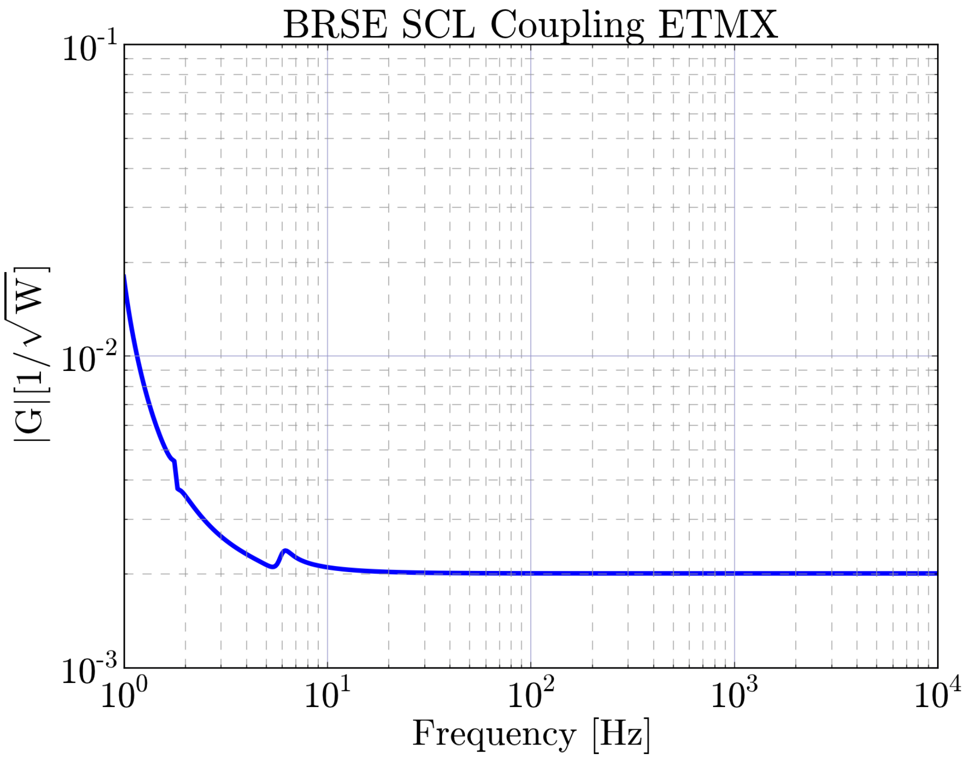
GW SB: $E_0 J_1(2kx) \approx E_0 k x$

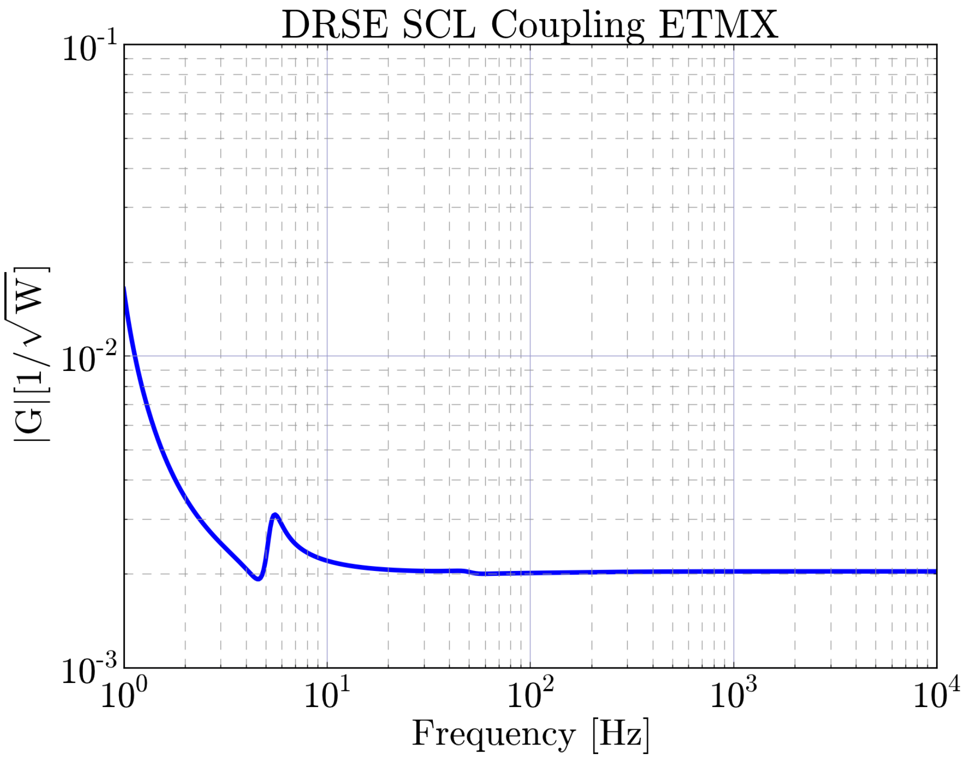
Equivalent displacement noise by SCL: $x_{scl} = G \cdot E_s \cdot a$

G: Scattered Light Gain $\sim 1/E_0 \sim 1/\mathrm{sqrt}(250\mathrm{kW}) \sim 1/500$

Scattered Light Noise Requirement

For SCL entering from ETMX
Requirement will be similar for other test masses

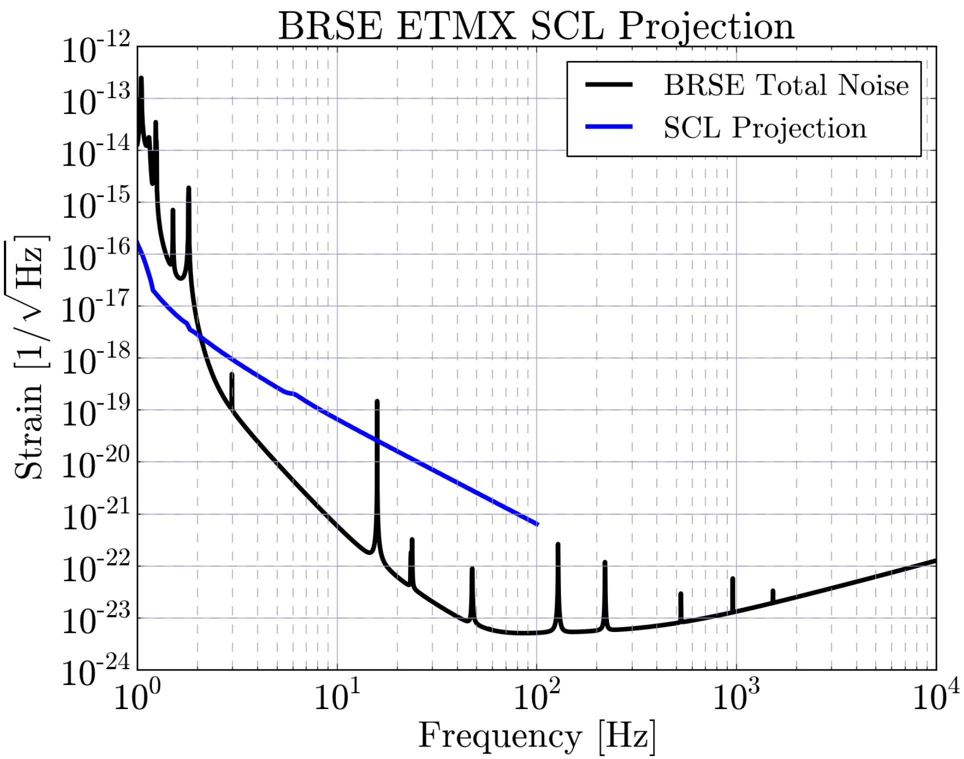


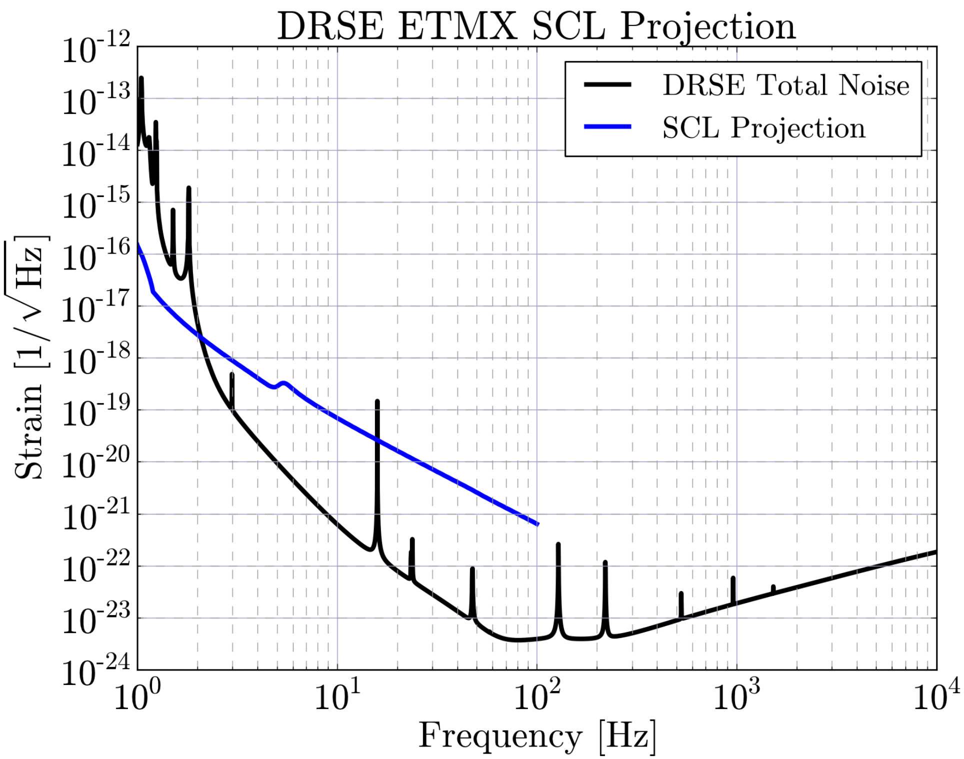


Projected Scattered Light Noise from ETM

Assumption:

- 10ppm scattering from TM HR surface
- 100% of the scattered light comes back (worst case)
- 10ppm will couple back to the interferometer
- Scattering surface vibrates with Kamioka seismic level (optimistic)



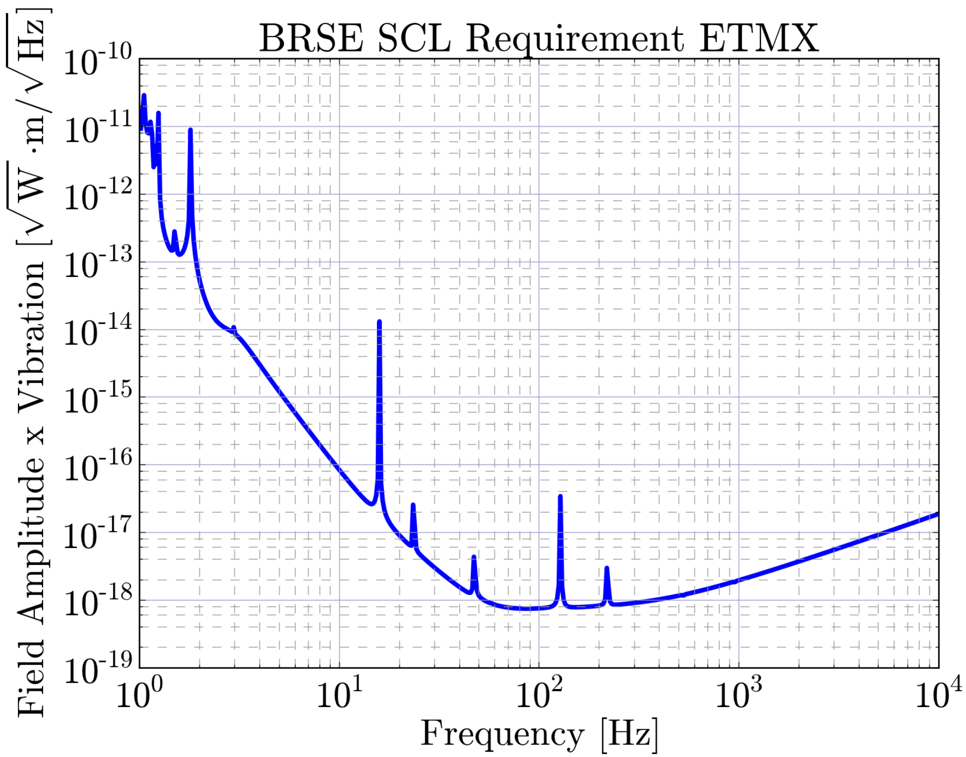


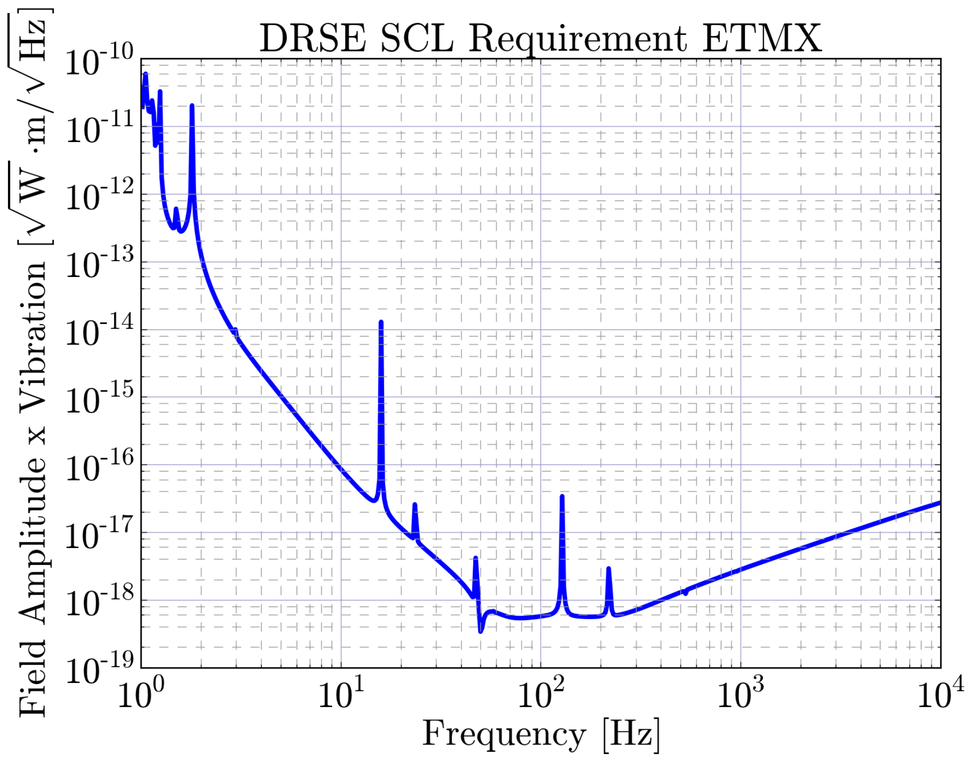
Scattered Light Noise Requirement on ETM

Requirement on $a \cdot Es$

Vibration of Scattering object → a

Scattered light amplitude coupling back to the interferometer → Es

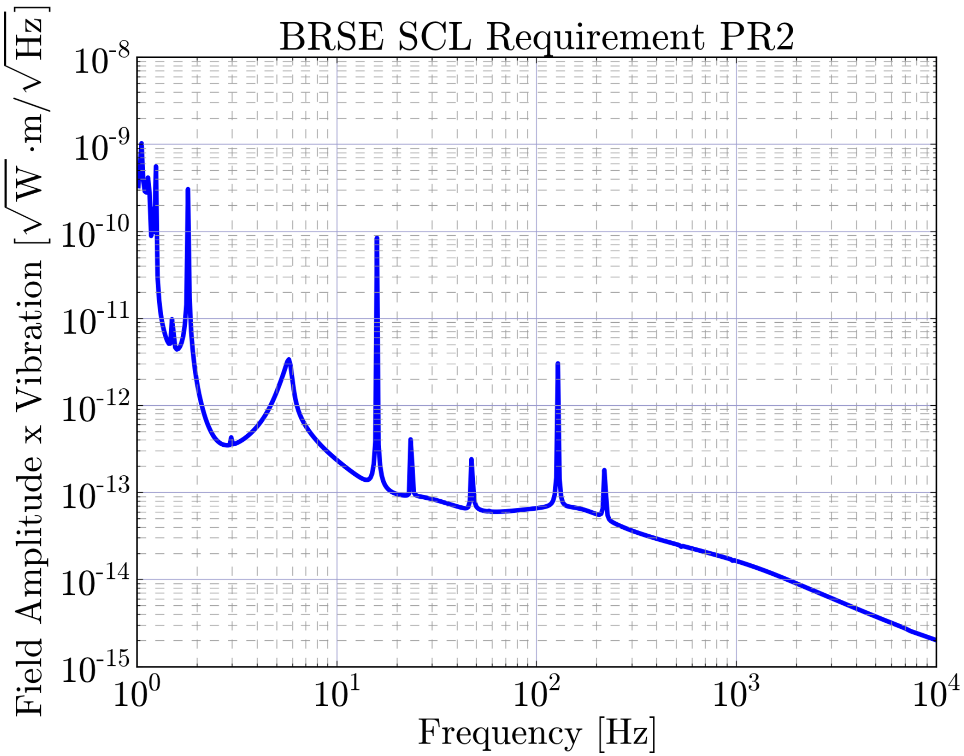


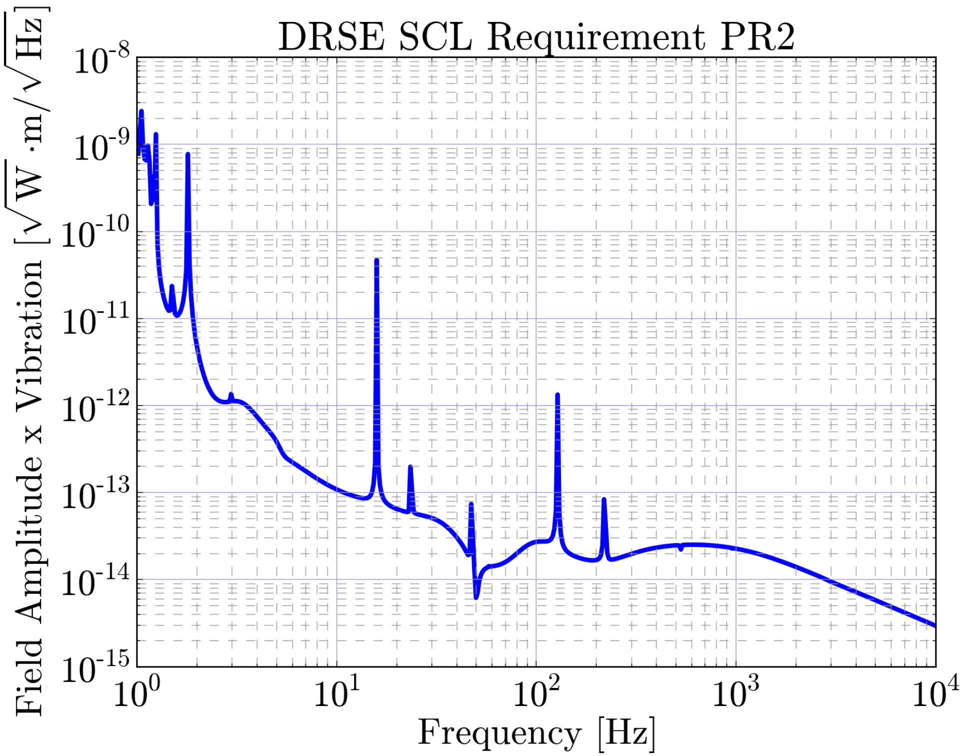


Safety Factor 10

Scattered Light Noise Requirement on PR2

For SCL entering from PR2
Requirement will be similar for other PRC mirrors

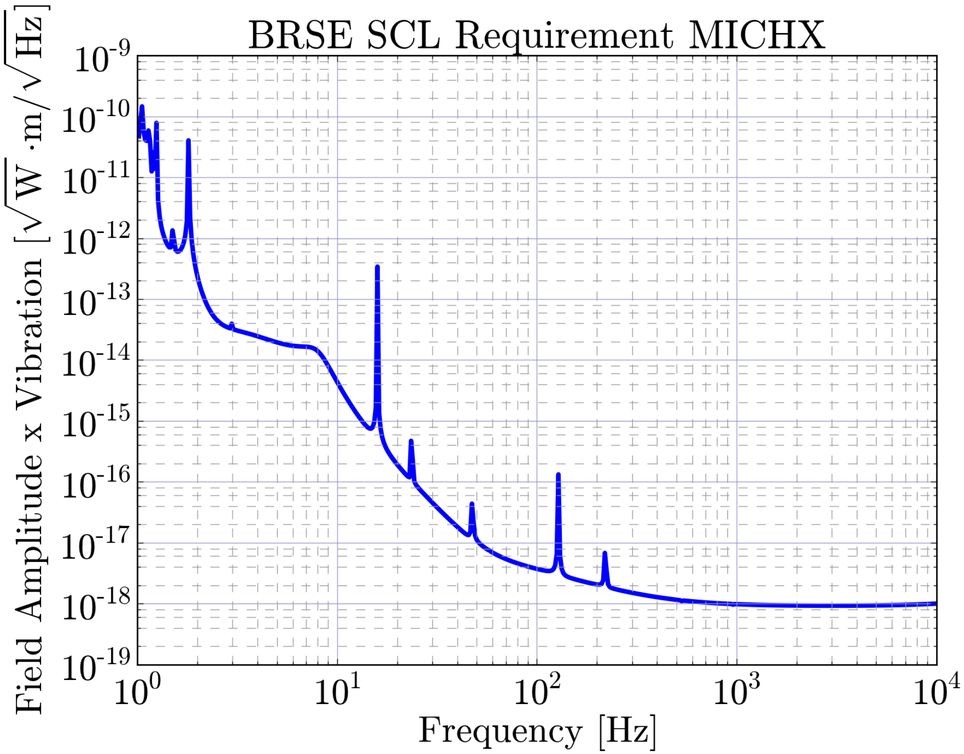


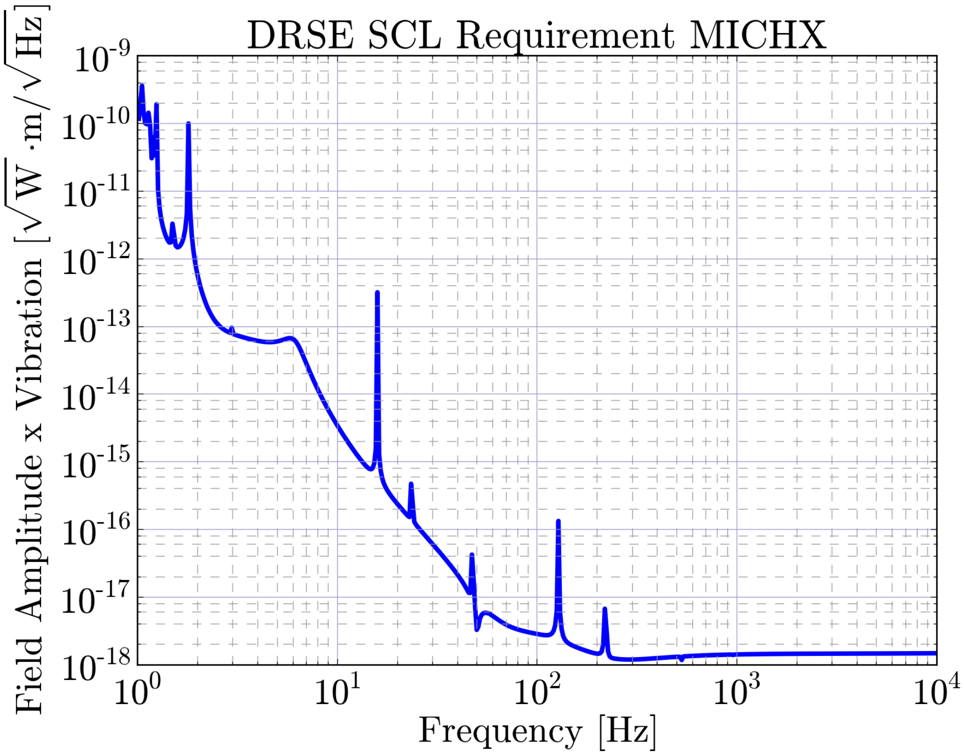


Safety Factor 10

Scattered Light Noise Requirement on MICH

For SCL entering from ITM AR.
Any scattered light coupled in MICH arm has a similar requirement.

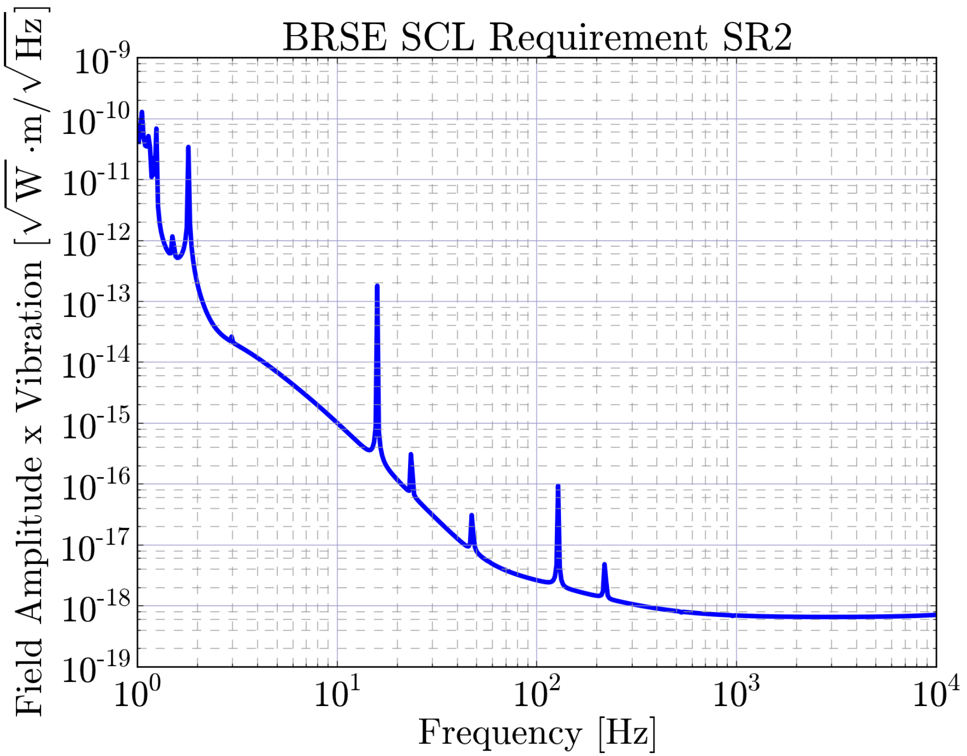


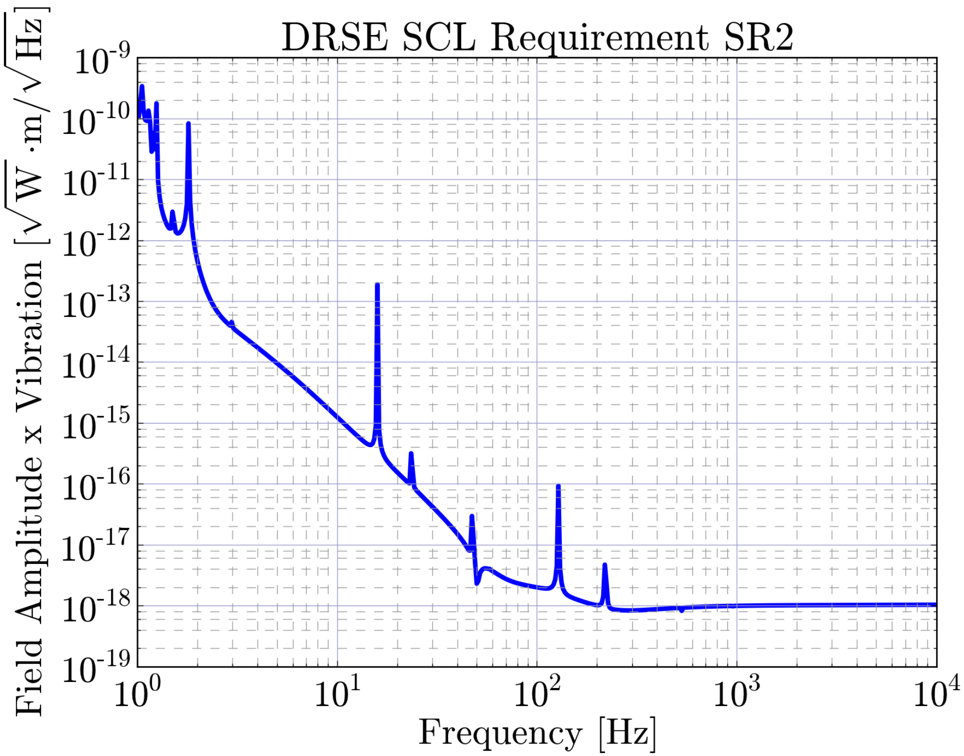


Safety Factor 10

Scattered Light Noise Requirement on SR2

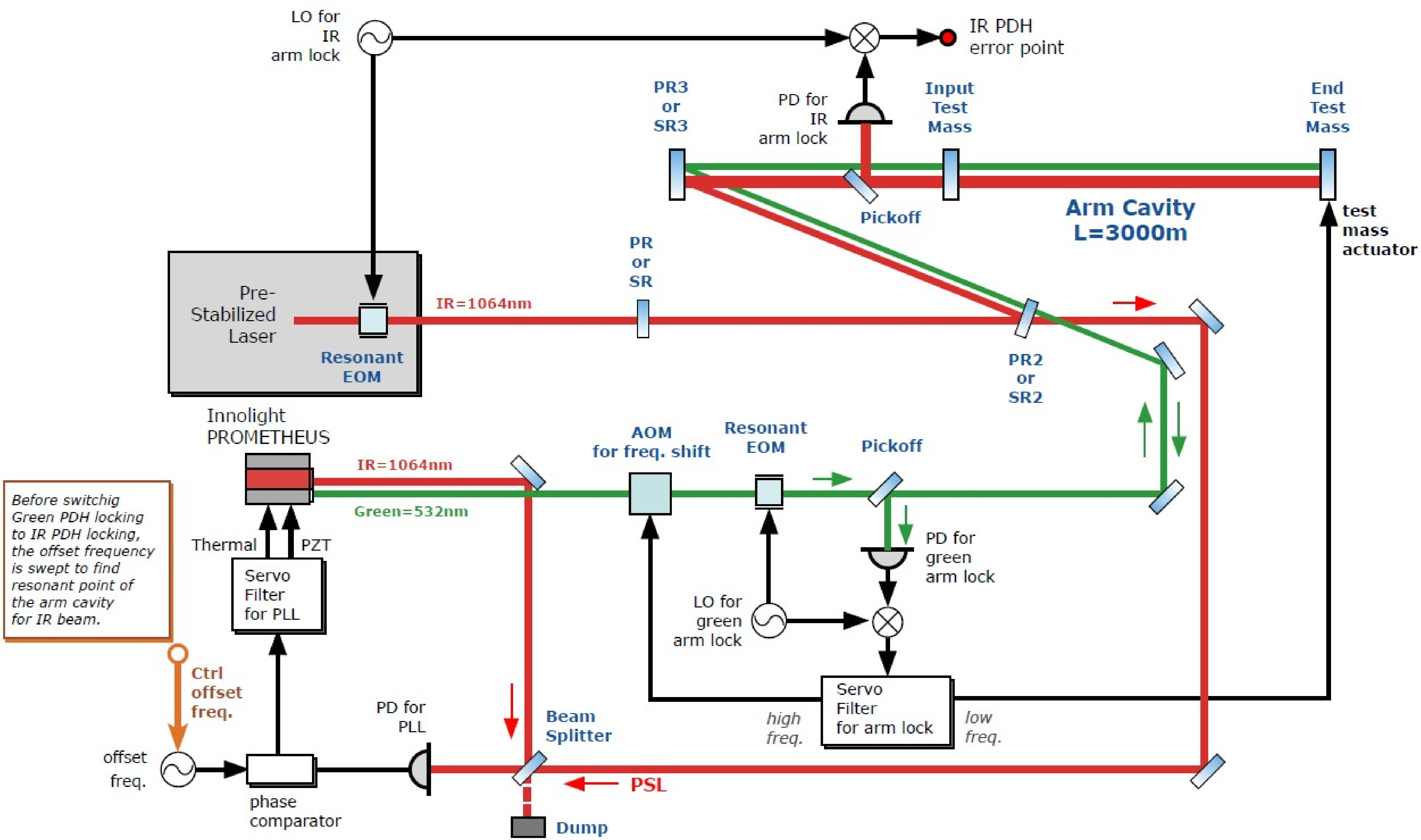
For SCL entering from SR2
Requirement will be similar for other SRC mirrors





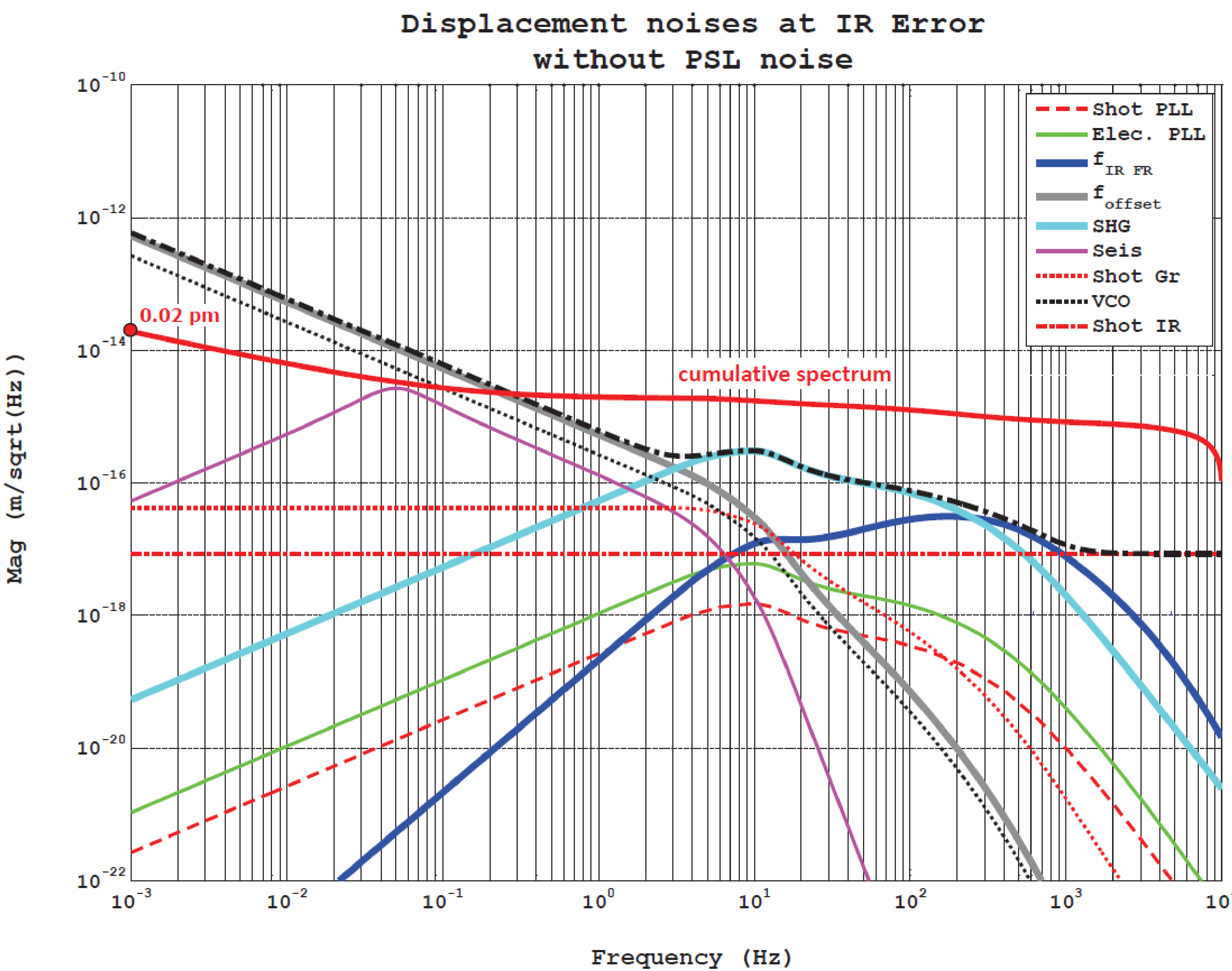
Safety Factor 10

Green Lock Setup



Arm Cavity Stability after Green Lock

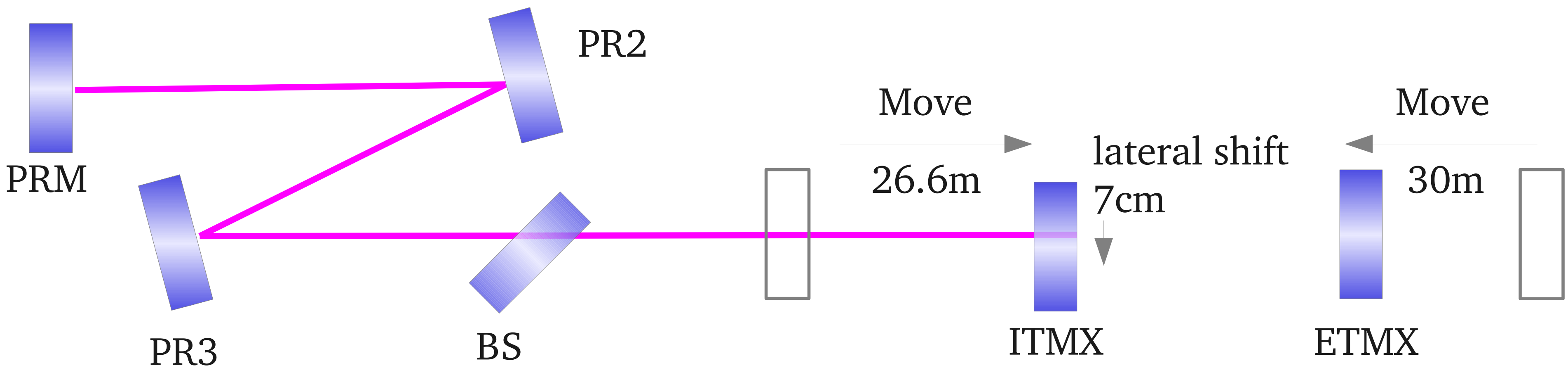
Requirement: 0.3pm RMS



(Virtual) Layout Change in iKAGRA

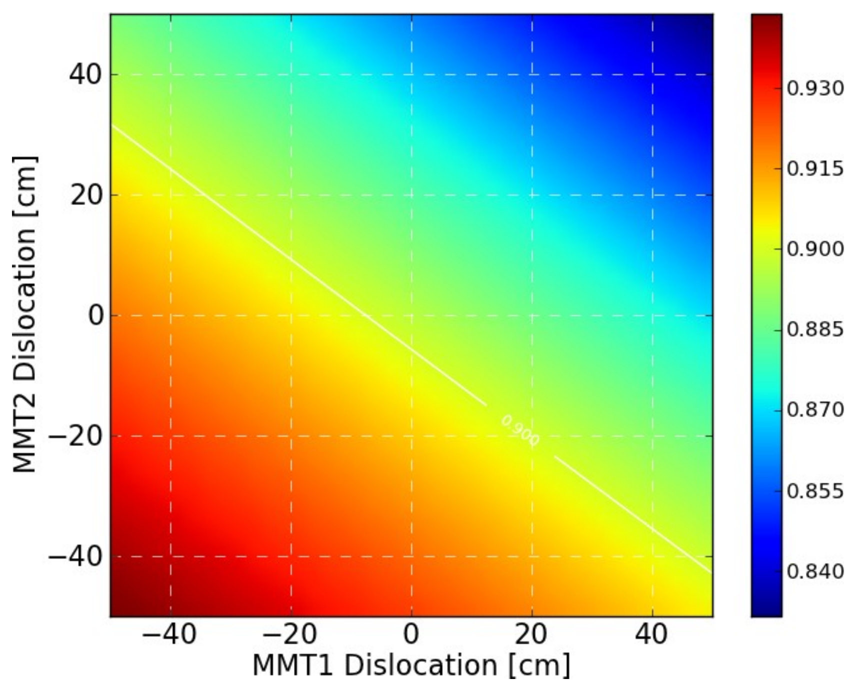
Compensate the change of ITM substrate and position

Location of ITMs: Shifted by 26.6m from the bKAGRA position
Location of ETMs: Shifted by 30m from the bKAGRA position
ITM lateral shift: 7cm

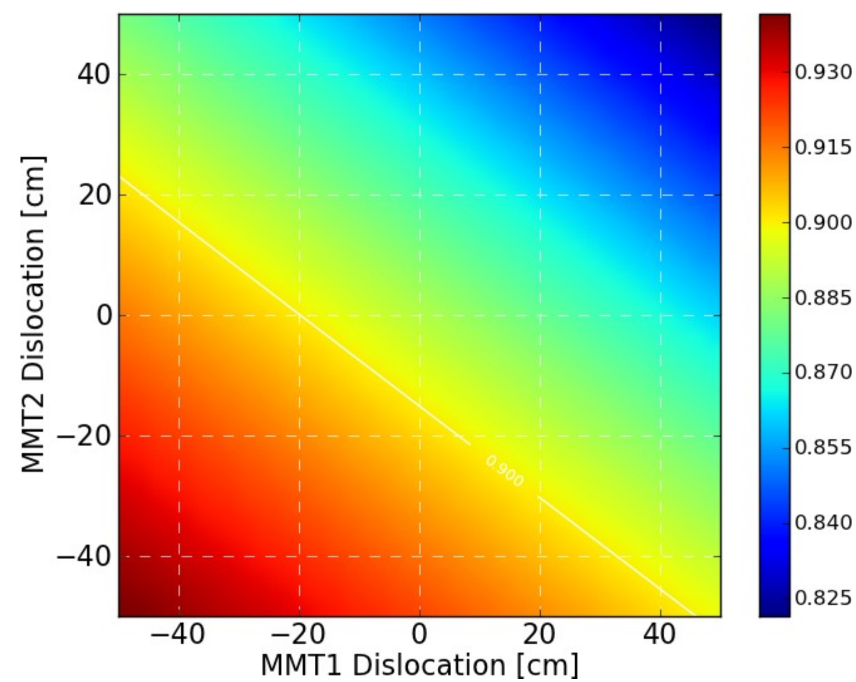


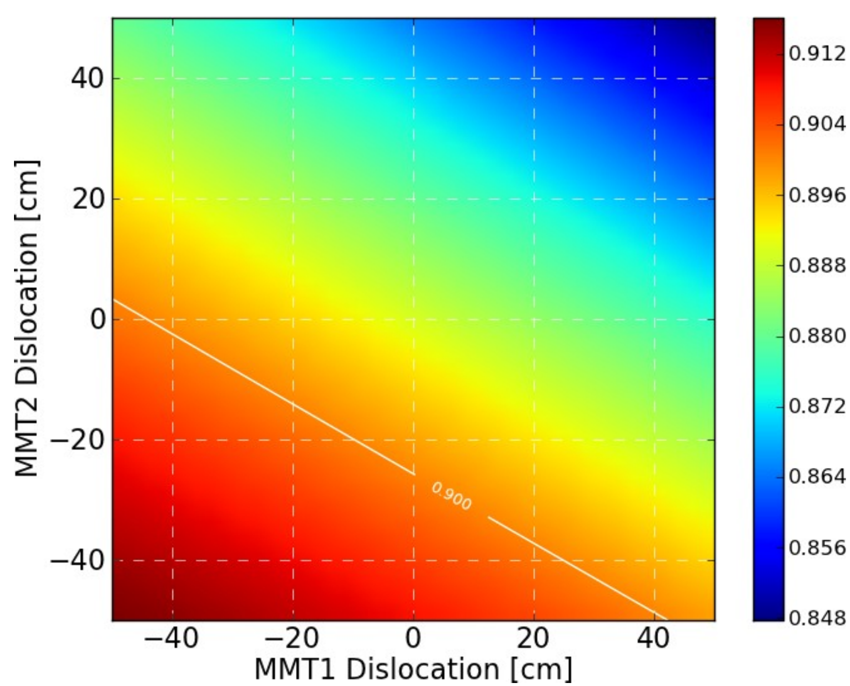
Mode Matching (iKAGRA-Ab2)

With PRM



Without PRM

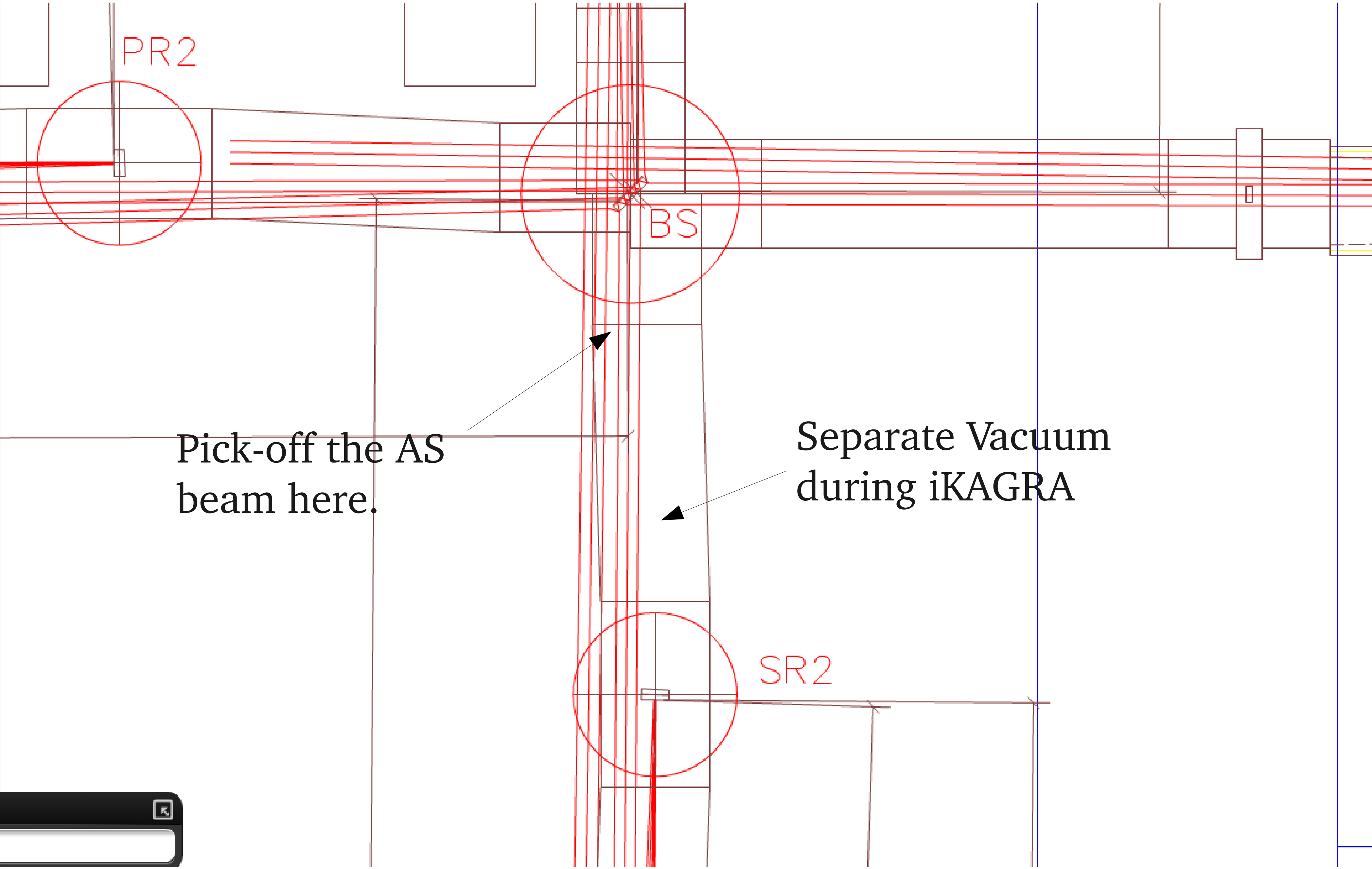




DRMI

JGW-G1200763-v1

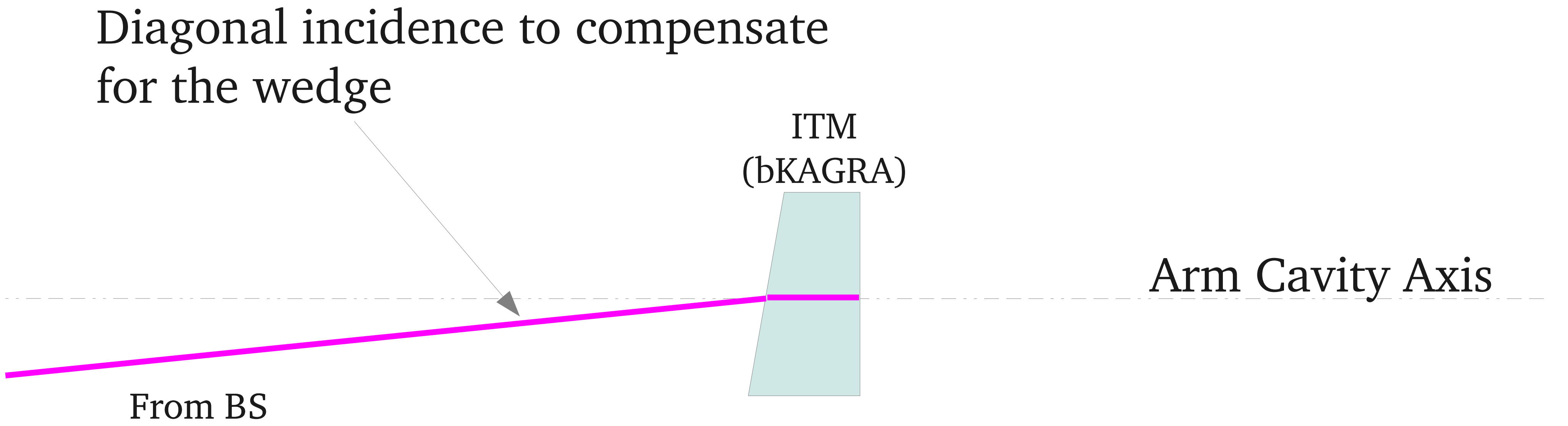
Vacuum Isolation of SRC



To Do List

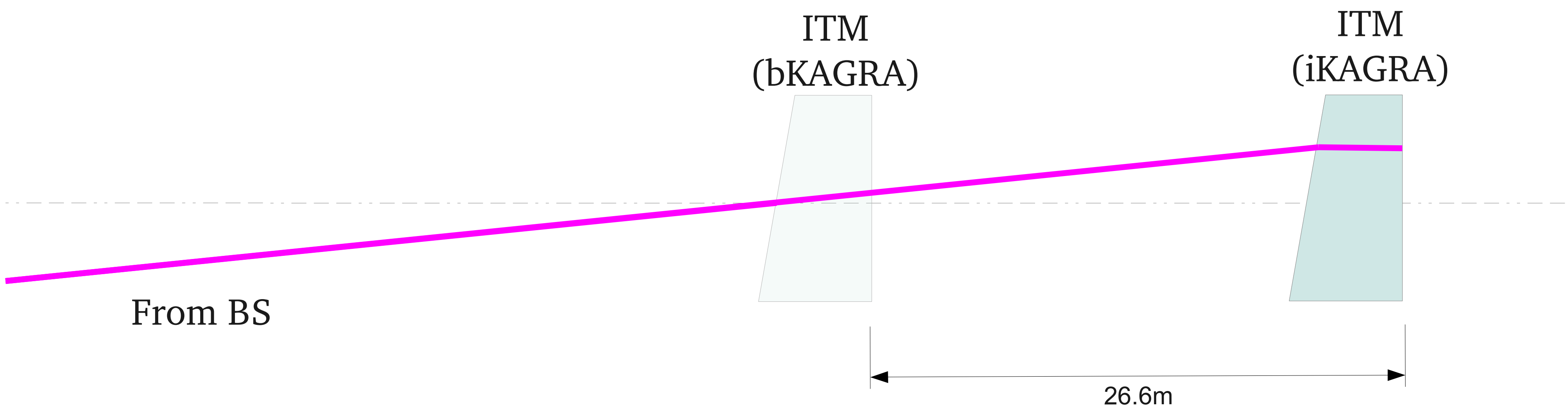
- Intensity noise, frequency noise requirements
- LSC/ASC Servo model including hierarchical actuation
- Frequency servo topology
- Servo model noise analysis
- Servo model implementation on RTS
- Green lock design
- Green injection system assembly
- Commissioning planning,
- Suspension positioning method
- Optical bench layout (with IOO)
- Analog electronics list up/Design

Appendix



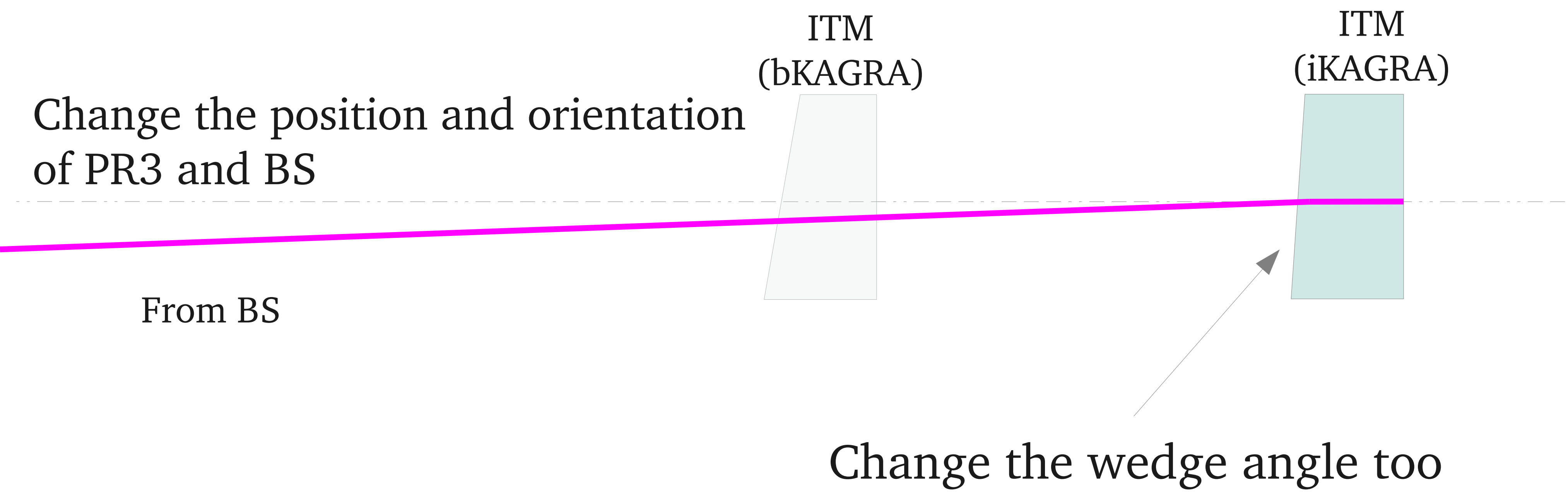
Diagonal incidence to compensate for the wedge
ITM (bKAGRA)
Arm Cavity Axis
From BS

Just moving the ITM 26.6m ahead will mis-center the beam



Adjustment Method 1

- Move BS, PR3
- Maximum movement 2cm
- Adjust SRC too



Adjustment Method 2

- Laterally move ITM
- Other mirrors stay untouched
- The beam does not go through the GV