Internal Review of Main Interferometer Subsystem

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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

Interface with other subsystems

- Mirror
  - Reflectivity, ROC, Loss, other specs.
- Suspension
  - Isolation requirements
  - Actuator design
  - Installation procedure
- Suspension+AOS
  - Local sensors
- Laser
  - Power
- IOO
  - Intensity Noise
  - Frequency Stabilization Path
  - Input/Output mode matching
  - Detection ports
  - OMC
  - Green lock
- AOS
  - Scattered light
- Digital System
  - Servo model
- Analog electronics
  - PD, QPD, I-Q demodulator, servo filters, etc
- Vacuum
  - Layout

Design Status

IFO params	semi-final	LSC principle	final
ASC principle	preliminary	Servo modeling	TBD
Green Lock Design	preliminary	Optical Layout	final
Frequency Servo	preliminary	Commissioning Plan	TBD
OMC	early stage	Analog Circuits	TBD

iLCGT Design

Target Specs

- Stably operate Fabry-Perot Michelson Interferometer
- No sensitivity requirement

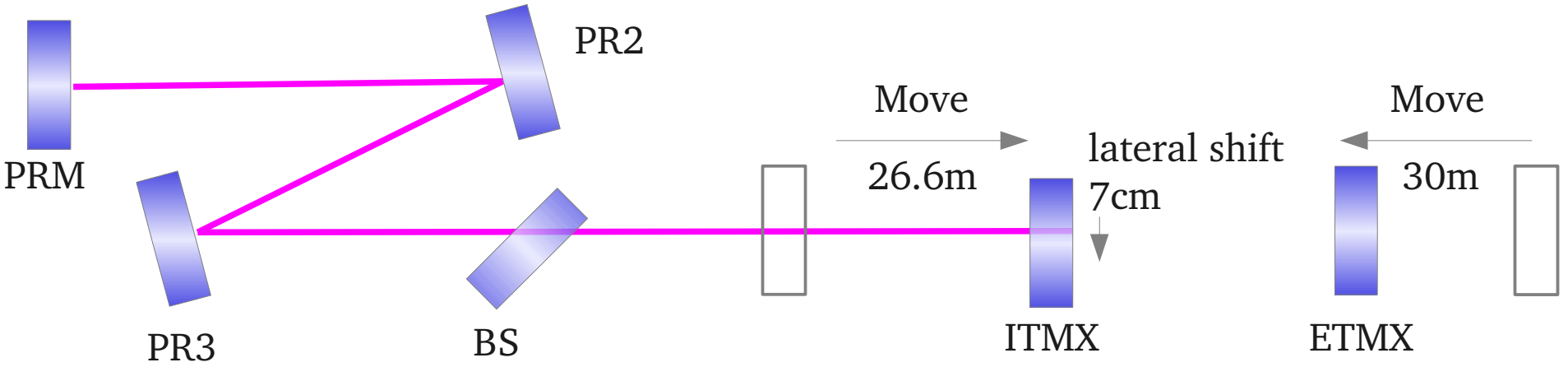
Final(?) Design

Based on bLCGT design

- Use Silica TMs
- ROCs are the same as bLCGT
- Locations of TMs are shifted by 26.6m/30m from bLCGT
  - ITMs laterally shifted by 7cm
  - Arm GV is shifted accordingly
- No folding part optimization
- PRM will not be installed (PR2, PR3 will be)
- Tweak the Input MMT to get a reasonable mode matching
- SRC is isolated vacuum wise.
- Pick-off the AS beam before the GV
- Green lock may be tested with X-arm

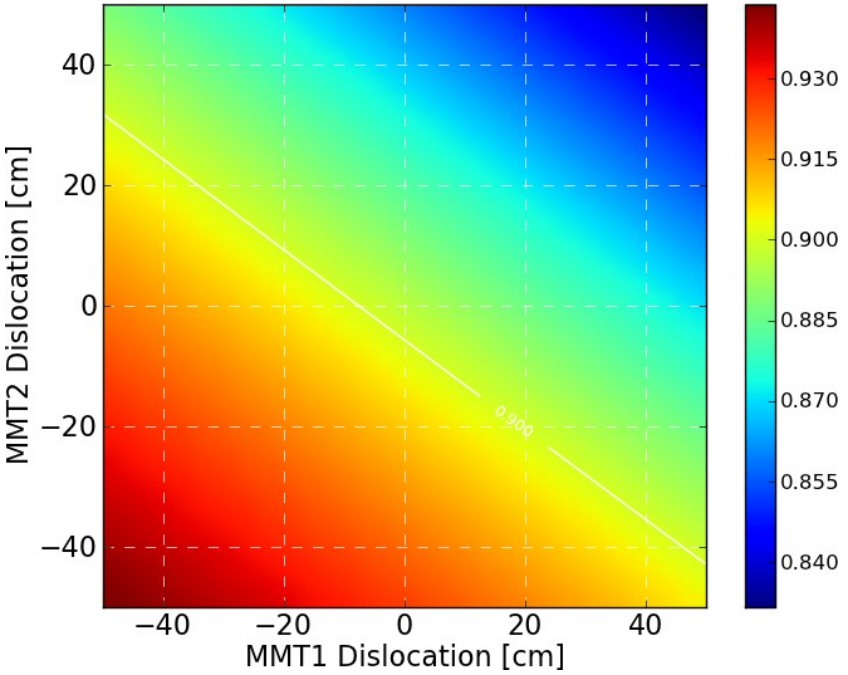
(Virtual) Layout Change in iLCGT

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

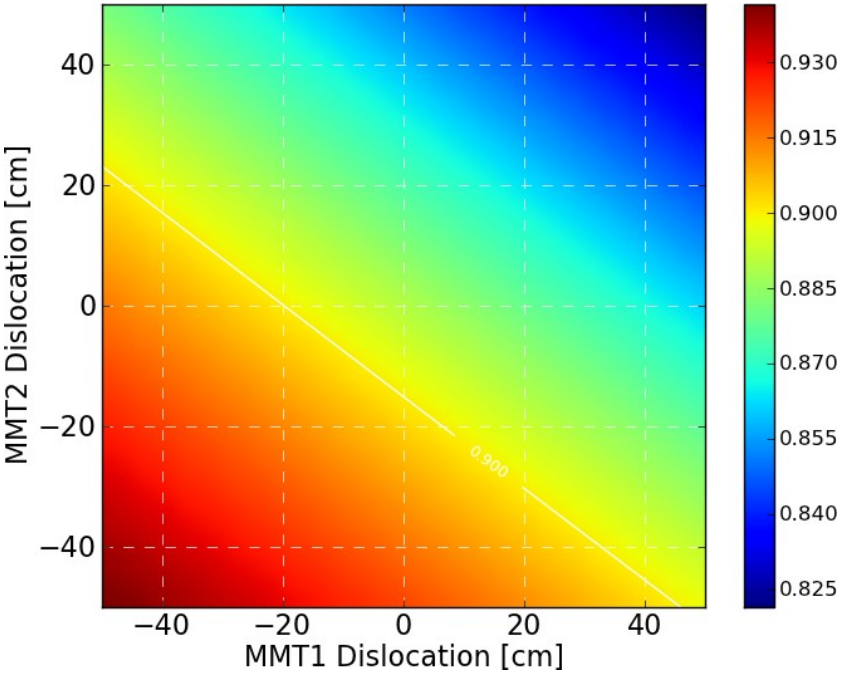


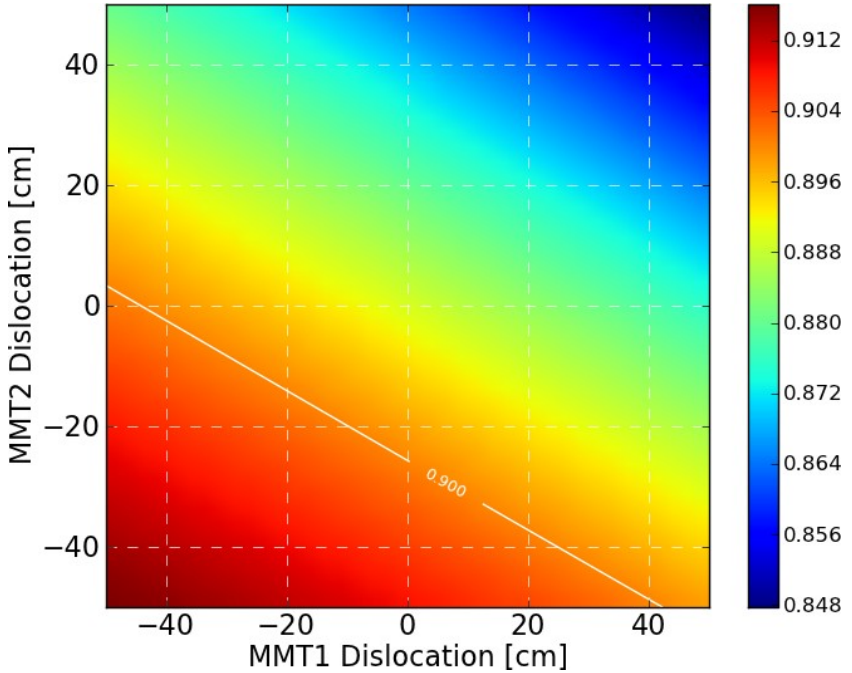
Mode Matching (iLCGT-Ab2)

With PRM



Without PRM

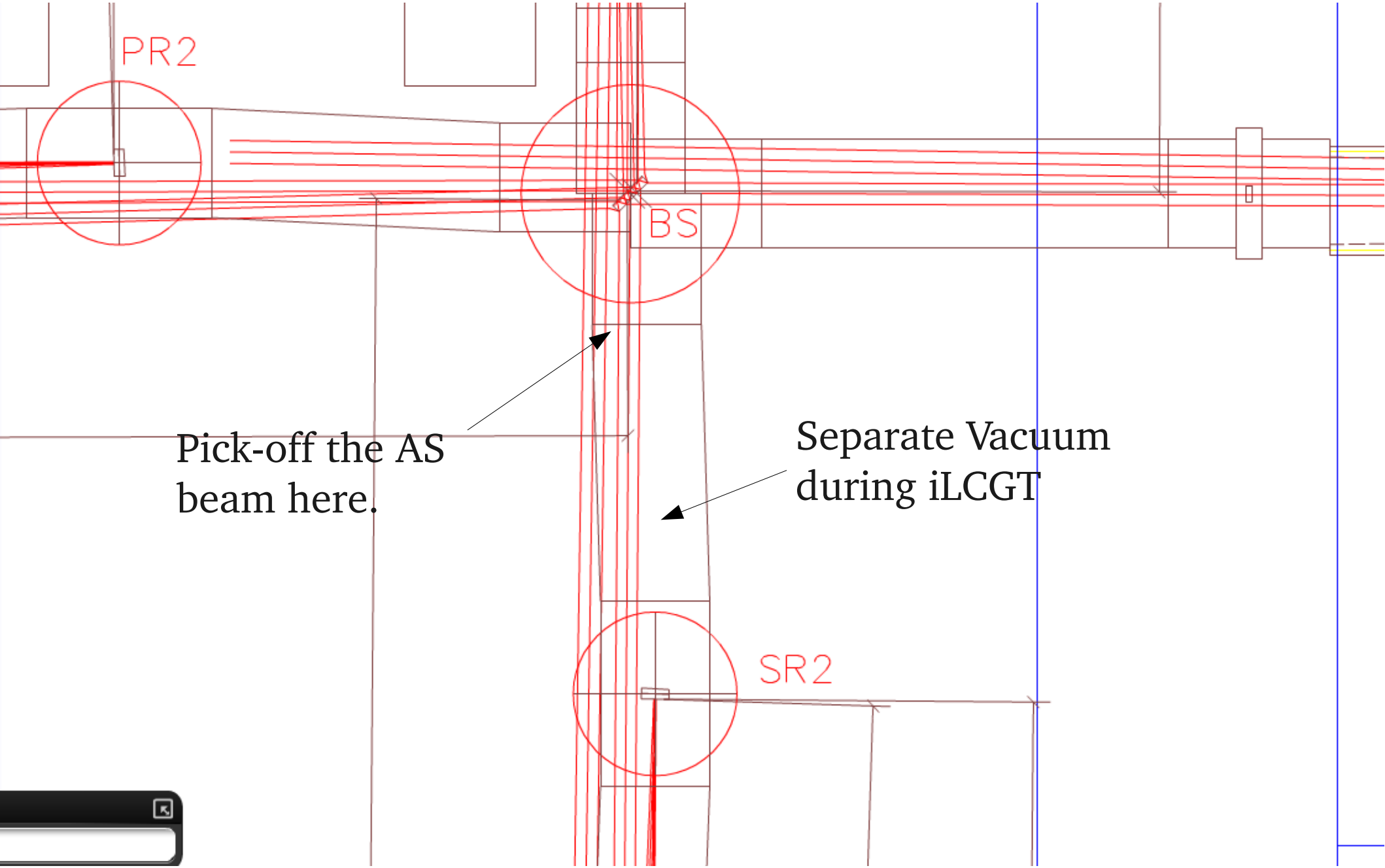




DRMI

JGW-G1200763-v1

Vacuum Isolation of SRC



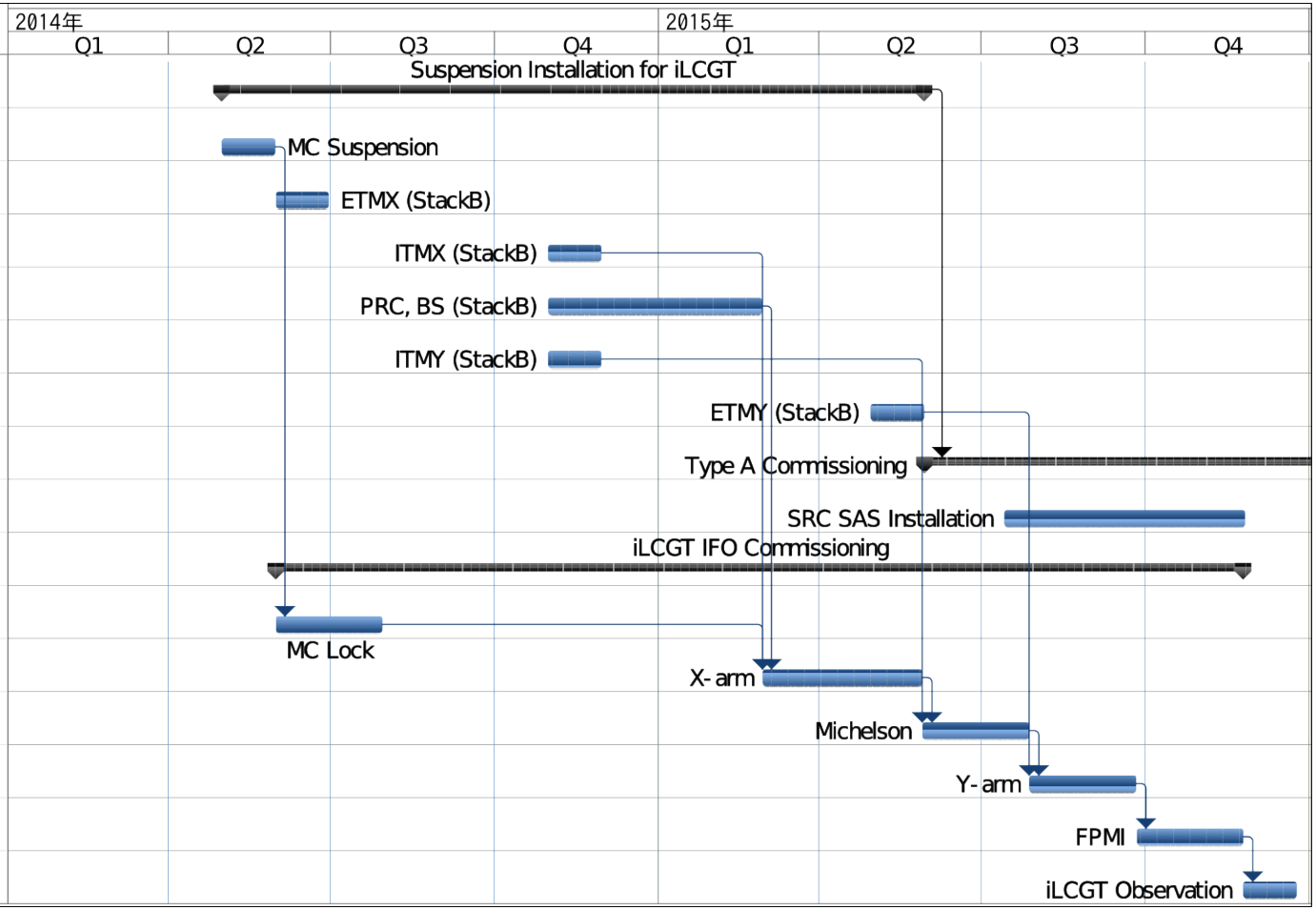
Schedule

Task list during tunnel excavation (to be finished by March 2014)

- 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

Installation & Commissioning Scenario

ID	タスク名	期間
40	**Suspension Installation for iLCGT**	394日
41	MC Suspension	1月
42	ETMX (StackB)	1月
43	ITMX (StackB)	1月
44	PRC, BS (StackB)	4月
45	ITMY (StackB)	1月
46	ETMY (StackB)	1月
47	**Type A Commissioning**	435日
55	SRC SAS Installation	4.5月
56	**iLCGT IFO Commissioning**	543日
57	MC Lock	2月
58	X-arm	3月
59	Michelson	2月
60	Y-arm	2月
61	FPMI	2月
62	iLCGT Observation	1月



Quality assurance

- Each component will be tested by corresponding subsystem (e.g. mirrors, laser, etc)
- The quality of MIF is the noise level of the interferometer
  - It is guaranteed that the quality will not meet the requirement at first
  - Thorough and careful planning for the commission is the best quality assurance

Risk Management

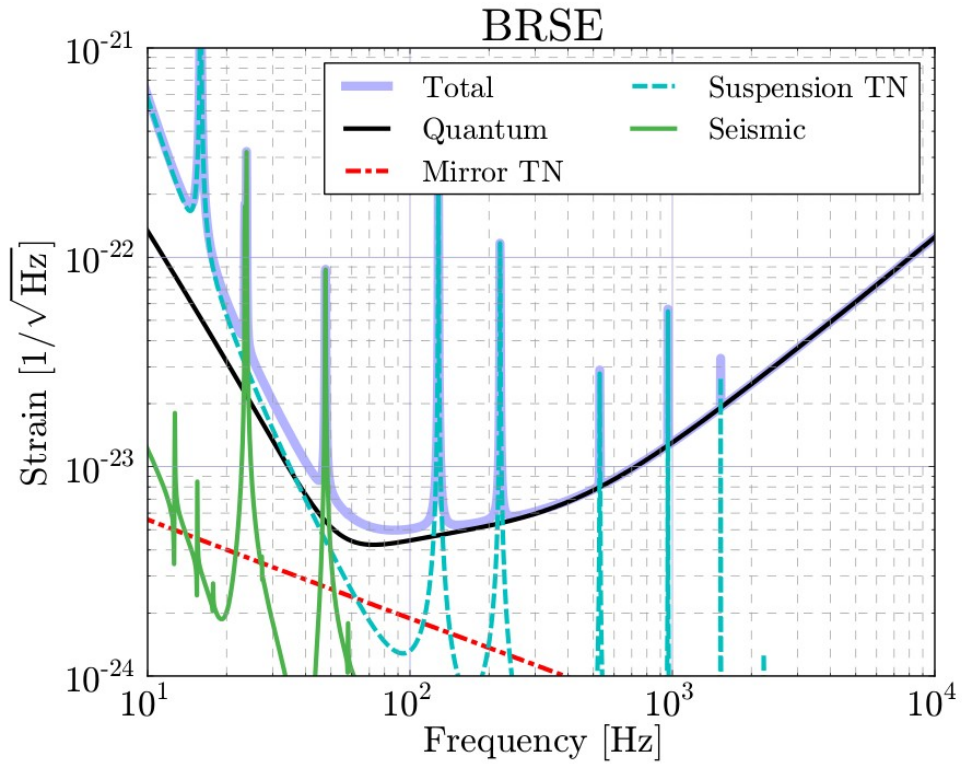
Risk factors

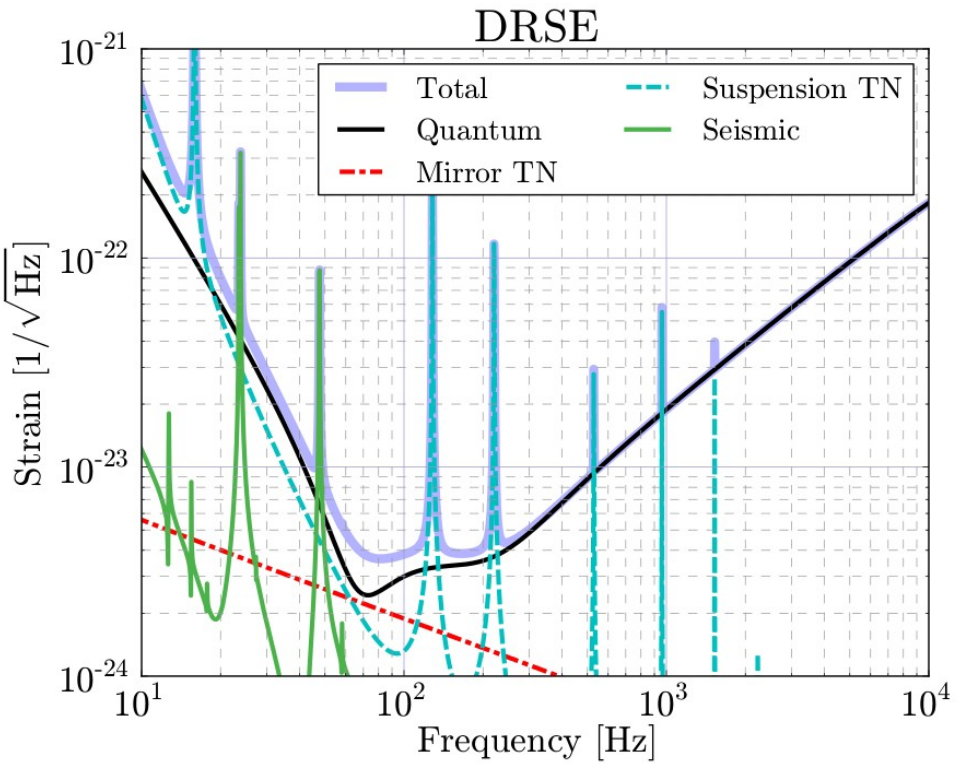
- StackB is too noisy
  => Strong damping, strong actuators at the expense of noise
- Laser frequency noise is too large
  => Spend more time on the frequency stabilization servo
- Mirror quality is poor
  => ....
- Commissioning takes too long (very likely to happen)
  => Work harder folks !

bLCGT

Requirements

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





Preliminary 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

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

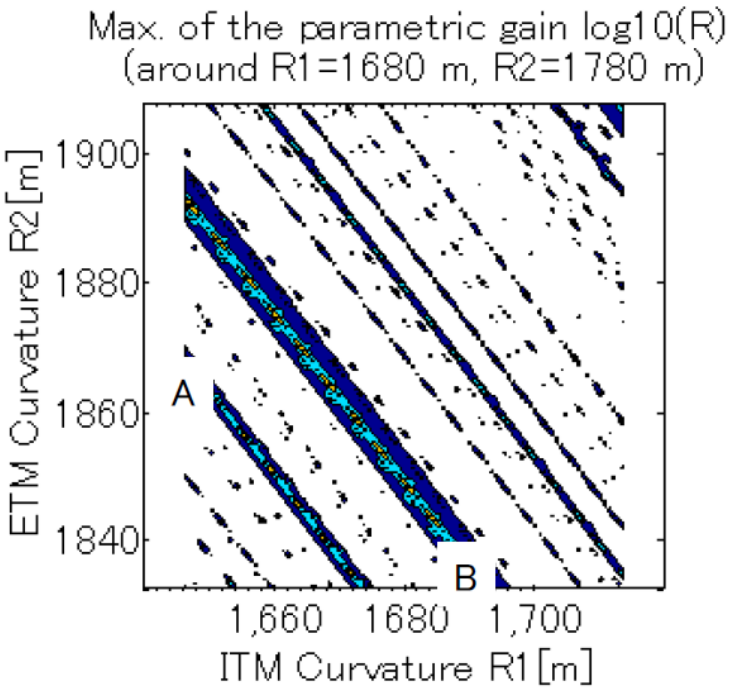
No significant difference between Positive and Negative

See JGW-G1200789

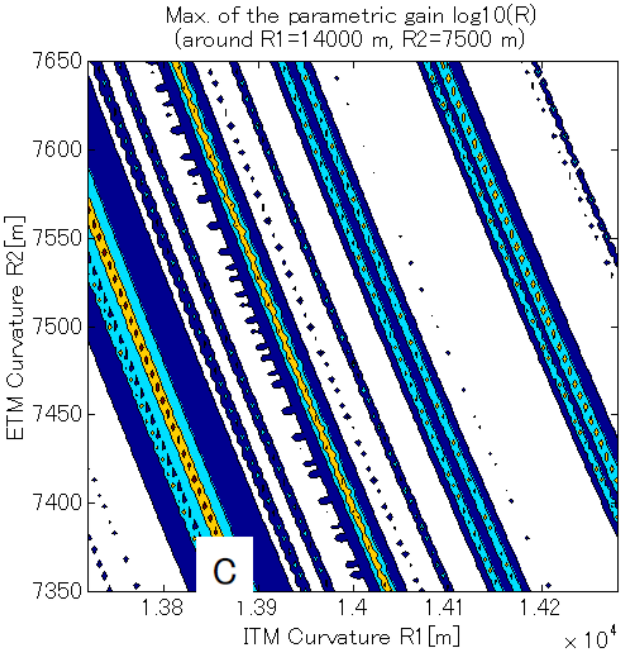
Parametric Instability

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

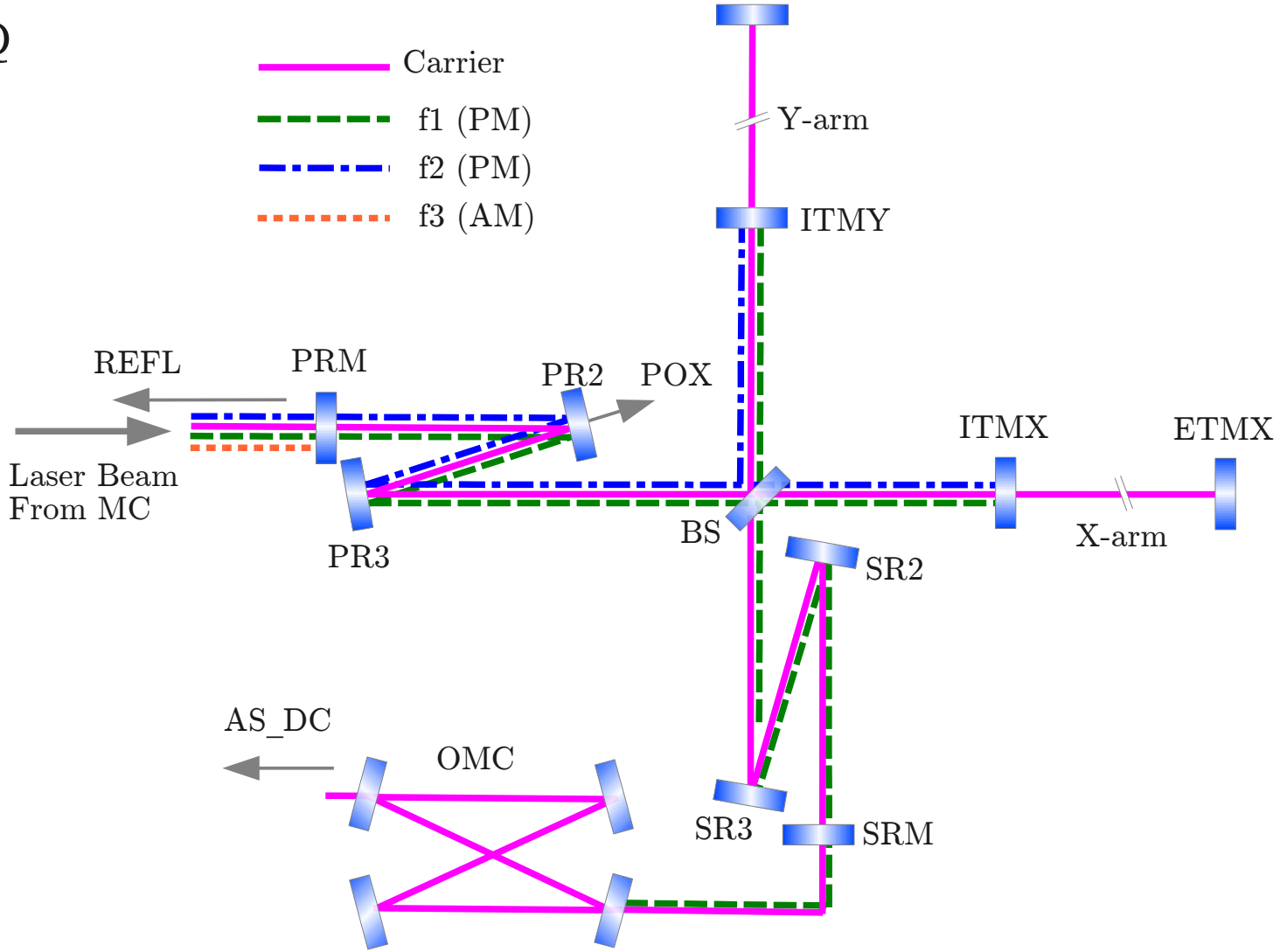
Negative g-factor is better

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

Sideband Resonant Conditions for Signal Extraction

Signal Ports

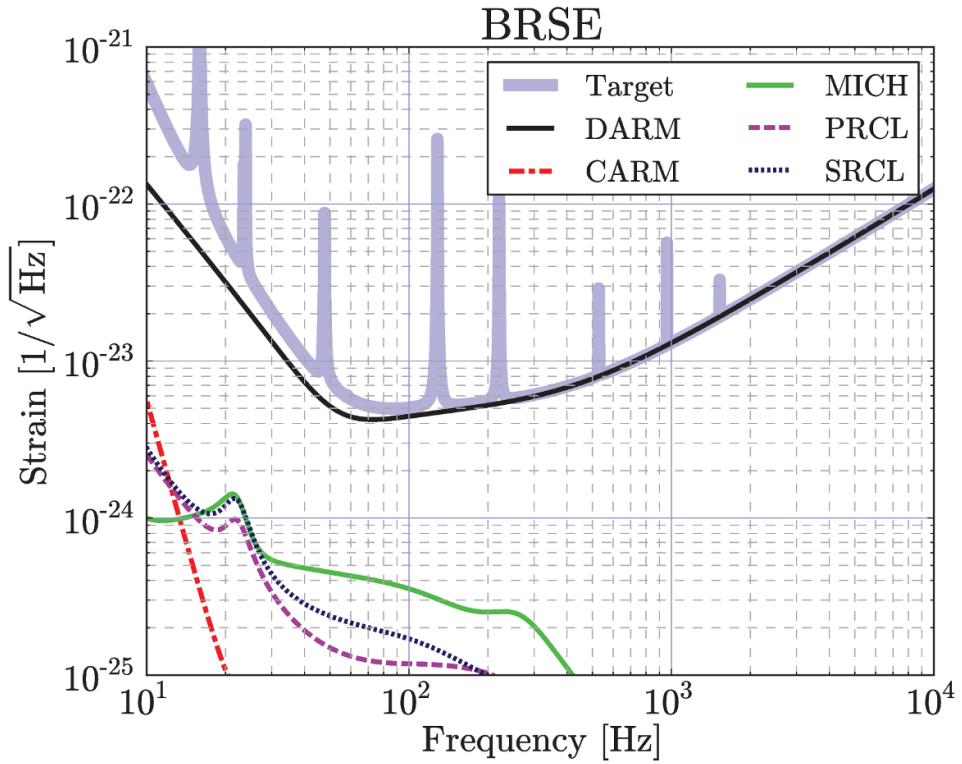
DARM: AS_DC
CARM: REFL_1I
MICH: REFL_1Q
PRCL: POP_2I
SRCL: POP_1I

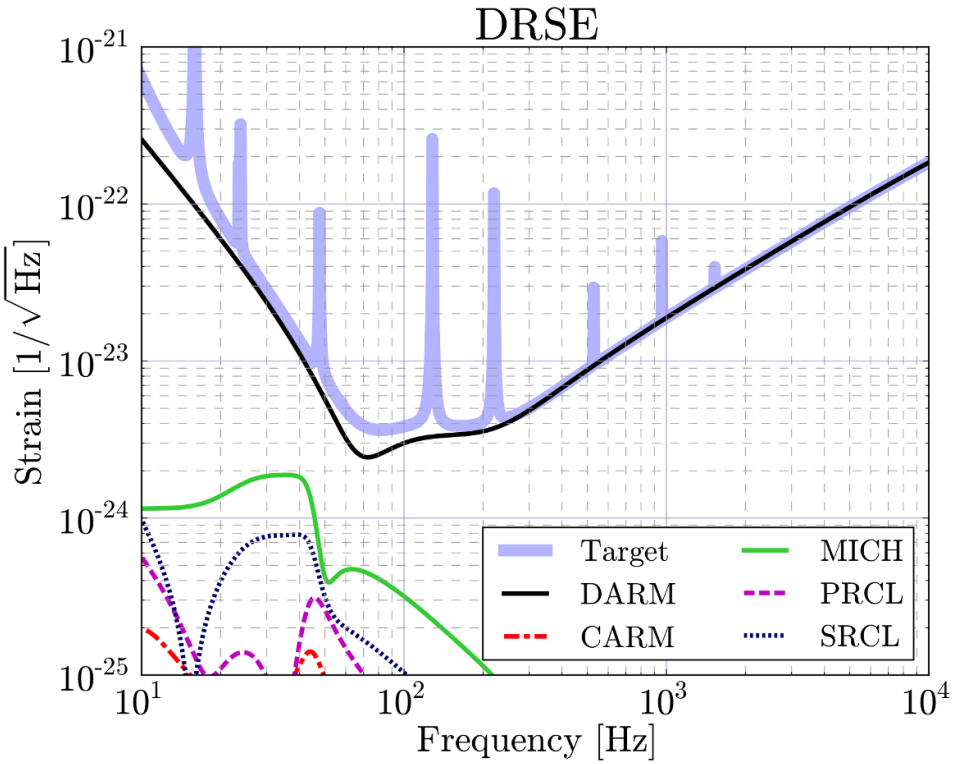


LSC Loop Noise Couplings

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

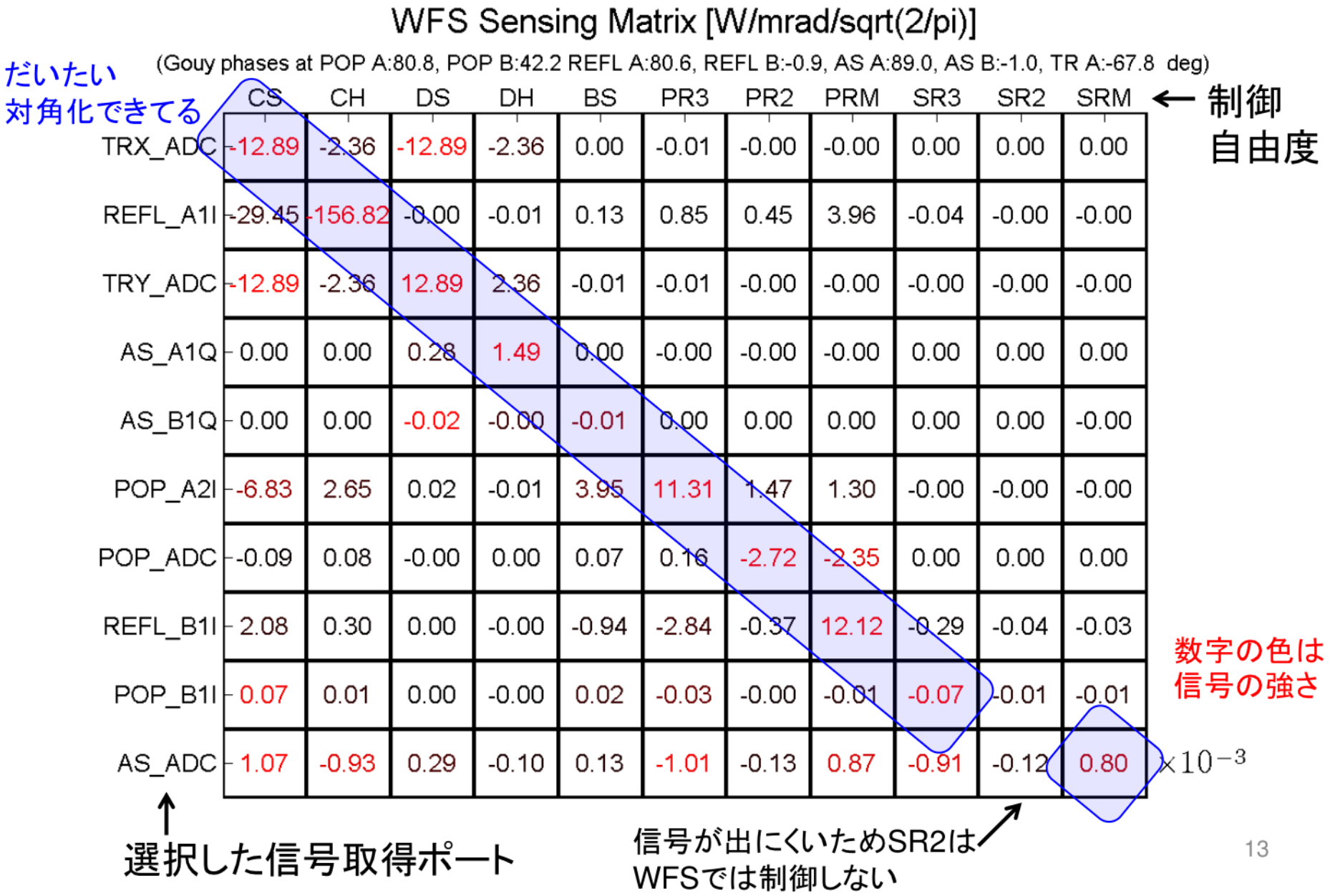
Feed Forward Gain: 100



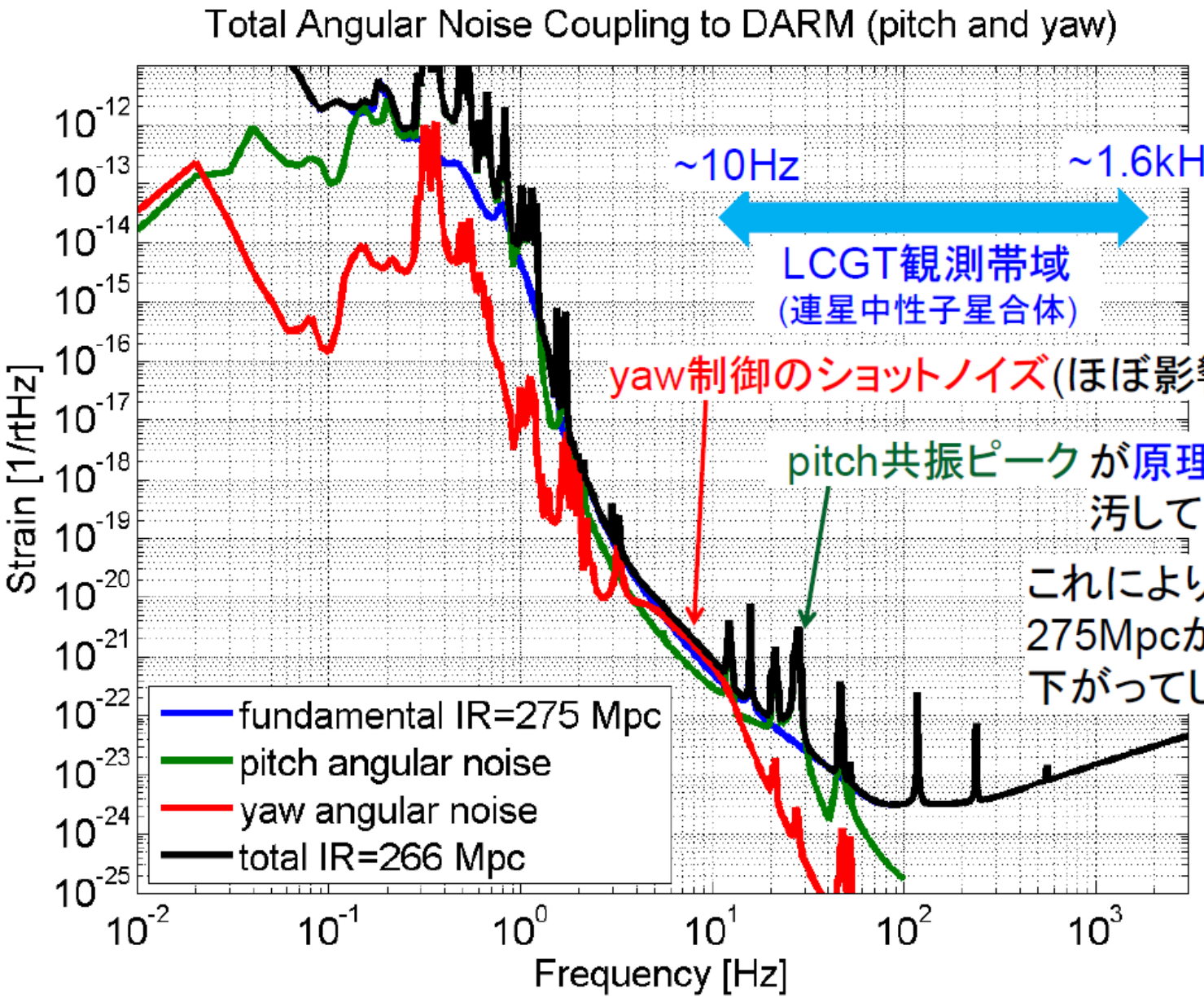


ASC

WFS＋OpLev



Total Angular Noise Couplings to DARM



~10Hz ~1.6kHz

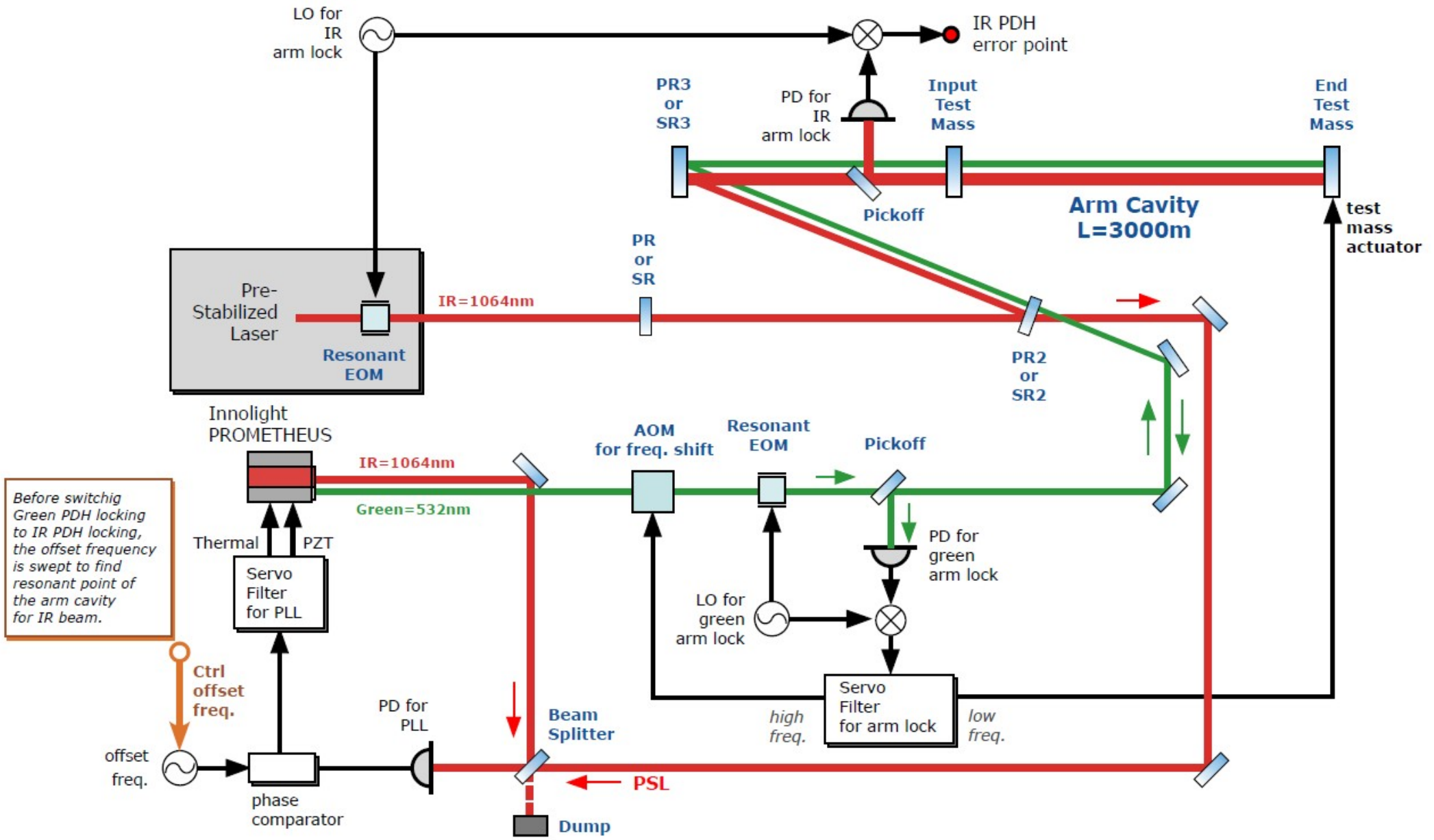
LCGT観測帯域
(連星中性子星合体)

yaw制御のショットノイズ(ほぼ影響なし)

pitch共振ピークが原理的雑音を汚している

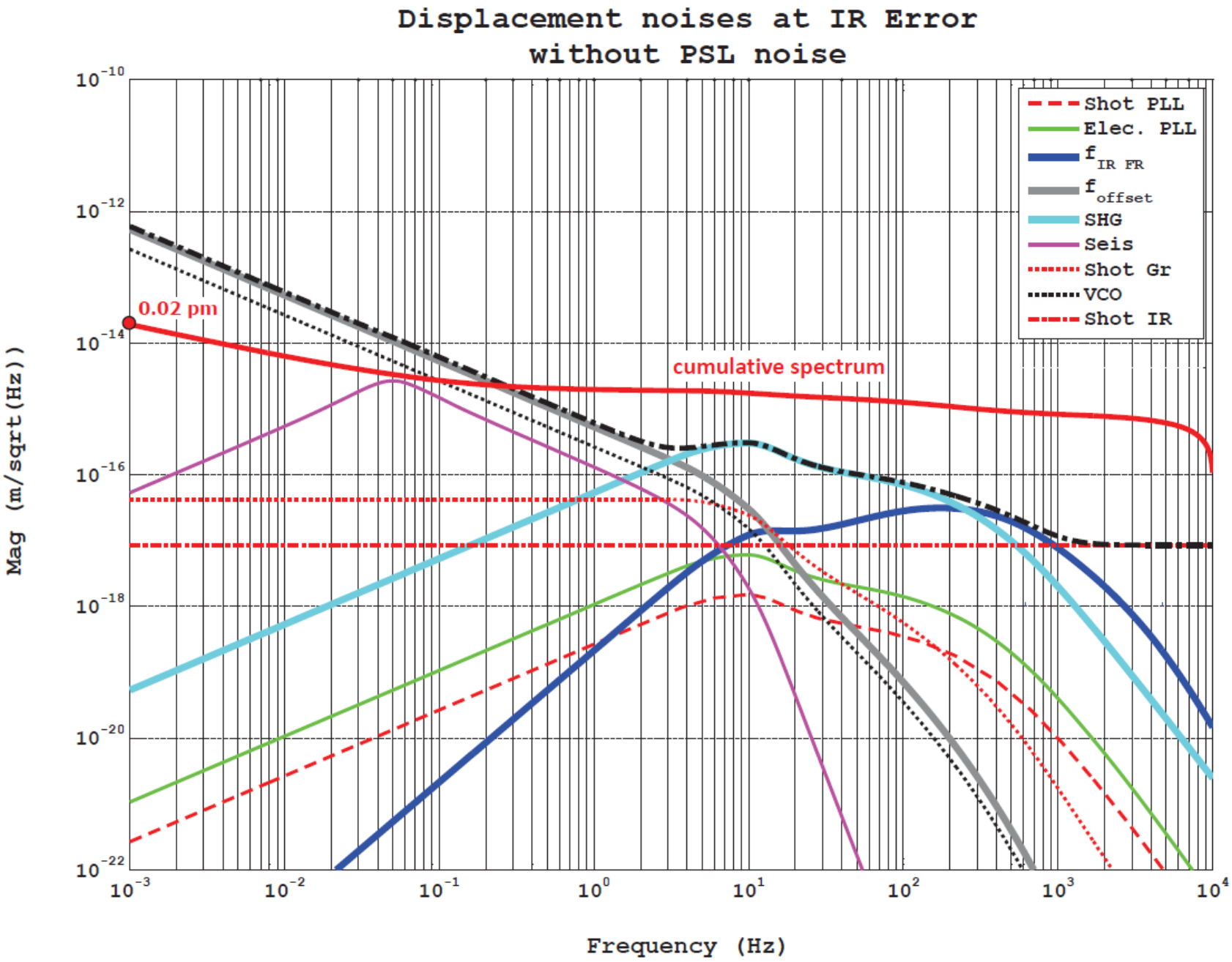
これにより観測範囲が275Mpcから266Mpcに下がってしまう

Green Lock Setup



Arm Cavity Stability after Green Lock

Requirement: 0.3pm RMS



Relevant documents

MIF design procedure: JGW-G1100604
LSC design: arXiv:1111.7147
ASC: JGW-G1100608, JGW-G1100533

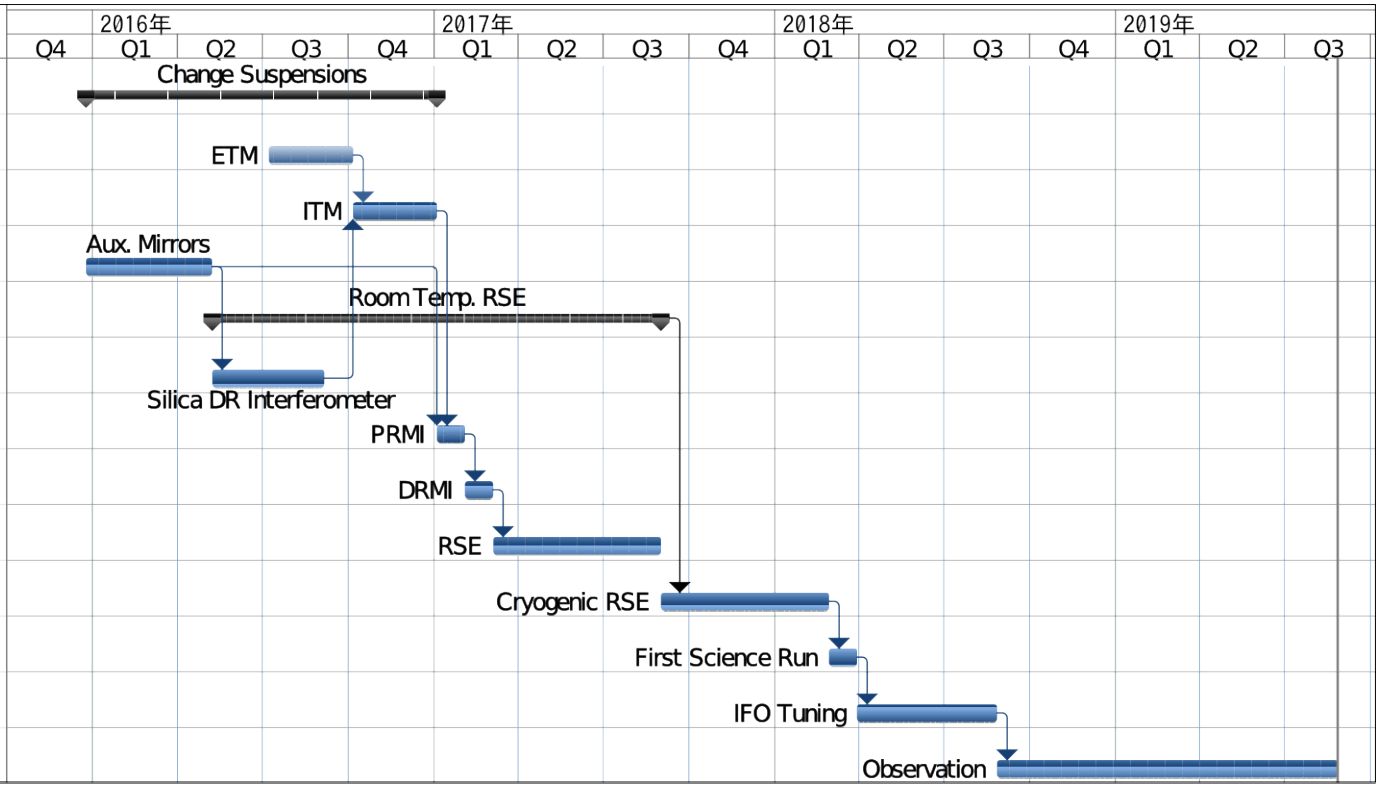
g-factor selection: JGW-G1200789, JGW-T1200787, JGW-G1200808

Input Mode Matching: JGW-G1200763
Parametric Instability: JGW-T1200787
Recycling Cavity Adjustment: JGW-T1100512
Wedge Angle Error Tolerance: JGW-T1100489

Green Lock: JGW-T1200788

Schedule & Installation Scenario

ID	タスク名	期間
64	**Change Suspensions**	**376日**
65	ETM	3月
66	ITM	3月
67	Aux. Mirrors	4.5月
68	**Room Temp. RSE**	**481日**
69	Silica DR Interferometer	4月
70	PRMI	1月
71	DRMI	1月
72	RSE	6月
73	Cryogenic RSE	6月
74	First Science Run	1月
75	IFO Tuning	5月
76	Observation	365日



Prototype Test

- ISC simulation using virtual interferometer on RTS
- Green injection table will be tested beforehand (Kashiwa ? NAOJ ?)

Quality Assurance

Commissioning is QA for MIF

Risk Management

Risk factors

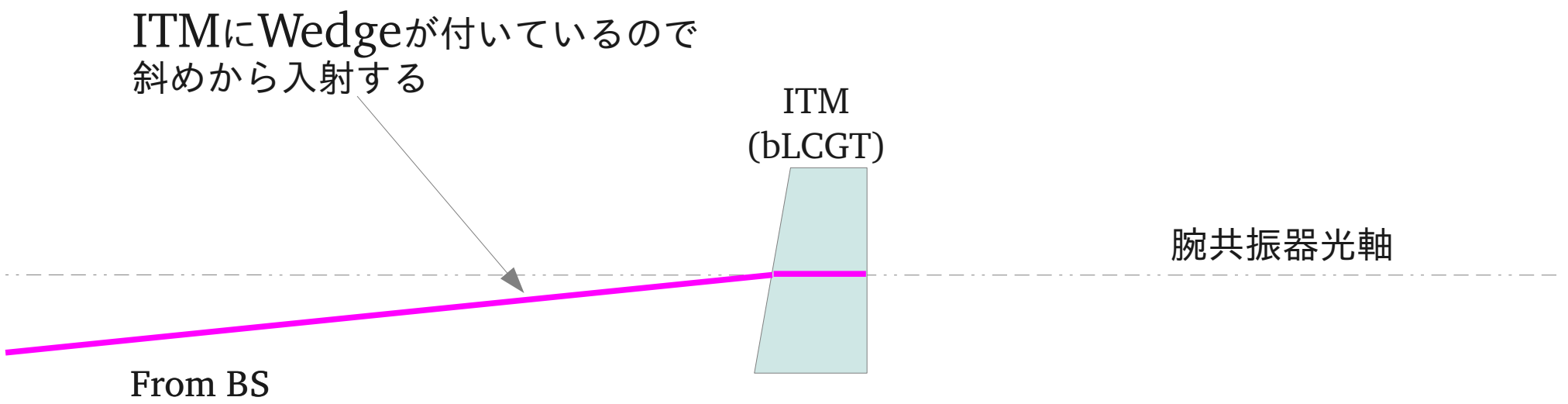
- Arm cavity loss is too large: PRC under-coupled
  => Prepare a spare PRM with lower reflectivity

- Arm cavity reflectivities are so matched that the homodyne phase cannot be set to around 45°
  => Forget about BAE

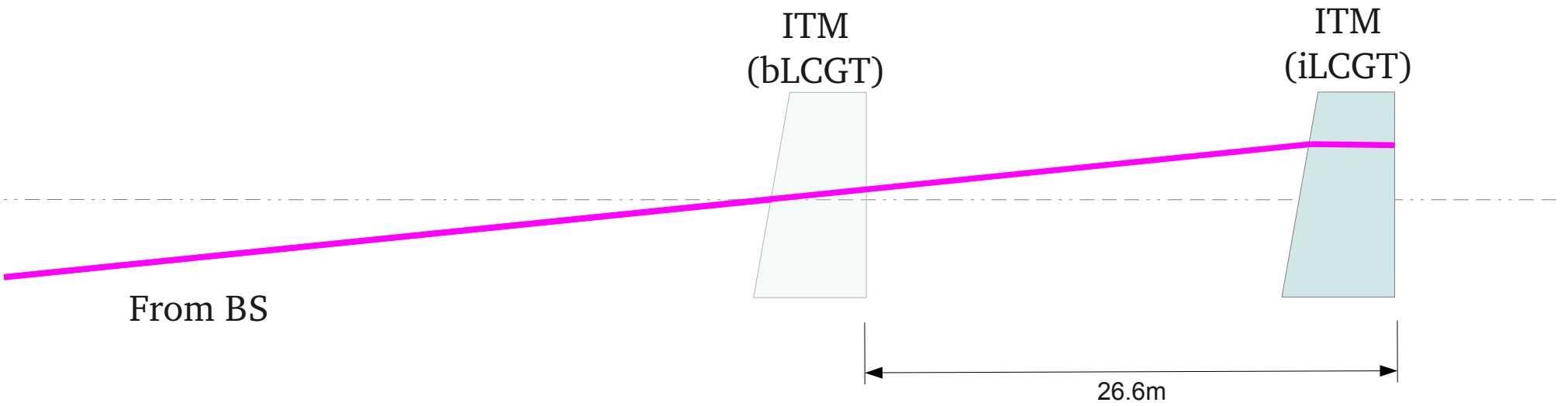
- Mirror quality is poor
  => ....
-
- Commissioning takes too long (very likely to happen)
  => Work even harder folks !

- Lack of man power
  => Get money to hire people

Appendix

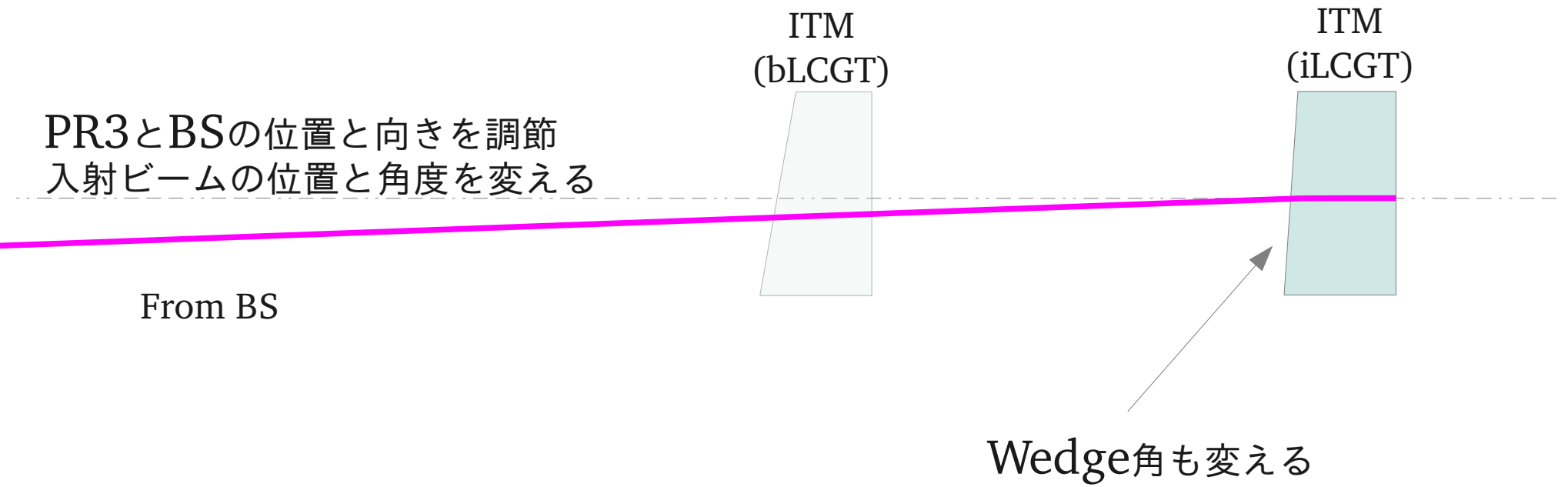

ITMにWedgeが付いているので
斜めから入射する
ITM
(bLCGT)
腕共振器光軸
From BS

そのまま26.6m先にITMを動かすと、中心にビームが当たらない



調整方法1

- BS, PR3を動かす
- 最大移動量2cm
- SRCも調整



調整方法2

- ITMを横に動かす
- 他のミラーには触れない
- GVの窓を通らない