Current Status of Main Interferometer Design

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2011/2/4, LCGT f2f Meeting

Contents

- Optical Parameters
  - Lengths
  - Figure Error
- Optical Layout
- Control Scheme
  - LSC
  - ASC

Optical Parameters

Which parameters does this working group deal with ?

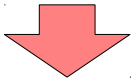
Lengths, Mirror ROCs, Wedge Angles, Reflectivities for AR and Green.

(Mirror Reflectivities are given by the detector configuration subsystem)

Steps to chose length parameters

Set nominal values

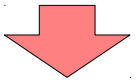
Larm = 3000: Set by the facility limit (i.e. mountain size)
Lprc, Las, Lsrc: Set to meet RFSB resonant conditions required by the LSC scheme.



Fine Adjustments

Lmc, Lprc, Lsrc, Las:

- Avoid RFSB resonance in the AC
- Compensate for small reflection phase by the AC
- HOM resonances



Strategies for handling ROC errors

Lmc, Lprc, Lsrc, Las: Which length has to be adjusted to compensate for the mirror ROC errors ?

Set Recycling Cavity Lengths

Requirements

- f1 is resonant in PRC-SRC
- f2 is perfectly reflected by MICH
- f2 is resonant in PRC
- MICH has a moderate reflectivity to f1 (~50%)
  - This is to make the resonance of PRC-SRC not too sharp
  - This requirement came from the variable detuning of SRC

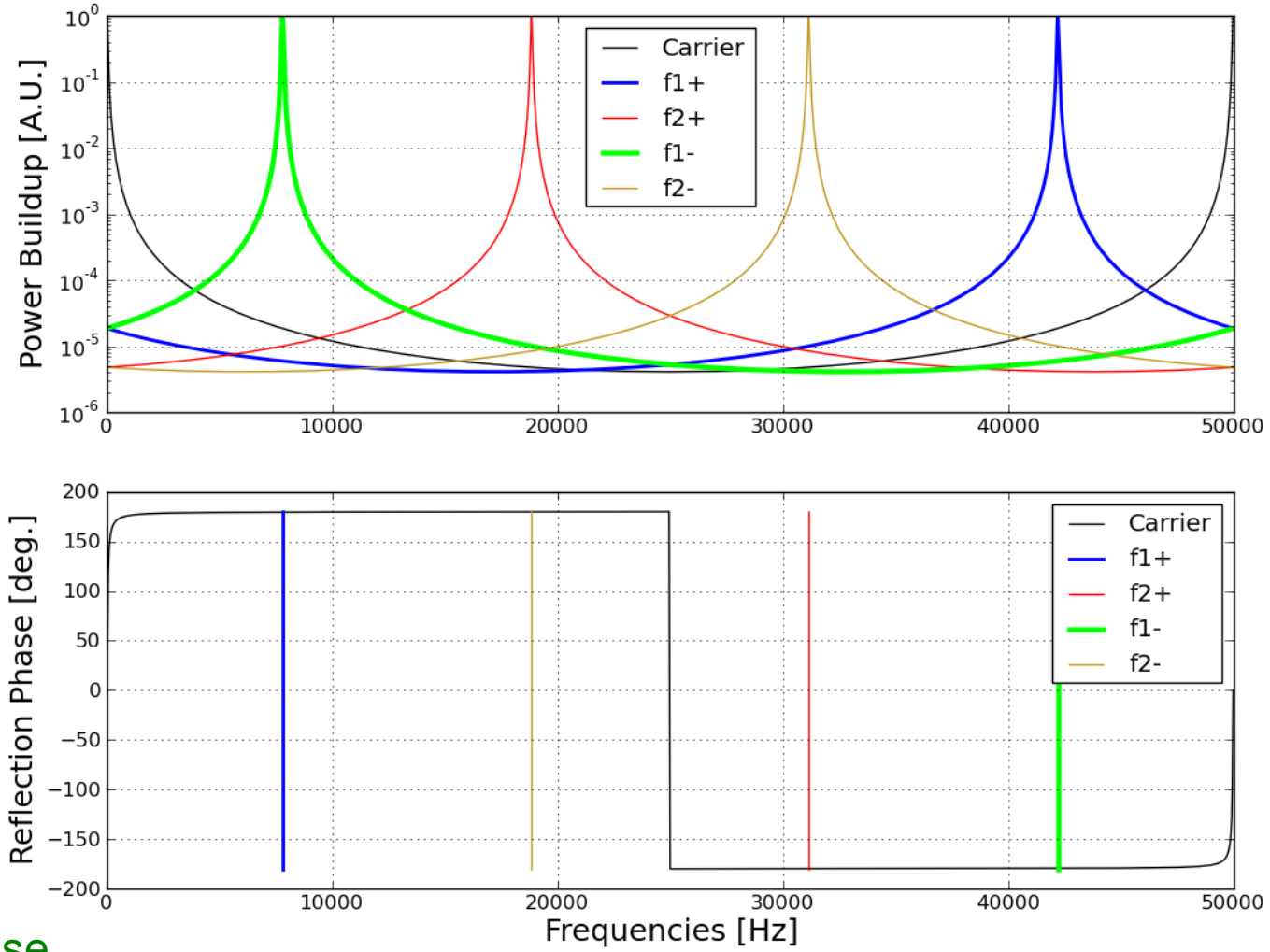
Nominal Values Chosen

Lprc	73.283 m
Las	3.331 m
Lsrc	73.283 m

Assumption Here: RFSBs are completely anti-resonant to the arm cavities.

Not True !

Locations of RF SBs in the FSR of AC



Reflection phase
f1(Φ1): -0.43 deg
f2(Φ2): 0.09 deg

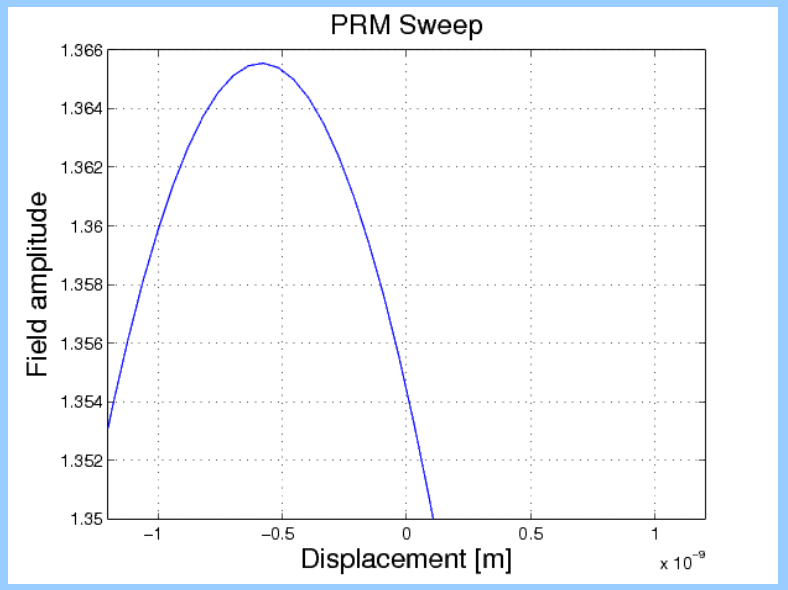
→ RF SBs are detuned in the RCs

What we do next

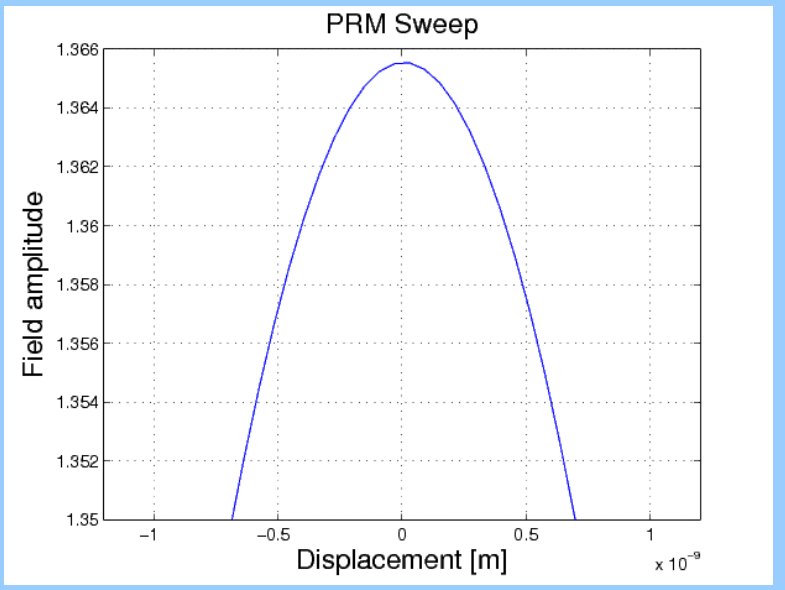
(1) Adjust Lmc to make Φ1:Φ2 = f1:f2
(2) Macroscopically adjust Lprc and Lsrc

Lmc adjustment = -1.37cm

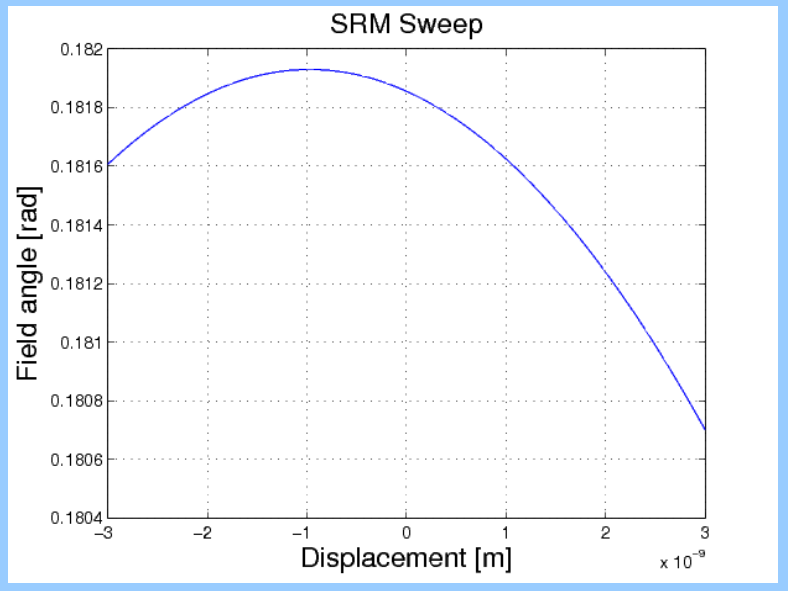
f2 resonance



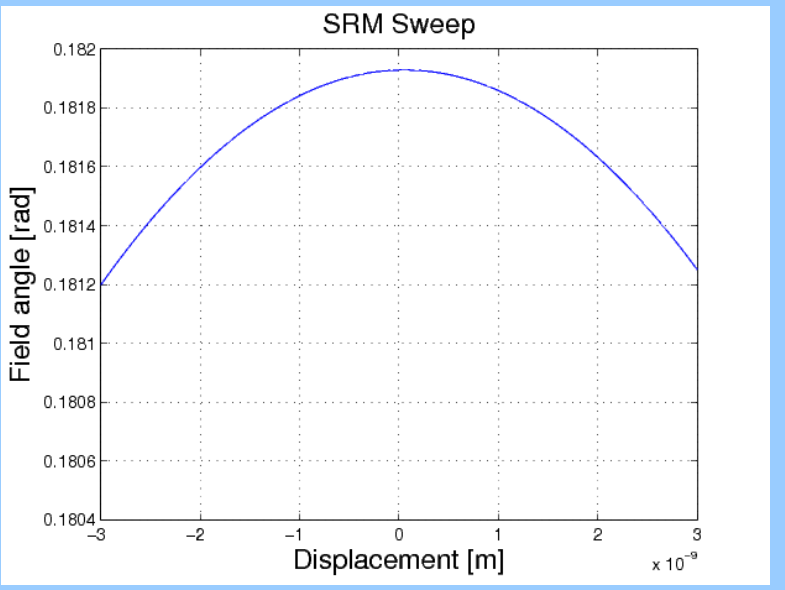
Adjust Lprc by 3.7mm



f1 resonance



Adjust Lsrc by 7.4mm

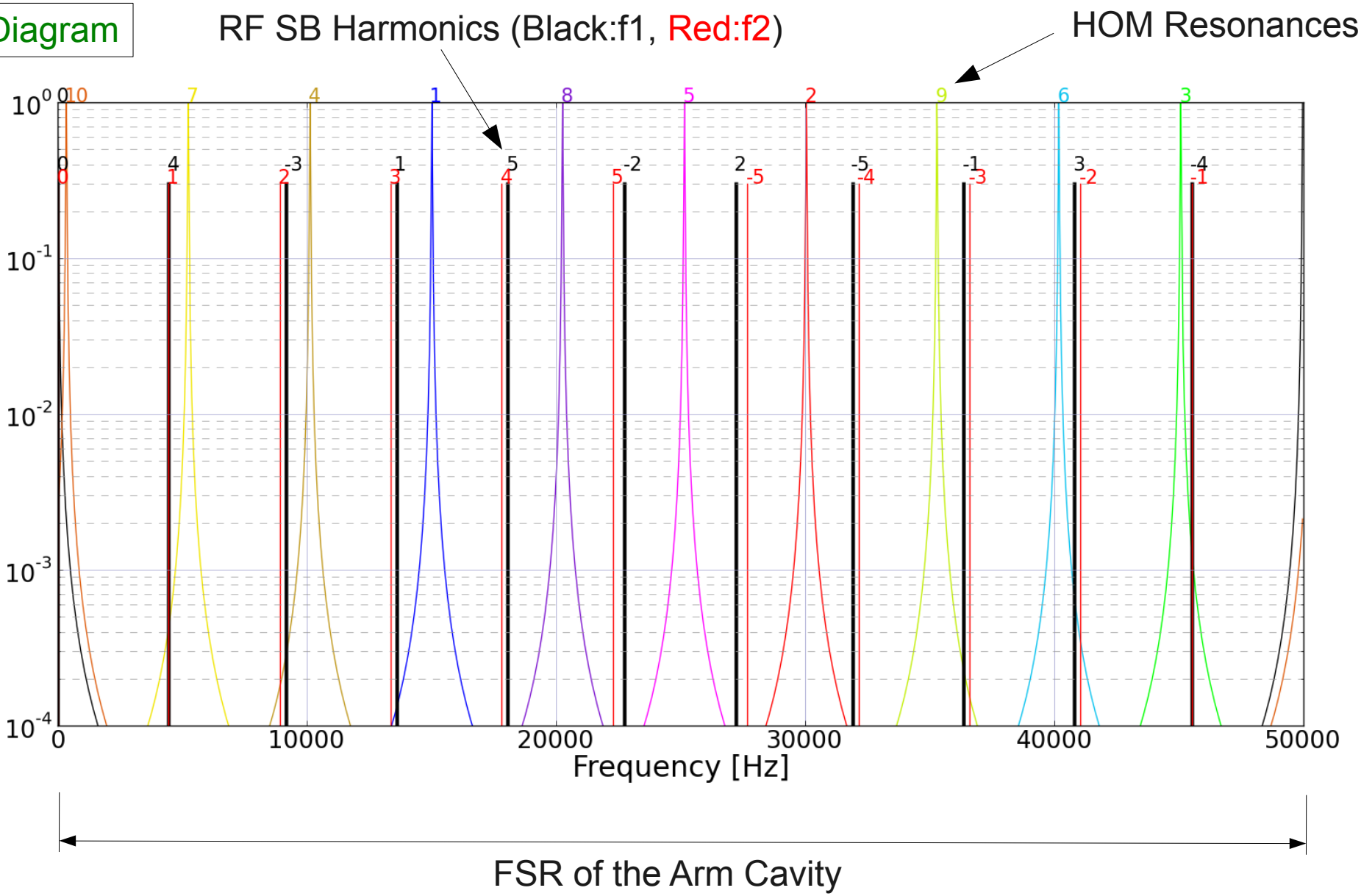


Check Higher Order Mode Resonances

We don't want ....

- TEM00 of the RF SB harmonics to be resonant in the AC
- HOMs of the RF SB to be resonant in the AC

JM Diagram



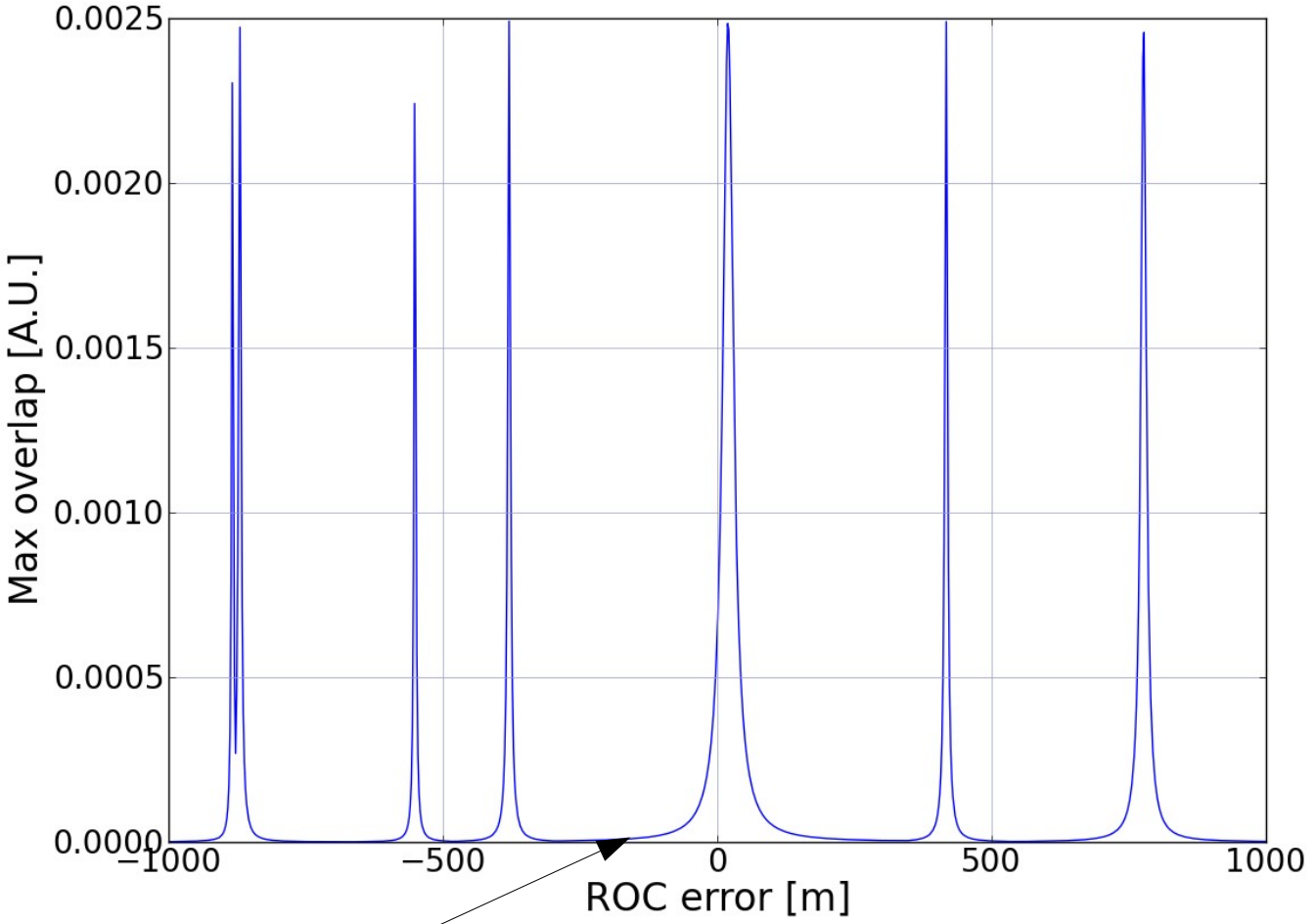
Mirror ROC Error

Mirrors are never perfect !

ROC ~ 7000m → 1% error = 70m

ROC error → HOM resonant curves move in the JM diagram
Accidental Overlap ?

HOM overlap figure of merit



Mirror ROC error can be negative but not positive

Comments on Length Parameters

- Larm may not be exactly 3000m
- Two arms will have different ROC errors
- Arm reflection phases depend on the arm finesse

→ Adjust Lmc, Lprc, Lsrc and Las based on the actually delivered mirrors.

Required adjustment range (rough estimate)
Lmc: +/- 1cm
Lprc, Lsrc: +/-10cm
Las: +/-3mm (no need to adjust ?)

Measurement Methods

- Measure the actual transverse mode spacing using the Arai-Stochino method.
- Measure Lmc, Lprc, Lsrc from FSR measurements
- Las can be measured by the demodulation phase difference between the independent lock of X and Y arms at REFL.

Adjusted Lengths

Lprc	73.2484 m
Las	3.329 m
Lsrc	73.2484 m
Lmc	26.634 m
f1	11.255822MHz

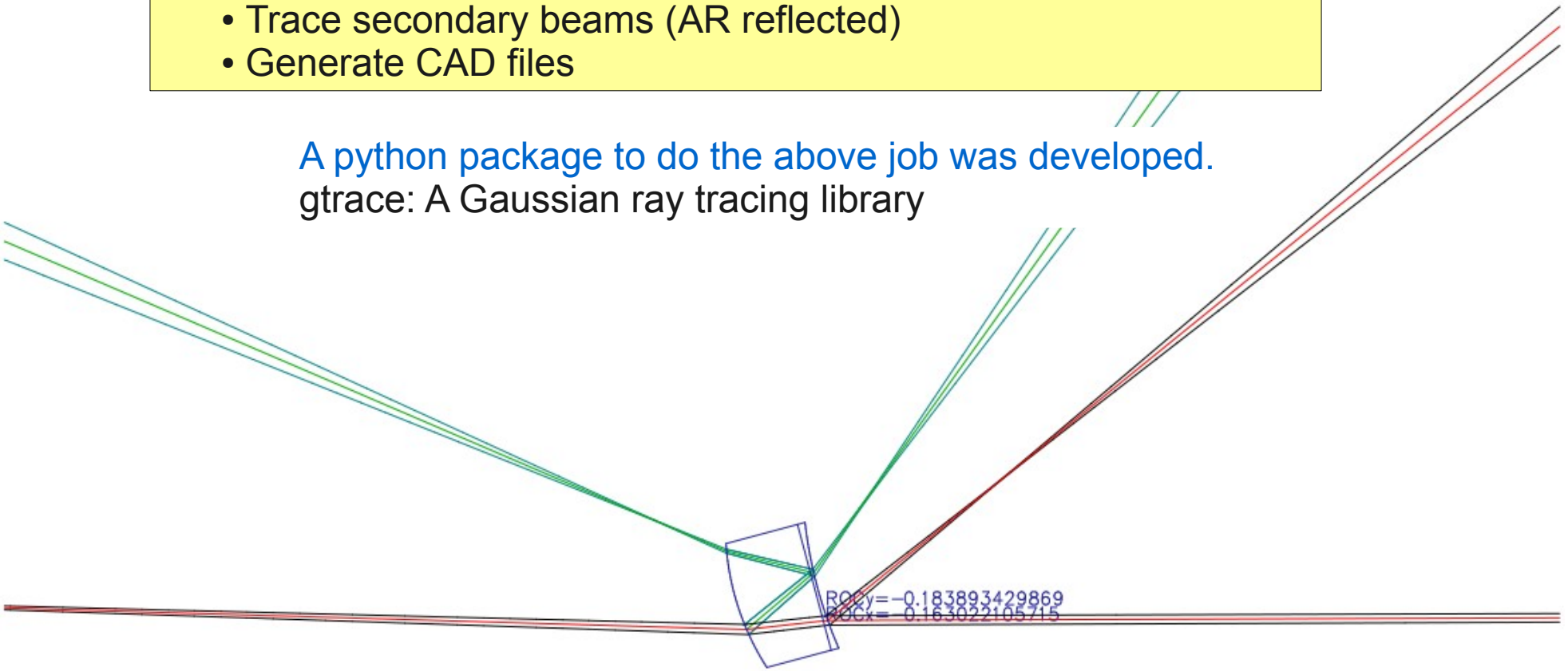
Optical Layout

Detailed optical layout design is a non-trivial task !

We have to ...

- Take into account wedge deflection
- Make the two arms at the right angle
- Track the optical path length (for SB resonant conditions)
- Track the Gaussian mode evolution
- Track the Gouy phase evolution
- Take into account the dispersion effect for the green beams
- Trace secondary beams (AR reflected)
- Generate CAD files

A python package to do the above job was developed.
gtrace: A Gaussian ray tracing library



Example: Substrate Change between iLCGT and bLCGT

iLCGT: Fused Silica TMs (n=1.45)
bLCGT: Sapphire TMs (n=1.754)

→ If two mirrors have the same wedge angle
Incident angle to the ITMs must be different

We have to change the ITM wedge angle between iLCGT and bLCGT

Wedge angle: Set to nicely separate POX and POY beams for bLCGT

bLCGT: 0.2deg ---> iLCGT: 0.33deg

(To keep the incident angle to ITMs the same)

Are the POX and POY still available for iLCGT ?

Answer: Yes

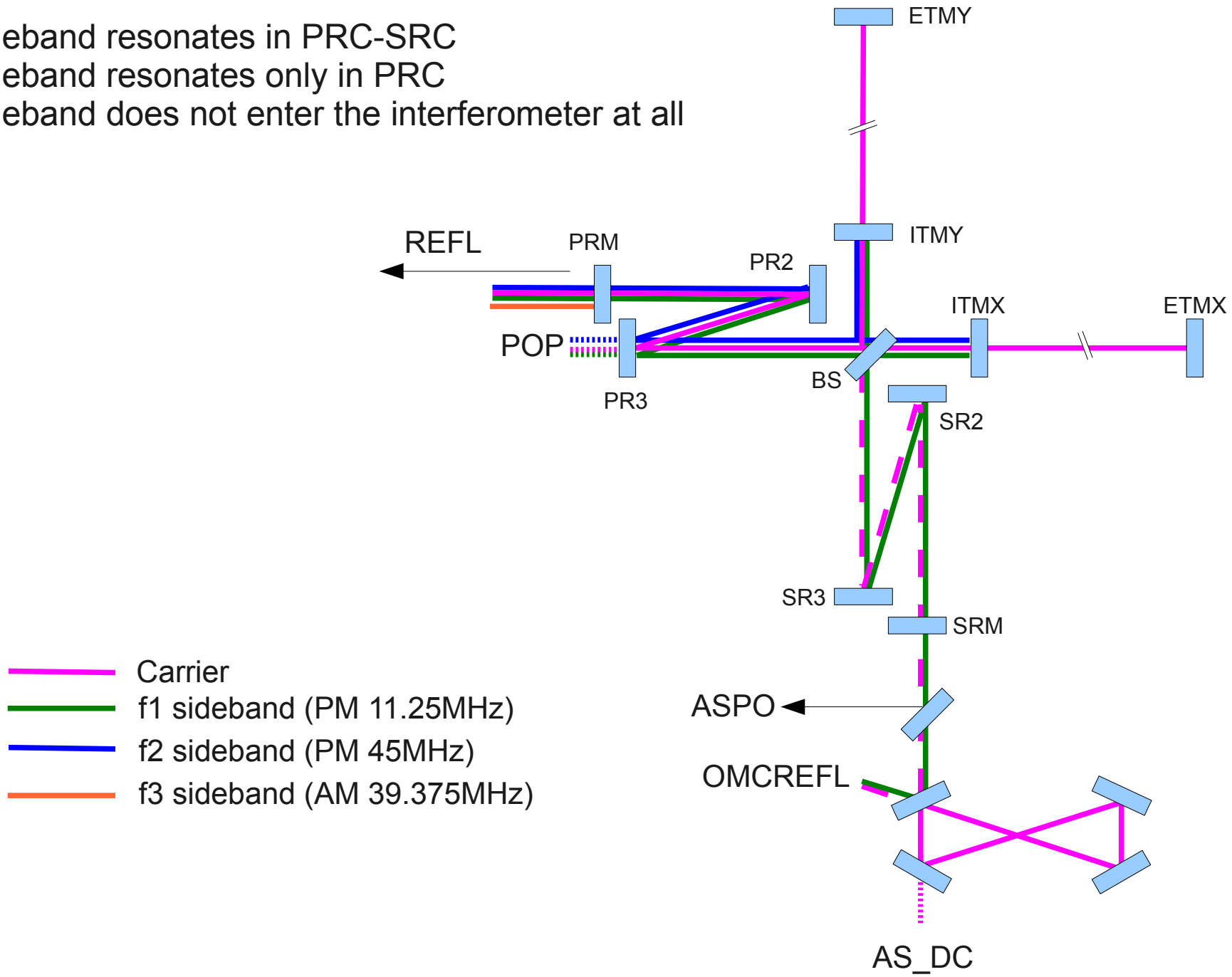
Length Sensing and Control Scheme

Current Status

- A new Optickle model with MZ and Folding
- PM-PM schemes have been explored (to be compatible with WFS)
- May use Non-Resonant Sidebands
- Several Options (SDM, no-MZ DDM, MZ DDM, etc)
- With a good feed forward gain (over 100), any scheme seem to work
- These schemes can be changed after installation

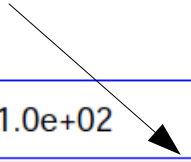
Sideband Resonant Conditions for Control Signal Extraction

- f1 sideband resonates in PRC-SRC
- f2 sideband resonates only in PRC
- f3 sideband does not enter the interferometer at all



Sensing Matrix with NRS
(BRSE, with MZ, measured at 100Hz)

Clean signal separation

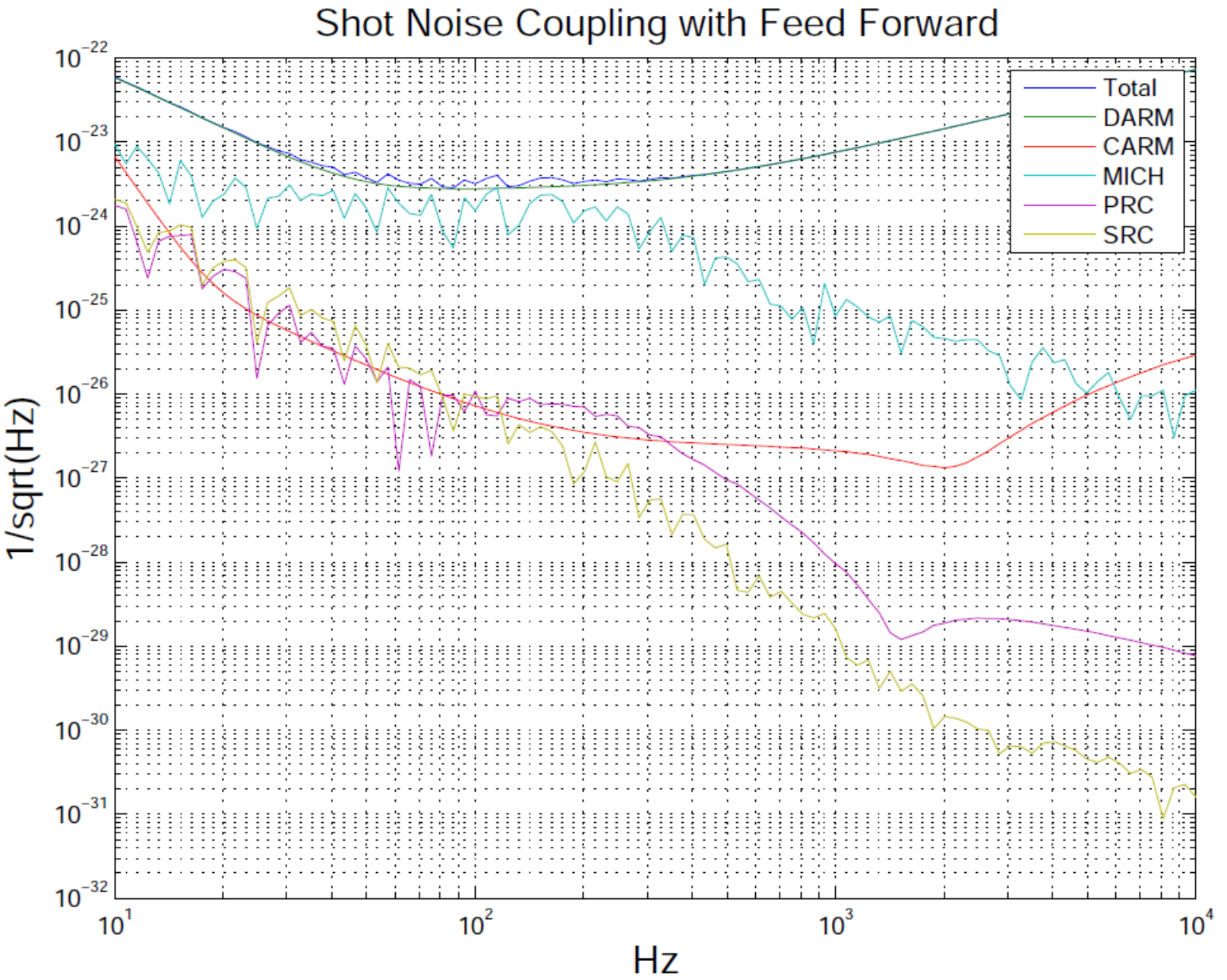


Sensing Matrix [W/m]

	DARM	CARM	MICH	PRC	SRC
REFL_2DmQ	1.0e+02	1.1e+01	1.8e+03	4.0e+03	1.3e+03
REFL_2DmI	5.5e+03	4.8e+04	4.7e+05	4.4e+07	4.2e+03
REFL_1DmQ	5.0e+03	1.8e+03	1.1e+06	1.9e+04	1.7e+03
REFL_1DmI	1.2e+04	1.4e+05	2.9e+05	2.7e+07	4.7e+06
POP_2Q	3.1e+03	5.6e+05	3.8e+01	1.3e+03	4.1e+00
POP_2I	1.9e+05	3.5e+07	8.5e+04	8.2e+06	1.2e+03
POP_1Q	1.1e+03	1.7e+03	2.2e+05	3.2e+05	5.3e+04
POP_1I	1.5e+05	2.8e+07	3.9e+04	5.0e+06	9.0e+05
REFL_1Q	1.7e+03	3.9e+03	4.2e+05	1.2e+06	2.3e+05
REFL_1I	1.2e+07	2.1e+09	1.8e+05	3.7e+06	2.5e+06
REFL_2Q	5.3e+01	1.3e+03	1.1e+03	1.5e+05	1.3e+04
REFL_2I	2.1e+07	3.7e+09	2.5e+05	3.4e+06	5.0e+05
ASPO_1Q	1.1e+02	1.6e+01	2.7e+02	2.2e+03	8.4e+02
ASPO_1I	2.4e+08	5.7e+04	2.4e+05	1.0e+04	6.9e+03
AS_DC	1.3e+10	5.6e+05	1.4e+07	6.3e+04	3.0e+05

BRSE DDM with MZ

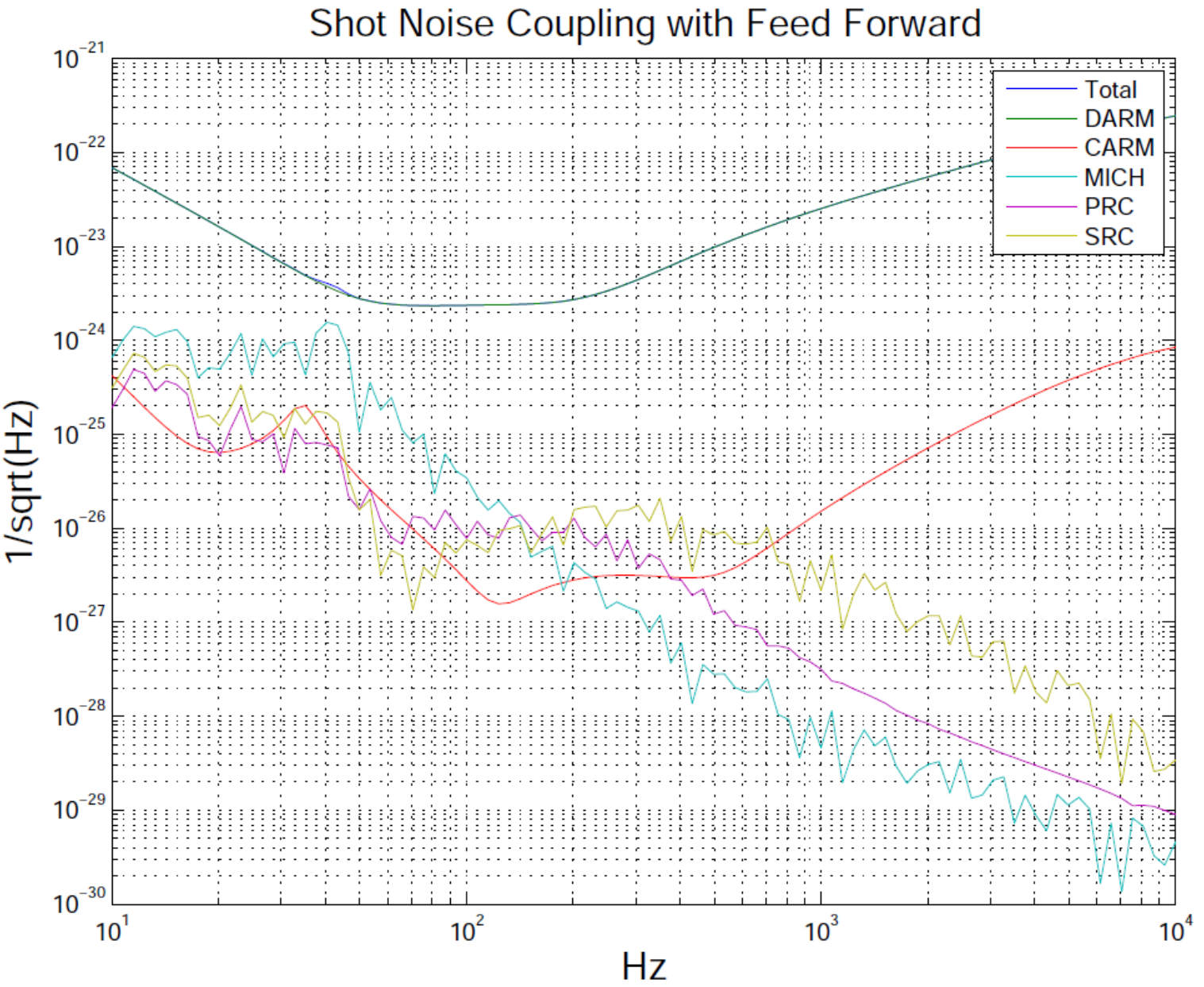
Feed forward accuracy = 3%



DRSE DDM with MZ

Feed forward accuracy = 1%

MICH UGF = 10Hz



Alignment Sensing and Control Scheme

- Michimura-kun is working on it using Optickle
- Checking the Optickle results with analytical calculation for Fabry-Perot
  → Good Agreement
- Problematic result for FPMI (iLCGT)
  - No signal separation of ITM and ETM at the AS port.
  - Checking with analytic calculations

- Agatsuma-kun has been doing ASC calculation independently
  - Need to merge the work force

Other Issues

- SRC Folding
- Arm cavity g-factor (positive or negative
- Lock acquisition (Green lock)
- Mirror specs

These issues will be discussed at
the next MIF subsystem meeting: Feb. 9th 13:00 -