Summary of the Current Issues with LCGT Main Interferometer Design

2011/8/5, Yoichi Aso
@LCGT F2F Meeting

Main Interferometer Subsystem (MIF)

- Originally Interferometer Sensing & Control (ISC) subsystem
- In charge of the design of the main interferometer part of LCGT
- Design of the length sensing & control (LSC) scheme
- Design of the alignment sensing & control (ASC) scheme
- Commissioning

Status

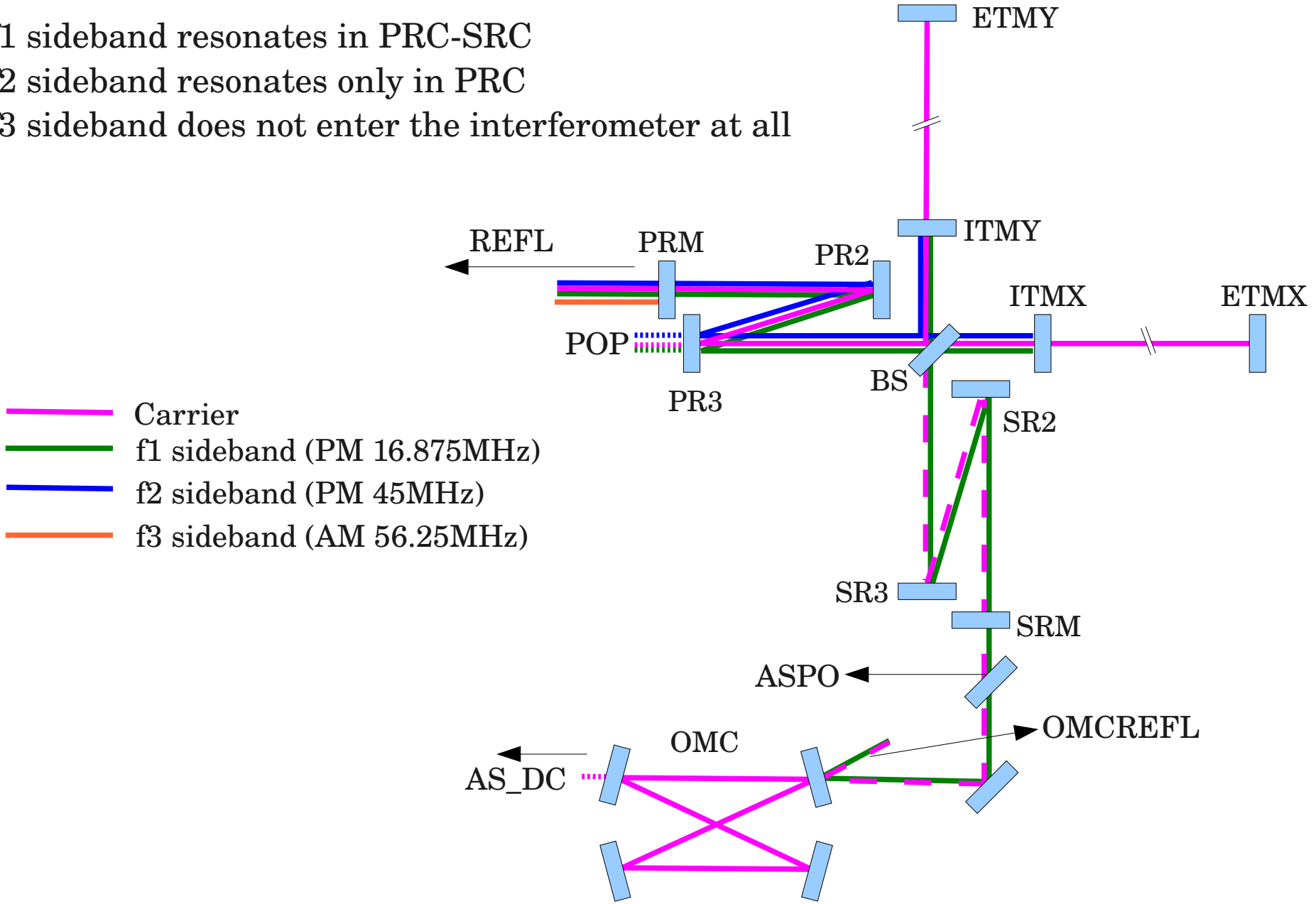
- bLCGT interferometer design is almost done (?)
  - Lengths of the various parts of the main interferometer are fixed
  - Recycling cavities will be folded (Agatsuma's talk)
  - Arm cavity g-factor is not yet fixed
- Basic LSC design is done
- ASC design is going on (Michimura's talk)
- HOM analysis of coupled cavities using Finesse (Kentaro, Fumiko, Andreas)

Plans

- Detailed design of the control topology, servo hardware/software have to be finished soon in collaboration with electronics and digital control group.
- All the equipments necessary for the interferometer control have to be ready by the end of the vacuum system installation
- Work with input/output optics group for OMC design, green laser lock system
- Work with auxiliary optics group for optical levers, secondary beam dumps, etc.

Sideband Resonant Conditions and Signal Ports

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



Recent discussions

bLCGT

- Arm Cavity g-factor
  - Positive or Negative
- TM size
  - 25cm -> 22cm
- Vacuum chamber separation (PRM-PR3, PR2-BS)
  - Expanded: 2.7m -> 4.7m or 3.7m

iLCGT

- ITM location
  - 26.6m further away from BS
- Arm Cavity g-factor
  - Flat - 7km

Test Mass Size for bLCGT

ITM
- The largest C-axis sapphire crystal = 22cm dia. for the moment
- No choice other than 22cm ? (Kamaboko ?)

ETM
- A-axis 25cm is possible
  - Two different masses: Violin mode split
- Possible A-axis coating problem
- 22cm C-axis for ETM as well ?

Two Patterns

(a) 22cm ITM, 25cm ETM

(b) 22cm ITM, 22cm ETM

Beam Size

- Maximum beam size on a 22cm mirror: 4.0cm
- BS with 12cm thick can transmit only 3.5cm
- BS may be cut to 8cm thick ==> 4.0cm is OK

bLCGT2 ?: 25cm test masses

Arm Cavity g-factor for bLCGT

Choices

(1) Positive or Negative ?

(2) Beam spot size (depend on the BS size)

Candidates

~~(a) 25cm TMs 12cm thick BS~~
~~Spot size: 3.5cm - 4.5cm~~
~~Positive: Flat - 7km~~
~~Negative: 1.5km - 1.9km~~

(b) 22cm TMs 12cm thick BS
Spot size: 3.5cm - 4.0cm
Positive: 14km - 7.5km
Negative: 1.68km - 1.87km

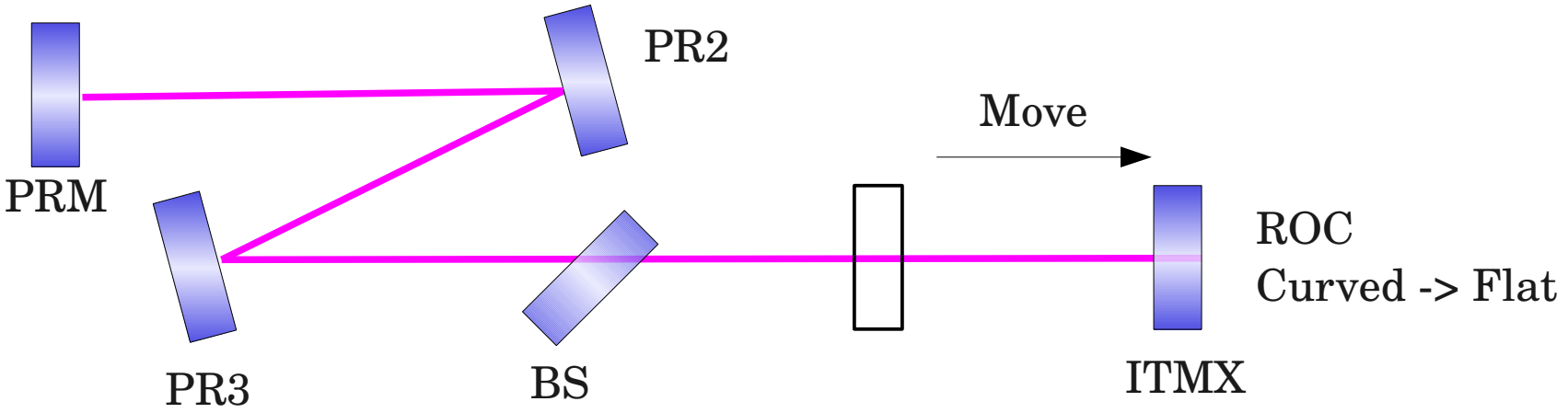
(c) 22cm TMs 8cm thick BS
Spot size: 4.0cm - 4.0cm
Positive: 13.2km - 13.2km
Negative: 1.69km - 1.69km

Factors to consider

- Angular optical spring instability: Negative g-factor is preferable
- Parametric instability (PI)
  - Smaller beam size is better ?
  - Stabler cavity is better
- Large mirror ROCs

Recent design changes to iLCGT

Location of ITMs: Shifted by 26.6m from the bLCGT position



Arm cavity g-factor: Flat - 7km
(These are the only available mirrors in time for iLCGT)

What will happen then ?

- Optical path will be different from bLCGT
  - Make sure a complete optical path can be constructed without moving the mirrors significantly from bLCGT positions.

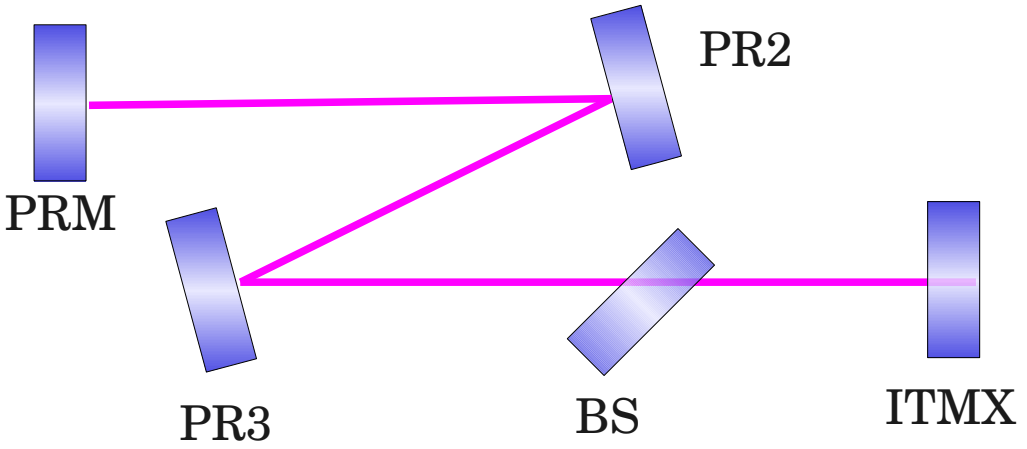
For Room Temp. RSE

- PRC/SRC can be unstable. Mode matching with the arm cavities will be poor.
  - Tweak the distance between PR2 - PR3 to recover the mode matching

1st. step: Optimize the ROCs of PR3 and PR2 for bLCGT

Method
- Propagate a beam matching the arm cavity mode from ITMX to PRM
- Repeat this with different
- combinations of PR3 and PR2 ROCs.
- PRM ROC is set to the ROC of the beam hitting PRM.
- Do the same for SRC

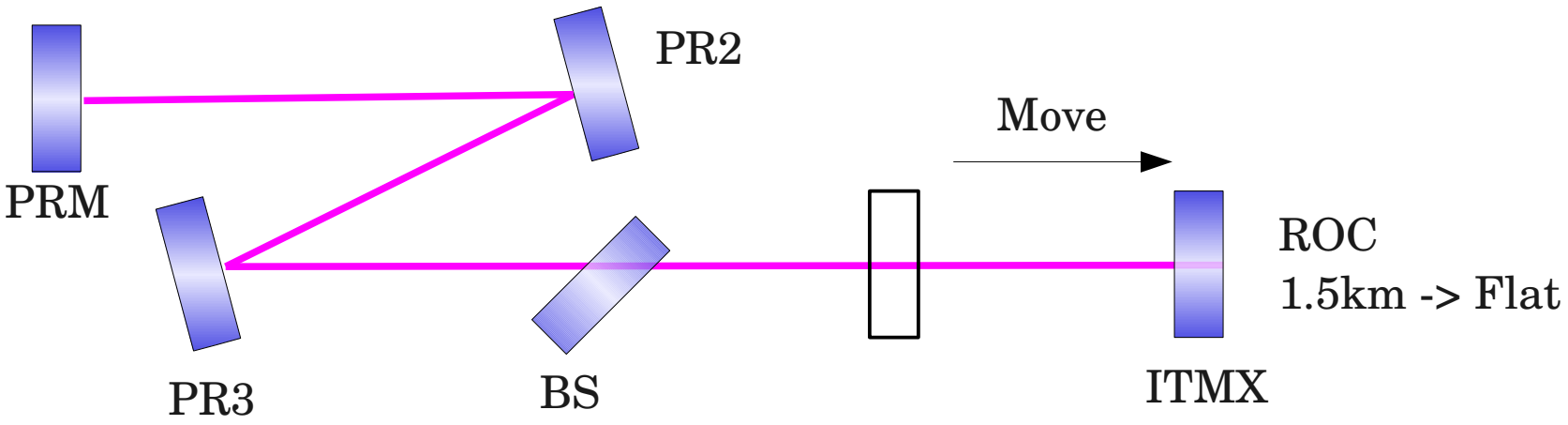
Target
- Gouy phase change from ITMX to PRM is 20 deg.
- Beam spot sizes on PR2 and PRM are equal



PRC/SRC parameters after the optimization

PRM ROC	PR2 ROC	PR3 ROC	PRM Spot Size	PR2 Spot Size	PR3 Spot Size
304.989m	-2.800m	24.574m	4.03mm	4.03mm	36.08mm
SRM ROC	**SR2 ROC**	**SR3 ROC**	**SRM Spot Size**	**SR2 Spot Size**	**SR3 Spot Size**
304.830m	-2.813m	24.585m	4.03mm	4.03mm	35.93mm

2nd step: Move and Change ITMs

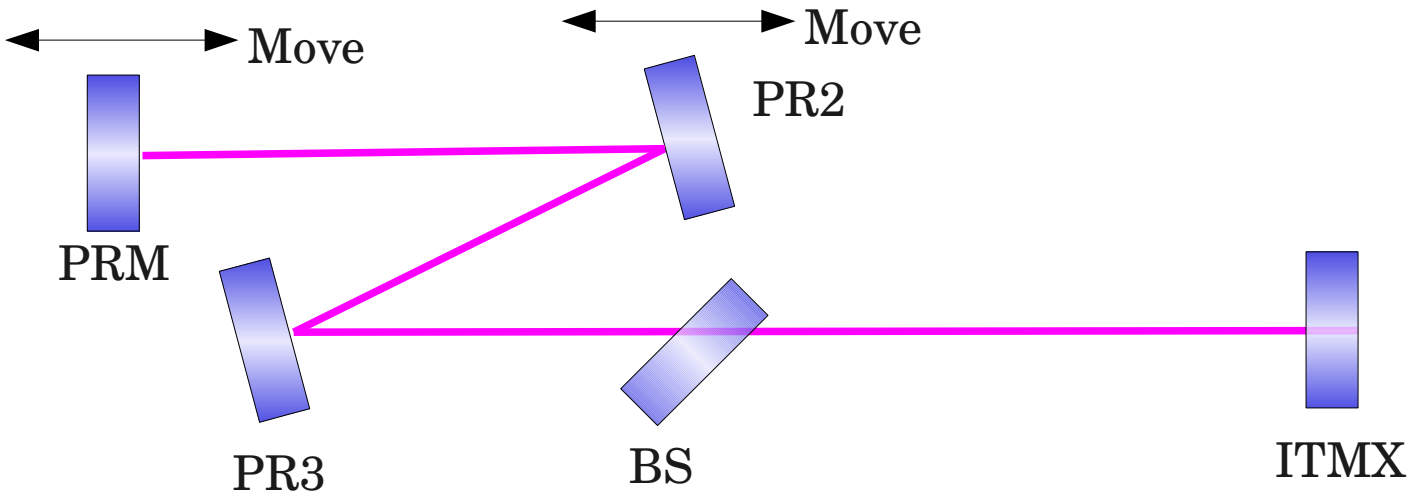


Need to tweak the positions and orientations of PR2, PR3 and BS to make the beam normal incidence to ITMs

Test: Is this PRC stable ?

- Calculate the round trip (PRM -> ITM -> PRM) ABCD matrix
- See if -1 < (A+D)/2 < 1 is satisfied ===> No ! (A+D)/2 = -1.85
- We cannot use this configuration.

3rd step: Tweak the distance between PR2 and PR3



- Instead of changing mirror ROCs, move PRM and PR2
- Keep the PRC length unchanged
- Find the optimal displacement to match the eigen mode of PRC with the arms
- By moving PR2 by 17cm and PRM by 34cm, the two modes match very well

Input beam mode matching: 99.8%
PRC - Arm Cavity mode matching: 99.99%
(Using the same mirrors and the same MMT, optimized for bLCGT)

Optimization Results

ITM Spot: 3.5cm, ETM Spot: 4.0cm (IR=245Mpc)

(b) Positive (14km - 7.5km)
Displacement of mirrors:
PRM/SRM: 3.7cm, PR2/SR2: 1.8cm
PRC-Arm Mode Matching: 99.99%
Input beam - PRC Mode Matching: 99.97%
One-way Gouy phase: 21deg
Unstable Kopt: 24.4 N·m/rad

(b) Negative (1.68km - 1.87km)
Displacement of mirrors:
PRM/SRM: 34cm, PR2/SR2: 17cm
PRC-Arm Mode Matching: 99.99%
Input beam - PRC Mode Matching: 99.8%
One-way Gouy phase: 22deg
Unstable Kopt: 4.5 N·m/rad

ITM Spot: 4.0cm, ETM Spot: 4.0cm (IR=248Mpc)

(c) Positive (13.2km - 13.2km)
Displacement of mirrors:
PRM/SRM: 1.5cm, PR3/SR3: 2.2cm
PRC-Arm Mode Matching: 99.99%
Input beam - PRC Mode Matching: 95%
One-way Gouy phase: 30deg
Unstable Kopt: 33.4 N·m/rad

(c) Negative (1.69km - 1.69km)
Displacement of mirrors:
PRM/SRM: 26cm, PR2/SR2: 13cm
PRC-Arm Mode Matching: 99.99%
Input beam - PRC Mode Matching: 92%
One-way Gouy phase: 34deg
Unstable Kopt: 4.3 N·m/rad

Discussions

- Two choices for bLCGT beam spot sizes (3.5cm-4.0cm or 4.0cm-4.0cm)
- 4.0cm - 4.0 cm is better for thermal noise
- 4.0cm - 4.0cm requires 8cm thick BS (waiting for an answer from the company)
- PRC/SRC mirrors are optimized for bLCGT
- Room Temp. RSE operation with iLCGT TMs require some tweaking of mirror positions
- Maximum 34cm displacement is required
- In every case, PRC/SRC and Arm Cavity mode matching can be recovered pretty well
- In the 4.0cm - 4.0cm cases:
  - the input beam mode matching is rather poor
  - One-way Gouy phase in PRC/SRC is large: WFS signal will be smaller
- Alternatively, we can replace PRC/SRC mirrors between iLCGT and bLCGT
- Sidles-Sigg instability is not much different for Negative g-factors
  - 3.5cm - 4.0cm is better for Positive g-factors
- Parametric instability must be assessed
- Positive g-factor requires very large ROCs

Conclusion

- Arm cavity g-factor has to be decided taking into account the new TM size
- Need to know if 8cm thick BS is possible
- My personal preference is 4.0cm-4.0cm negative g-factor if 8cm thick BS is available
- All the optimization was done by a python script
  - DXF file is automatically generated for CAD import