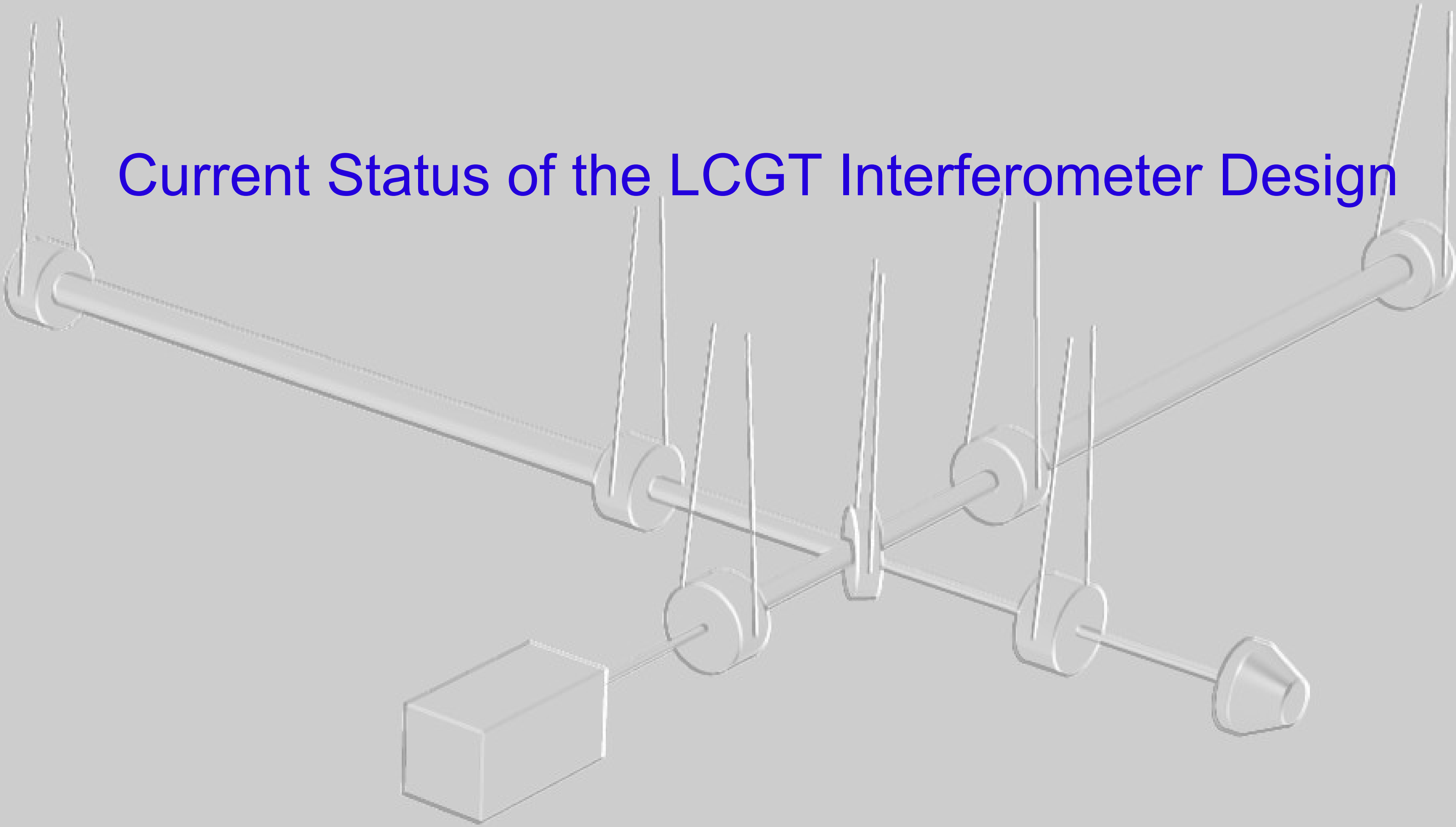
Current Status of the LCGT Interferometer Design



Yoichi Aso on behalf of the LCGT ISC Group
2010/9/27 LCGT F2F Meeting

Summary of the current status

- Working to fix parameters necessary for procurements
  - Parameters relevant to tunnel digging
    - Lengths of various parts of the IFO
    - Central part topology, i.e. folding or not
  - Parameters relevant for mirror order
    - Size, reflectivity, ROC, wedge, error tolerance, etc

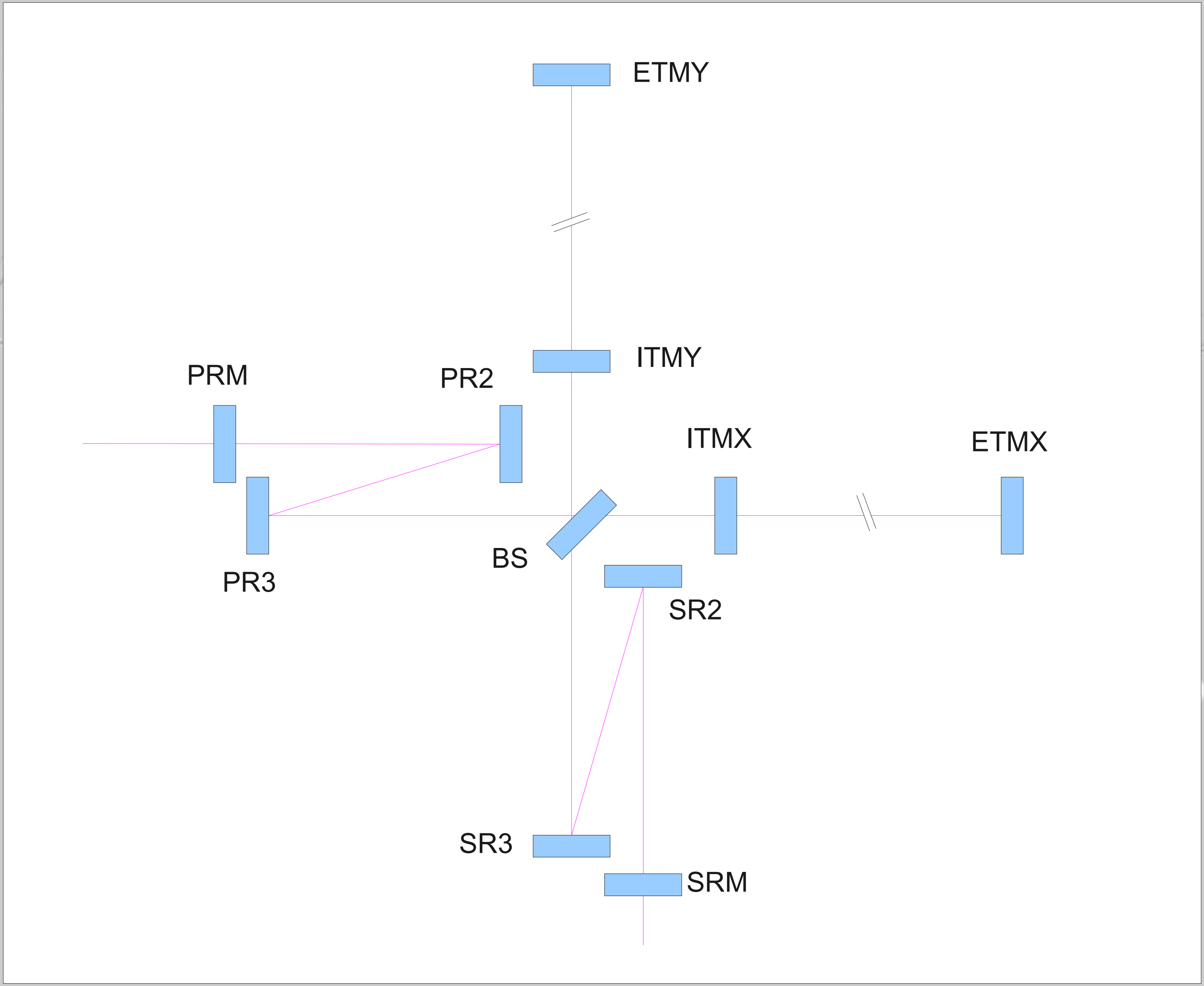
TO DO

- Detailed optical layout
- Alignment Control
- Green lock design
- Double-check of the design (review)

Basic Interferometer Parameters

Arm length	3km	
Arm Cavity Finesse	1550	
Arm Cavity g-factor	sqrt(1/3) or -sqrt(1/3)	Negative g-factor reduces the optical spring instability
PRC length	73.3m	Folded
SRC length	73.3m	Folded
MI asymmetry	3.33m	
PRG	10	
SRG	24	
Test Mass Size	Φ25cm x t15cm	Sapphire
BS Size	Φ ~ 40cm	
PRM, SRM size	Φ >= 10cm	

Mirror name conventions



Arm Cavity g-factor

Factors to consider

- Cavity must be stable (no low-order HOMs should not resonate)
- Angular instability caused by radiation pressure should be small enough
- The parametric instability also depends on the g-factor

g-factor	sqrt(1/3) --> L=3000m, ROC=7098.08m (Conventional number)
Candidates	-sqrt(1/3) --> L=3000m, ROC=1901.92m (Alternative)

Beam Size: 3.5cm for both cases
HOM degeneration: the same for both cases
Angular instability:

Eigen-frequencies: 1.66Hz and 0.86Hz
Positive g-factor → 1.66Hz is unstable
Negative g-factor → 0.86Hz is unstable

} Different WFS bandwidth

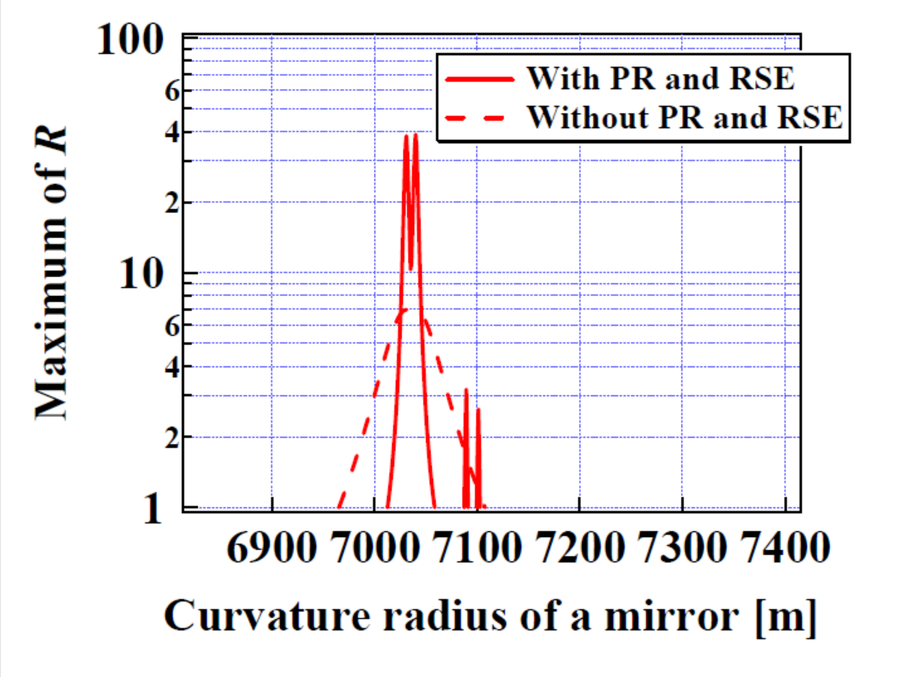
Parametric Instability:

There are preferred regions in the g factor space from the view point of PI.
The regions are the same for positive and negative g.
However, dg/dR is different by a factor of 13 (negative g is larger).
Therefore, negative g is more sensitive to the ROC error (not limited to the PI actually).

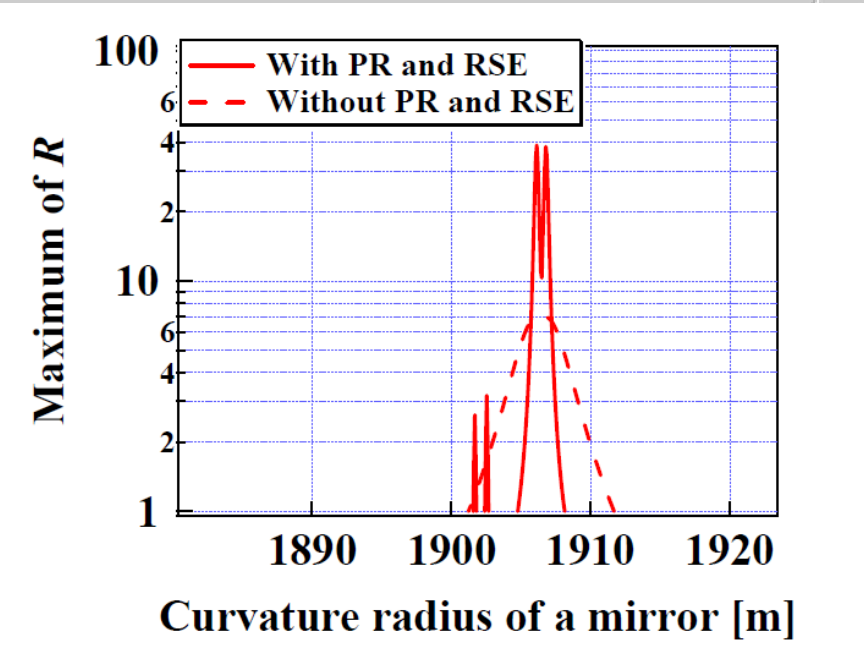
Negative g-factor is more prone to the mirror ROC error for PI

PI calculation by K. Yamamoto

Positive g-factor



Negative g-factor



The error requirement on the mirror ROC is stricter for the negative g-factor.

Folding

Why folding is necessary ?

Degenerated recycling cavities: Source of headaches

(Sideband mode is not determined, unstable control signal, bad contrast, GW sideband reduced)

We want to stabilize the RCs, but how much ? (to be assessed by MIST and Finesse)

According to LIGO and Virgo studies, one way Gouy phase shift of 20deg seems reasonable

Is folding possible within the LCGT constraints ?

Yes, there are solutions

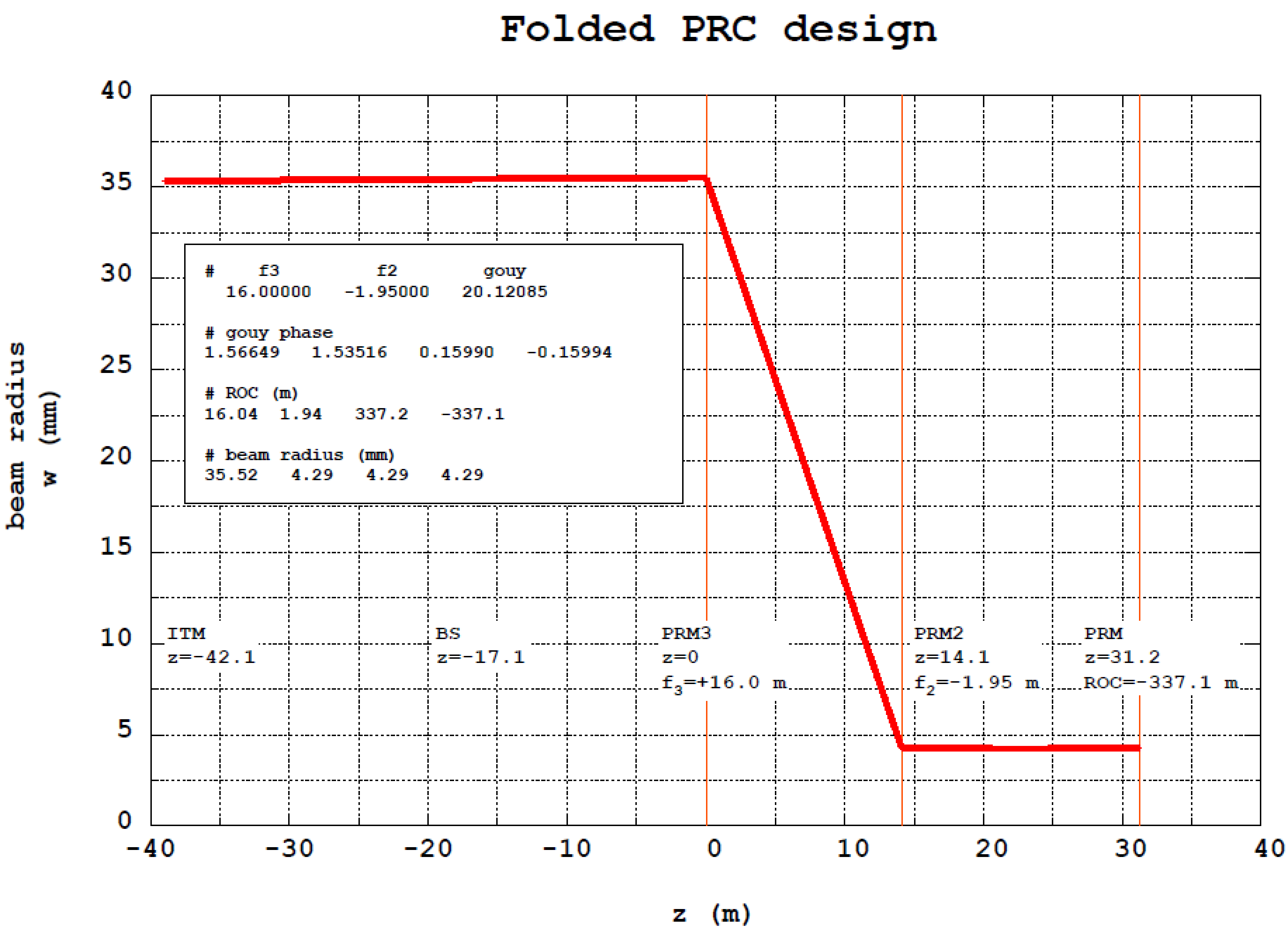
Many factors to consider:

Beam spot size, susceptibility to errors, ease of adjustment, back scattering, etc ...

Folding Mirror Positions ← Uniquely determined by the geometric requirement to minimize the incident angles (to avoid astigmatism)

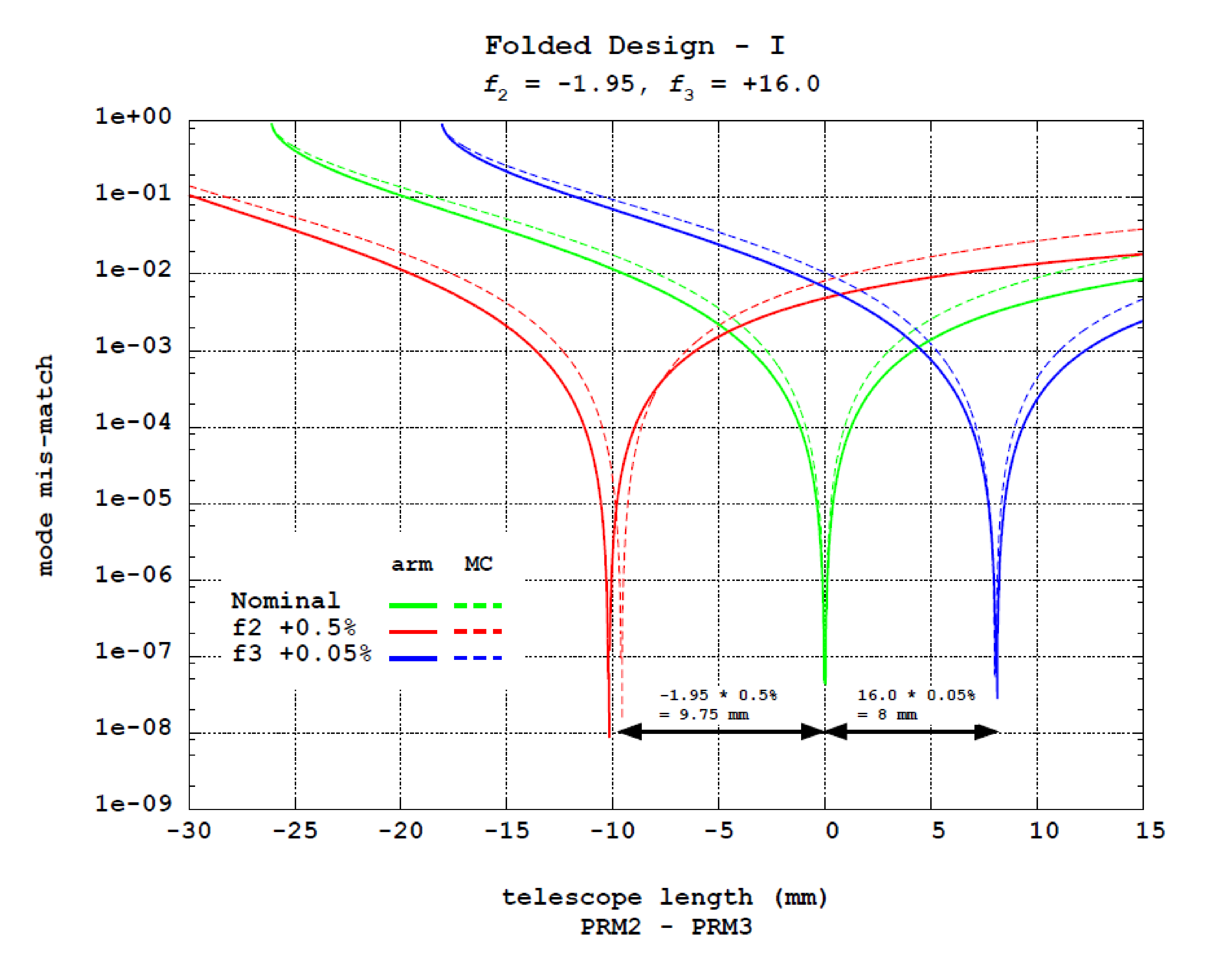
↑ Necessary for vacuum system design

Folding configuration by D. Tatsumi



Effect of the ROC errors in the folding mirrors

We have to be able to adjust the folding mirror positions by +/-5cm or so.



Mirror Size

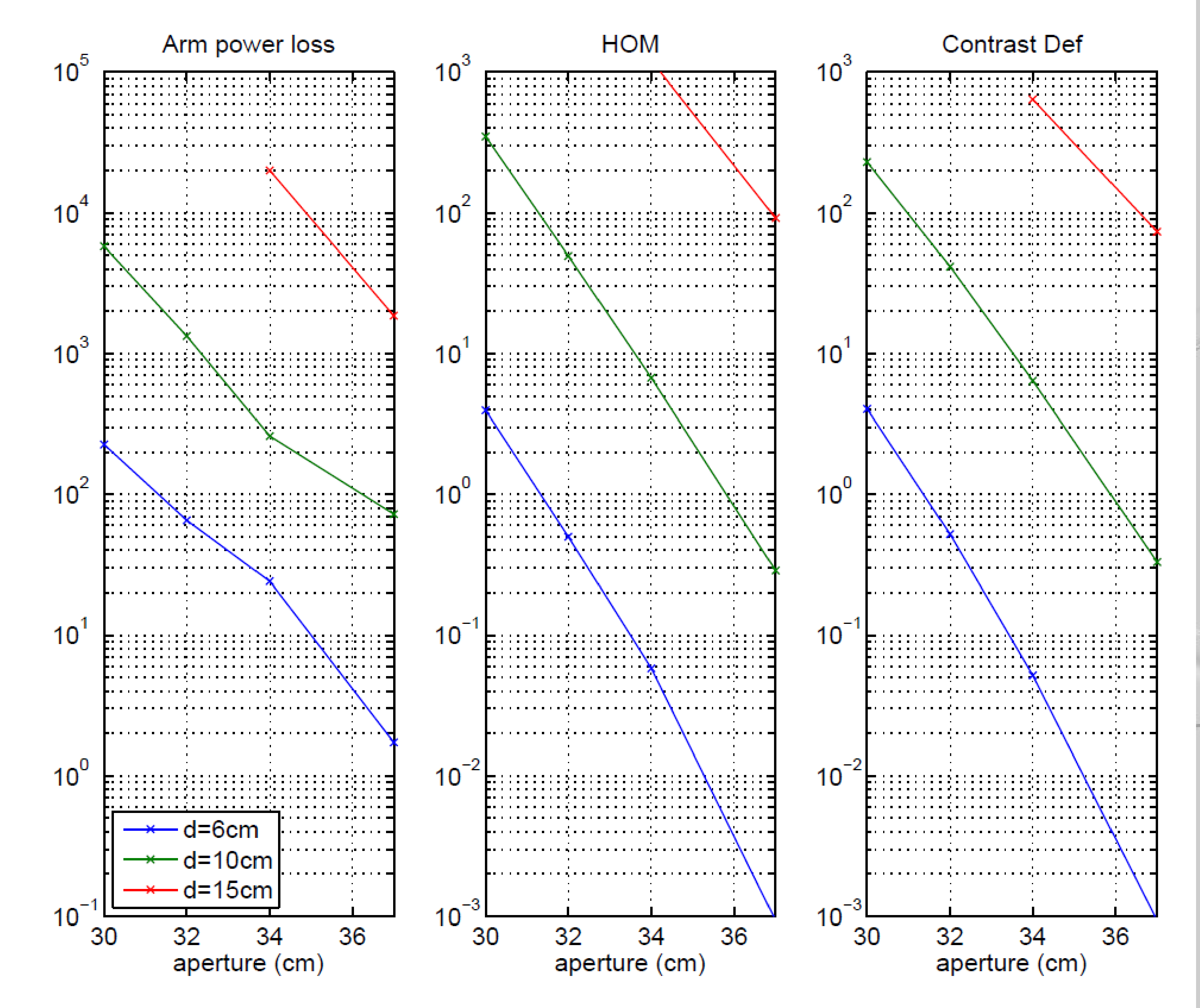
Factors to consider

- It is desirable to have as few as possible variations of size and weight of the mirrors from the view point of SAS
- Especially, changing the weight is costly.
- What is the maximum possible mirror size ?

Mirror Size Requirements from IFO's point of view

Optics	Beam Spot Size (1/e^2 radius)	Minimum Mirror Size (diameter)
ITM	3.5 cm	19 cm
ETM	3.5 cm	19 cm
BS	3.5 cm	3.5*6*sqrt(2)+2*t/sqrt(2*n^2-1), where t is the thickness and n is the refractive index. For t=10 cm, d=40 cm. Probably this value is a bit overkill. See Hiro Yamamoto's Calculation.
PR3	3.5 cm	19 cm
SR3	3.5 cm	19 cm
PR2	less than 1 cm	10 cm is enough
SR2	less than 1 cm	10 cm is enough
PRM	less than 1 cm	10 cm is enough
SRM	less than 1 cm	10 cm is enough

Optical Loss in the PRC by BS size effect by H. Yamamoto



Mirror Size Plans

Plan A: 16kg plan

For iLCGT: All the mirrors are 16kg fused silica

For bLCGT: ITMs and ETMs are replaced with 30kg Sapphire ones

Suspension

For iLCGT, ITMs and ETMs are suspended by the Type B platform
It will be replaced by Type A SAS in bLCGT
Everything else can be suspended by Type B SAS

Plan B: 30kg plan

For iLCGT:
ITM, ETM, BS, PR3, SR3: 38cmx12cm 30kg fused silica mirrors
PRM, PR2, SRM, SR2: 10cm TAMA sized mirrors

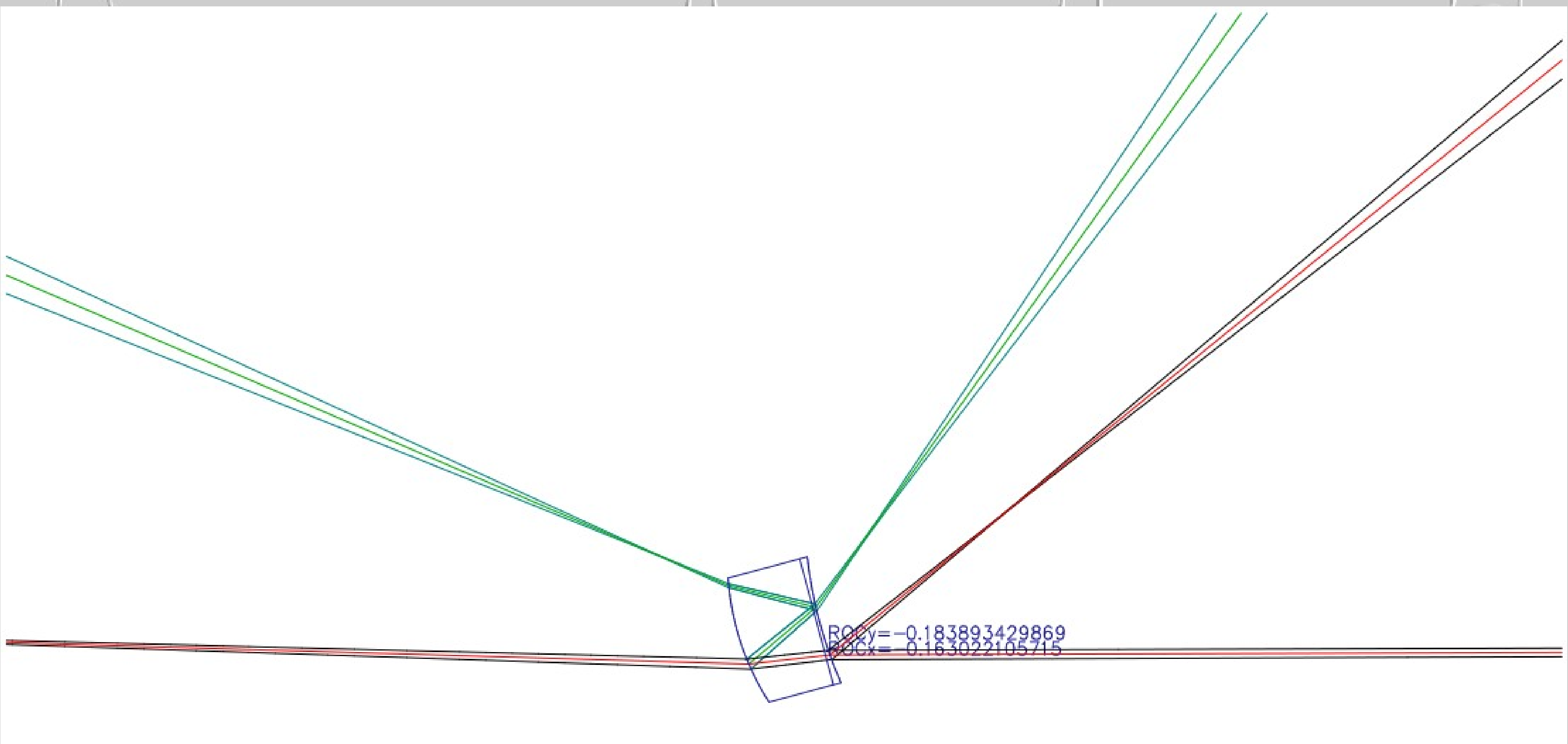
For bLCGT: ITMs and ETMs are 25cmx15cm 30kg sapphire mirrors

Suspension

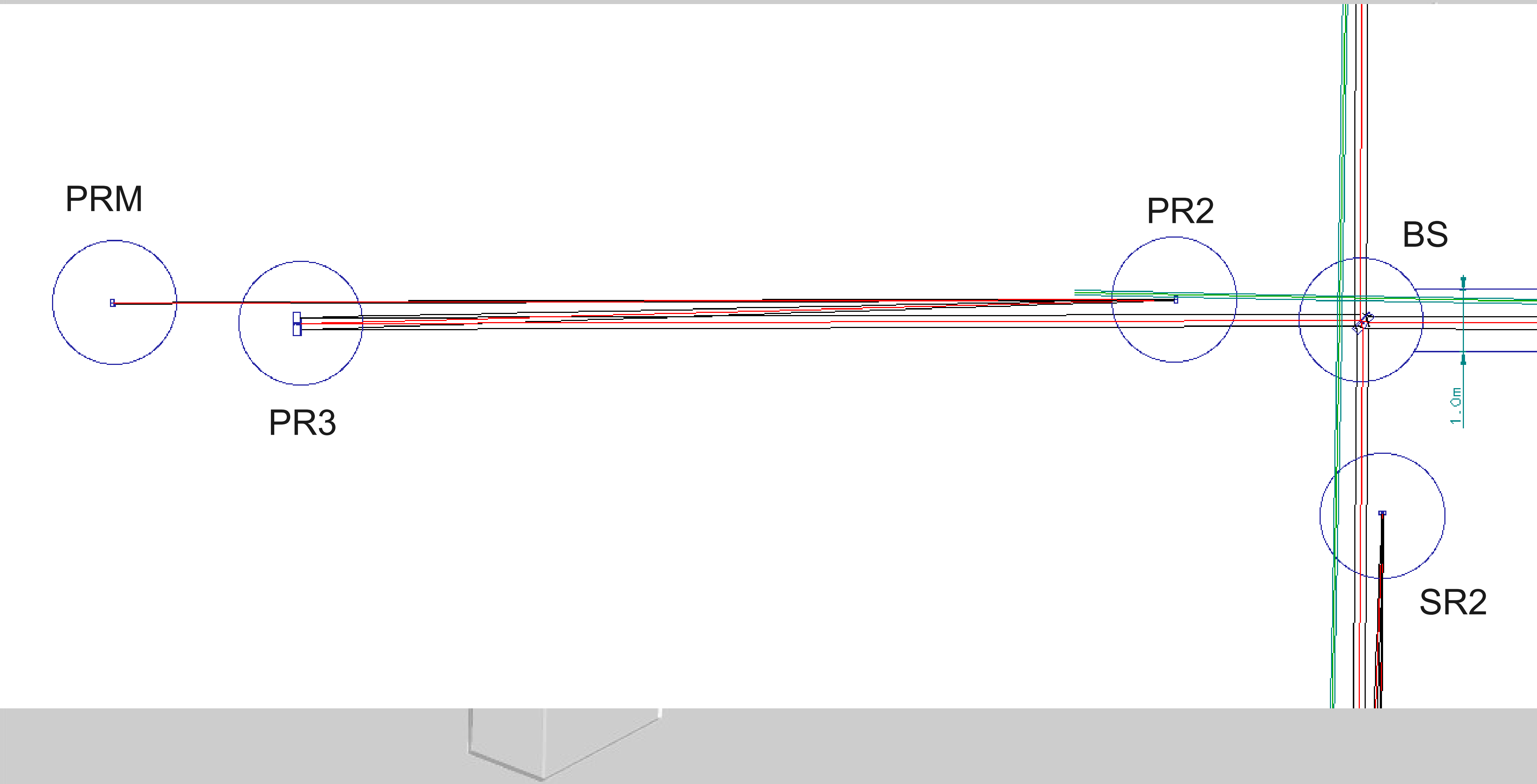
No need to change suspensions between iLCGT and bLCGT
There will be more TypeA SAS
10cm optics could be suspended with simpler suspensions

Optical Layout Tool

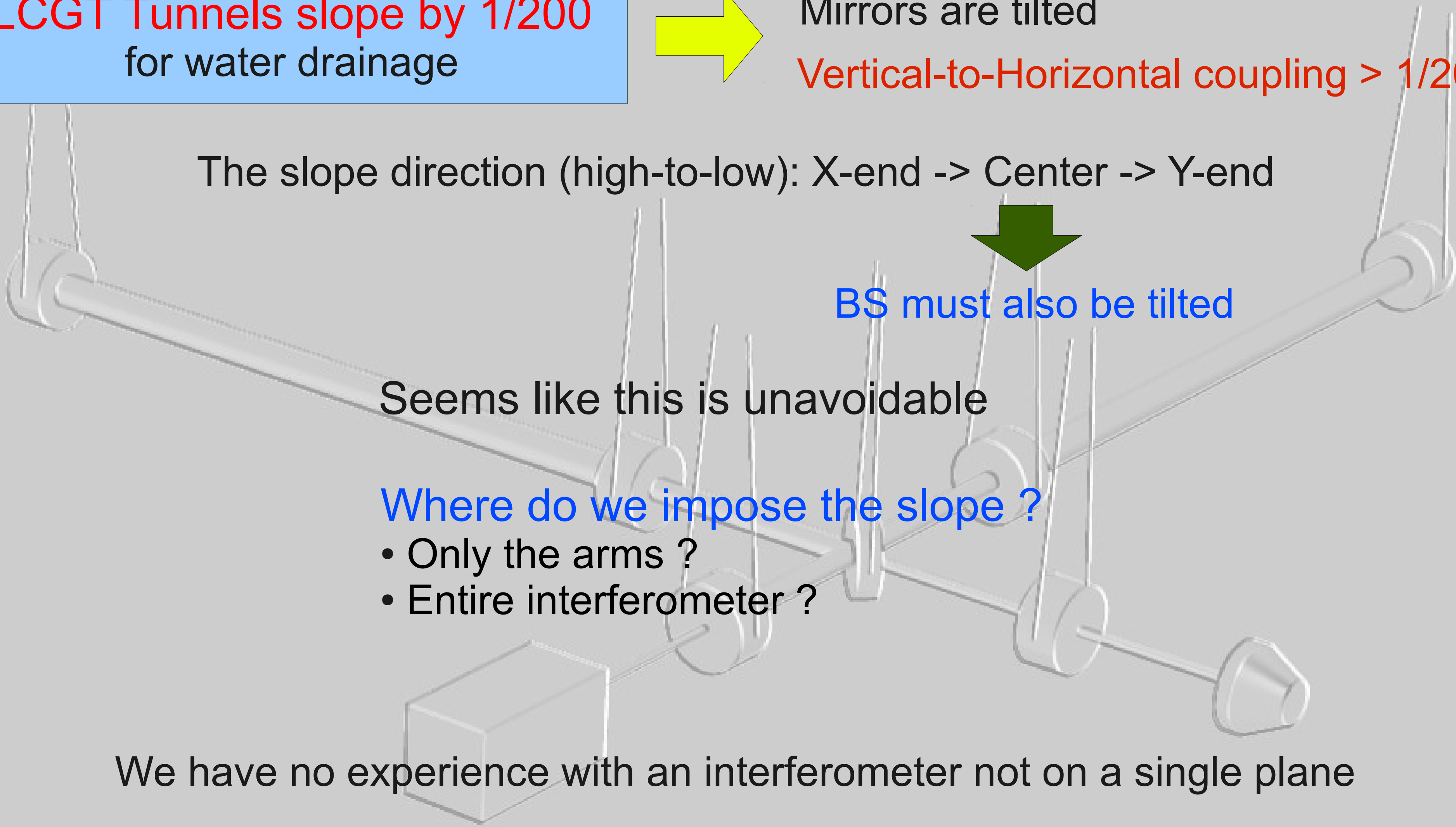
- A python module to automatically compute the propagation, reflection, deflection of Gaussian beams.
- Programmatic design of the IFO optical layout to satisfy various quantitative requirements at the same time



Power Recycling Cavity Folding Part



Tunnel Slope



LCGT Tunnels slope by 1/200
for water drainage

→ Mirrors are tilted

Vertical-to-Horizontal coupling > 1/200

The slope direction (high-to-low): X-end -> Center -> Y-end

BS must also be tilted

Seems like this is unavoidable

Where do we impose the slope ?

- Only the arms ?
- Entire interferometer ?

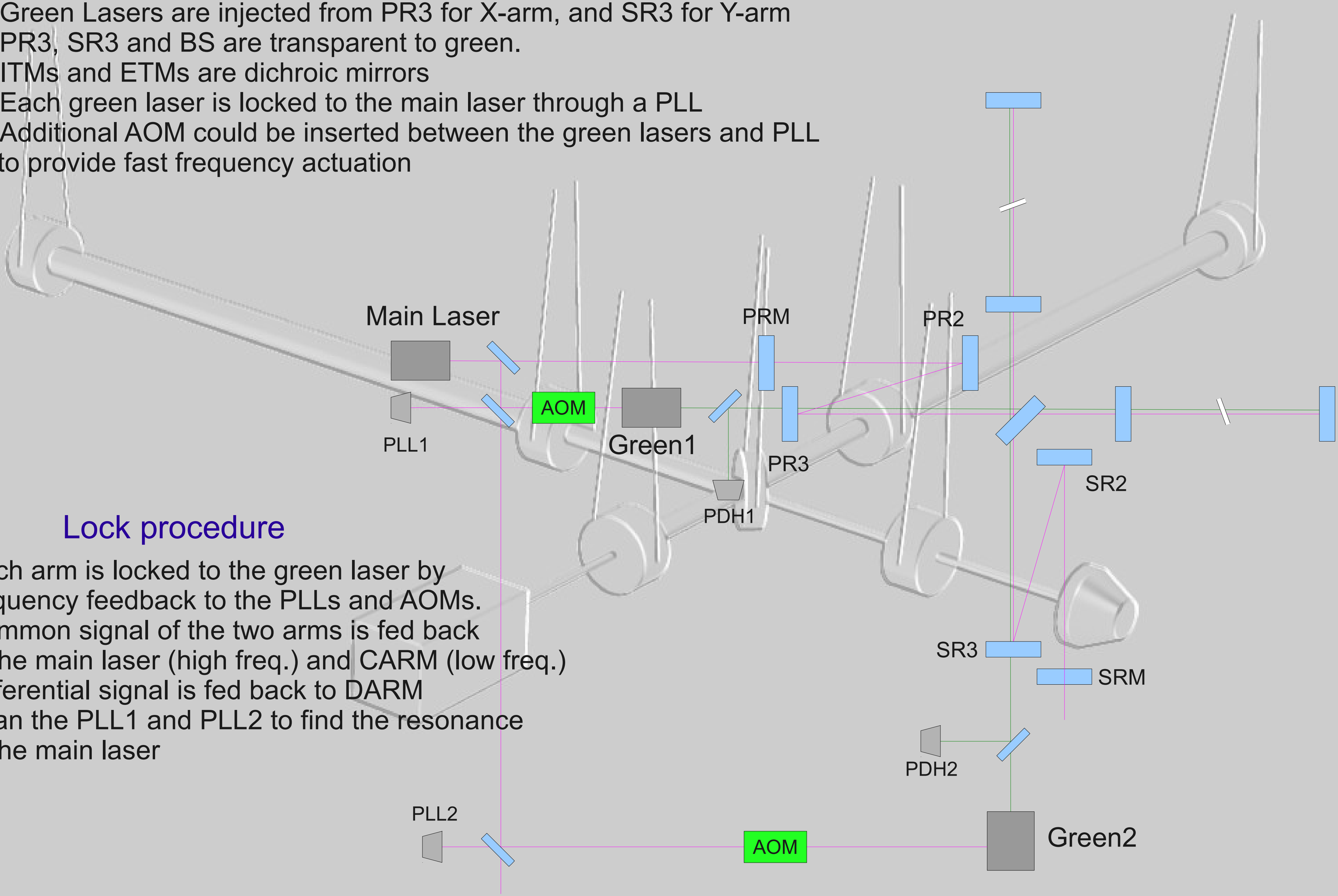
We have no experience with an interferometer not on a single plane

→ Put the entire interferometer on a single (but slanted) plane

Lock Acquisition

Basic ideas for green laser lock

- Green Lasers are injected from PR3 for X-arm, and SR3 for Y-arm
- PR3, SR3 and BS are transparent to green.
- ITMs and ETMs are dichroic mirrors
- Each green laser is locked to the main laser through a PLL
- Additional AOM could be inserted between the green lasers and PLL to provide fast frequency actuation



Lock procedure

- Each arm is locked to the green laser by frequency feedback to the PLLs and AOMs.
- Common signal of the two arms is fed back to the main laser (high freq.) and CARM (low freq.)
- Differential signal is fed back to DARM
- Scan the PLL1 and PLL2 to find the resonance of the main laser

Summary and TO DO List

Parameters necessary for Tunnel, Vacuum and Mirrors are almost fixed

Mirror specs needs to be discussed more.
But sizes are soon to be fixed.

TO DO

- Find an ASC Scheme
- Check the GW signal degradation with MIST and Finesse
- Finalize folding design
- Finalize the green locking design
- Finalize mirror specs
- Finalize the optical layout
- Determine the isolation requirements for RC suspensions
  etc ...