AIGO 2K

Australia - Italy Workshop 2005

7th October 2005

Pablo Barriga
for AIGO group

ACIGA Mission

- High Optical Power Test

Development of high power optics in collaboration with LIGO

- Low noise 80m base line

Demonstrate noise performance of high power interferometer

- Advanced gravitational wave

AIGO

First in the Southern Hemisphere

- Primary Institutions:
  - University of Adelaide
  - Australian National University
  - University of Western Australia

Affiliate Institutions:

- Monash University
- CSIRO-Optics

SUB CRUCE LUMEN

NATURAM PRIMUM COGNOSCERE RERUM

SEEK WISDOM

Vacuum System

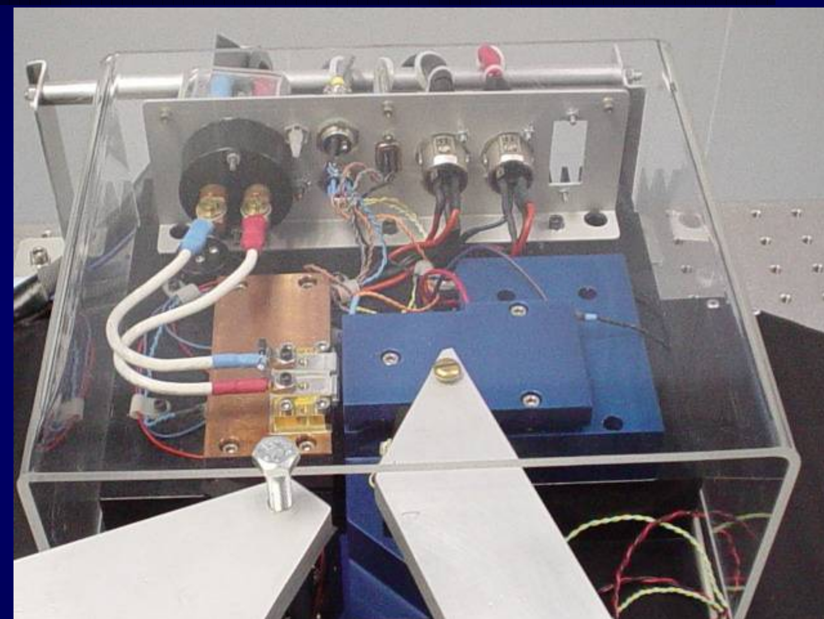
Single increment

3.5m high vacuum tanks

400mm diameter pipes? (R. De Salvo)

Input Laser

- Injection locked 10W Nd:YAG laser has been developed by The University of Adelaide.



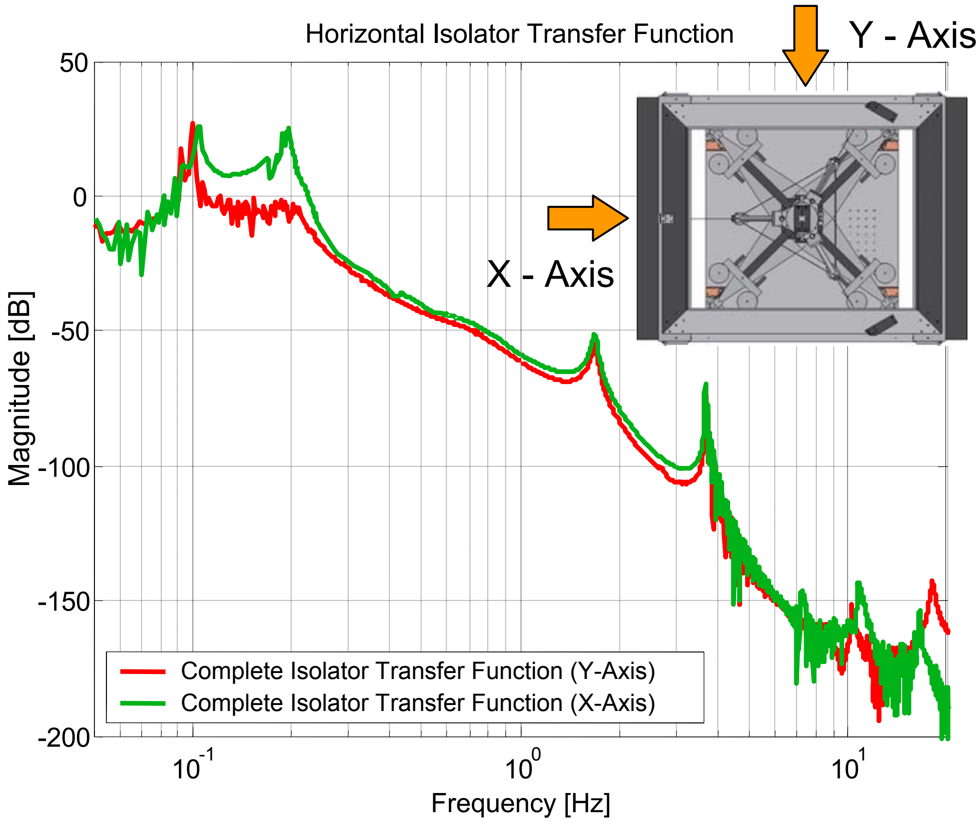
- High power laser clean room near Class 100.

- Future laser >100W

Talk by Peter Veitch

High Optical Power Mode Cleaner

- Astigmatism and thermal lensing calculations.
- Isolation system transfer function shows good performance.
- Control system design and implementation underway.

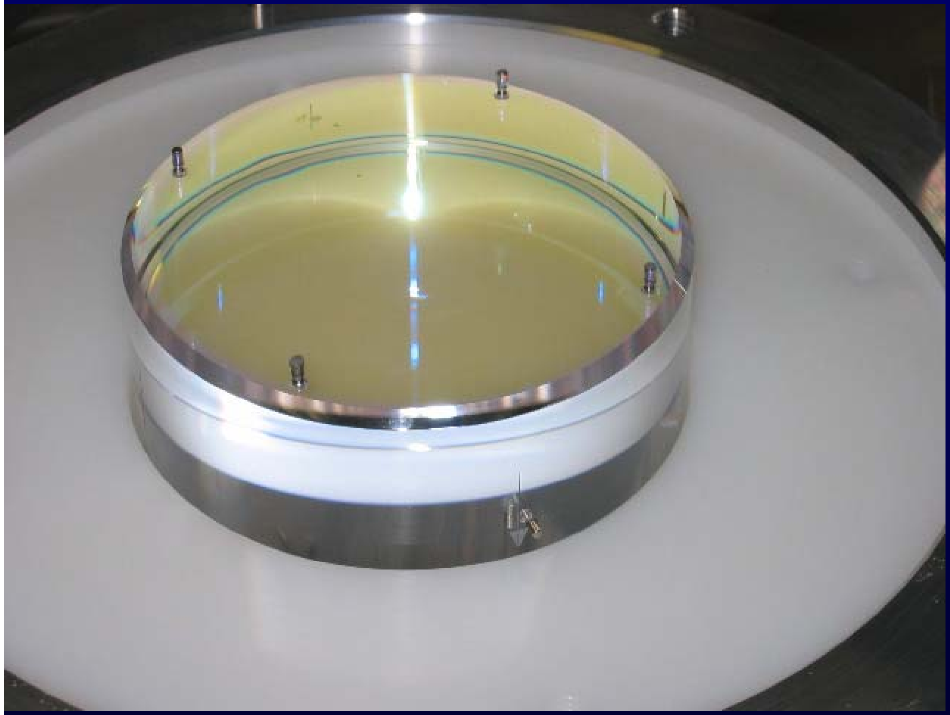


Test Masses

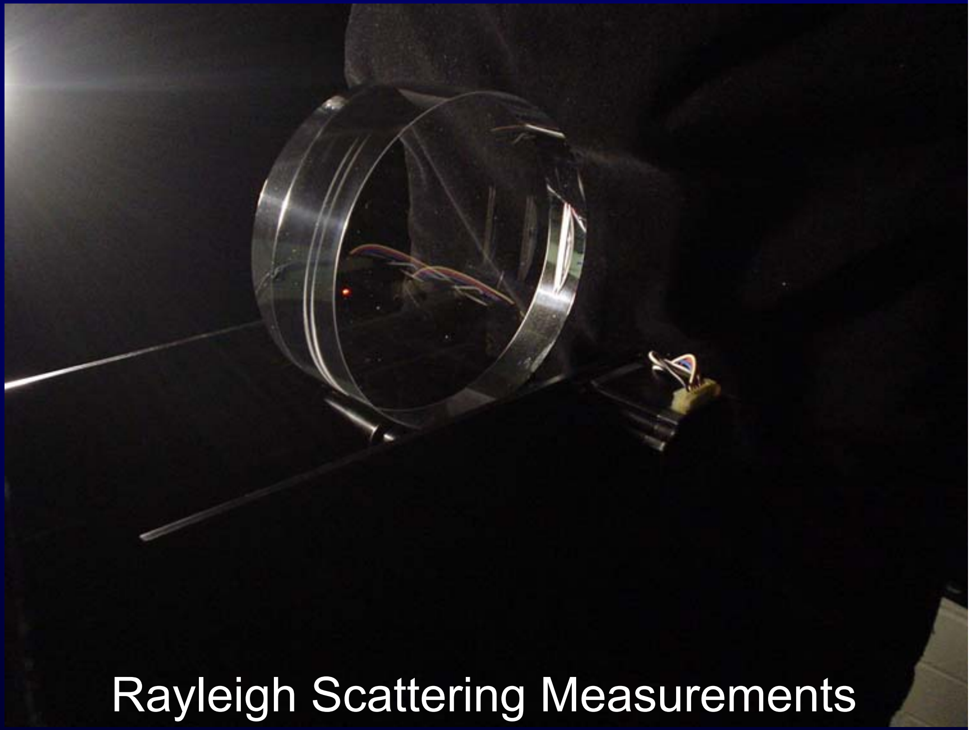
Fused Silica or Sapphire?

Start with small test masses ~10kg

Second stage 40kg (Advanced LIGO)



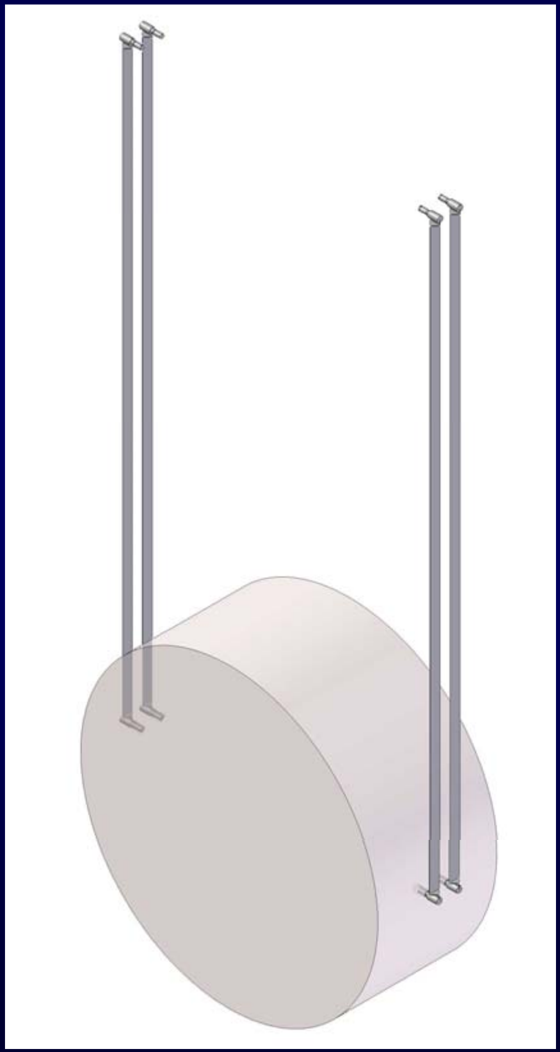
Sapphire Input Test Mass



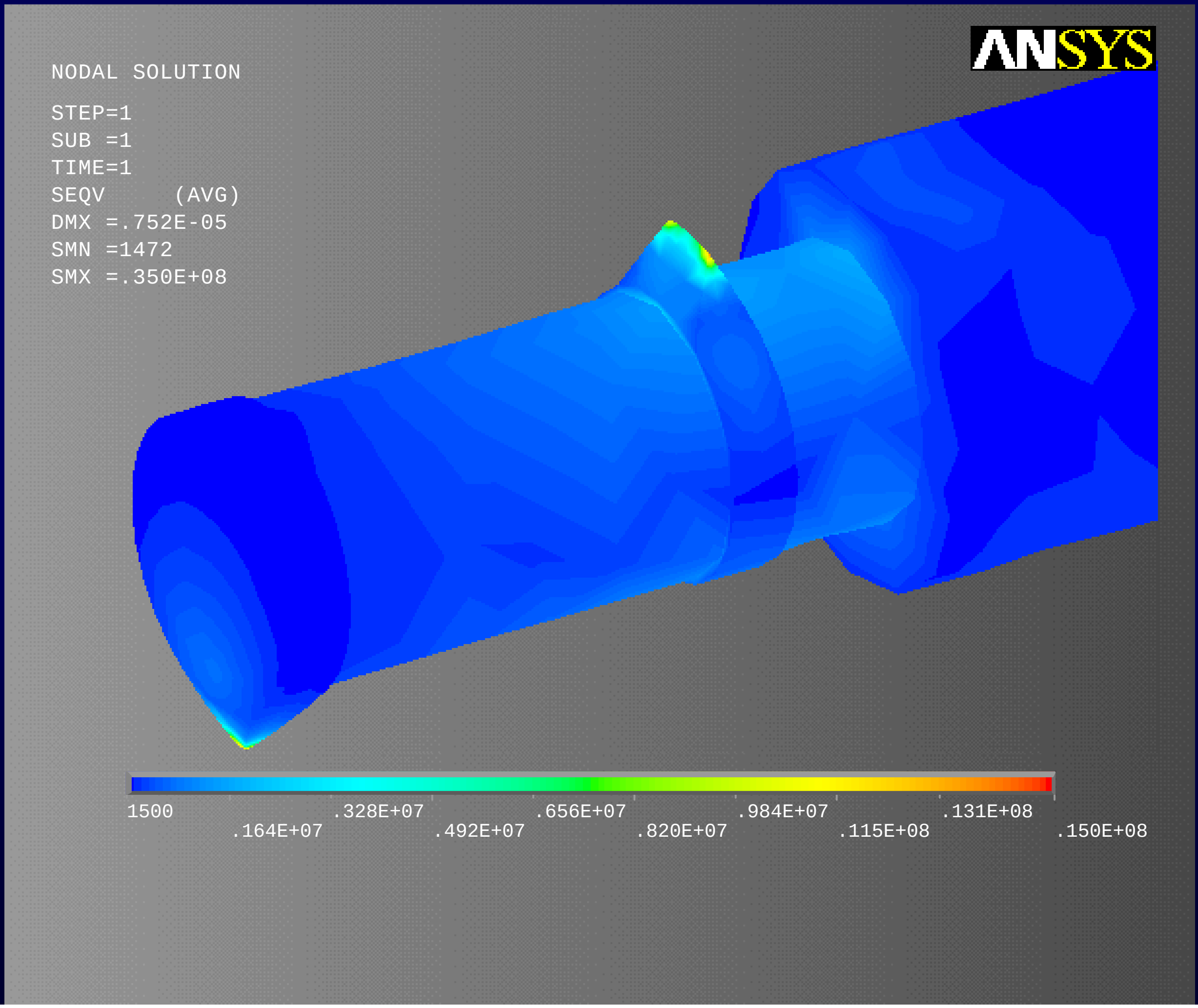
Rayleigh Scattering Measurements
Talk by Zewu Yan

Suspension System

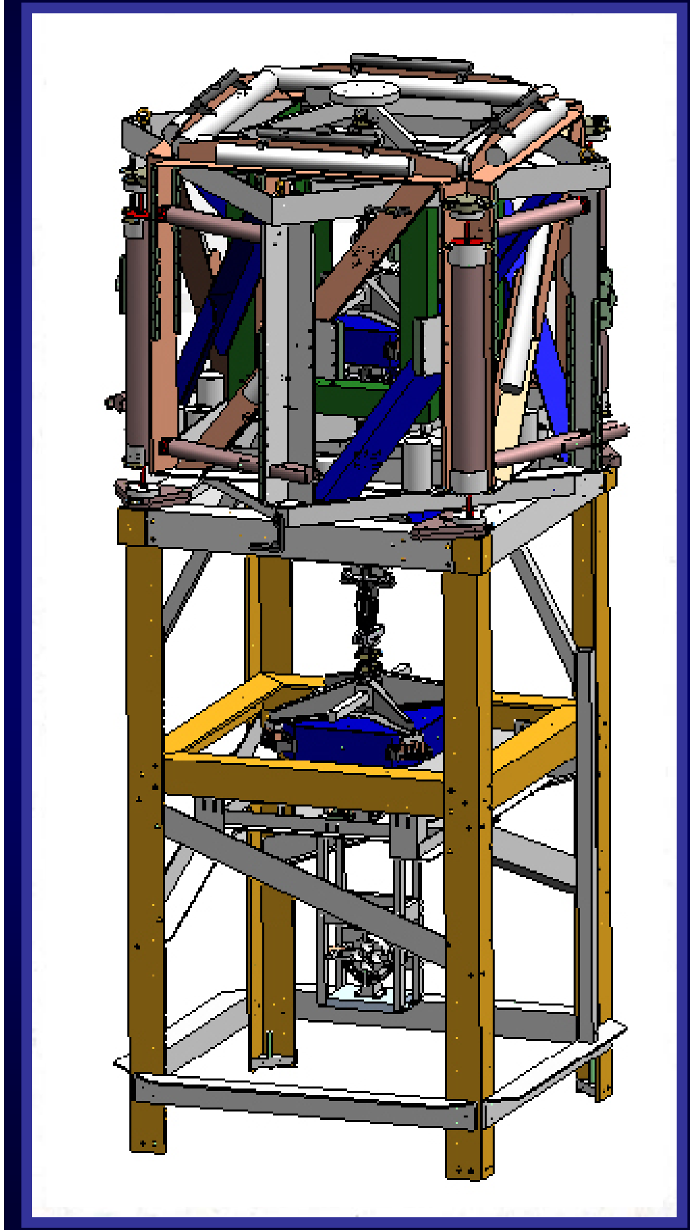
Stage 1: Niobium Flexures ❾ Stage 2 : Fused Silica Flexures

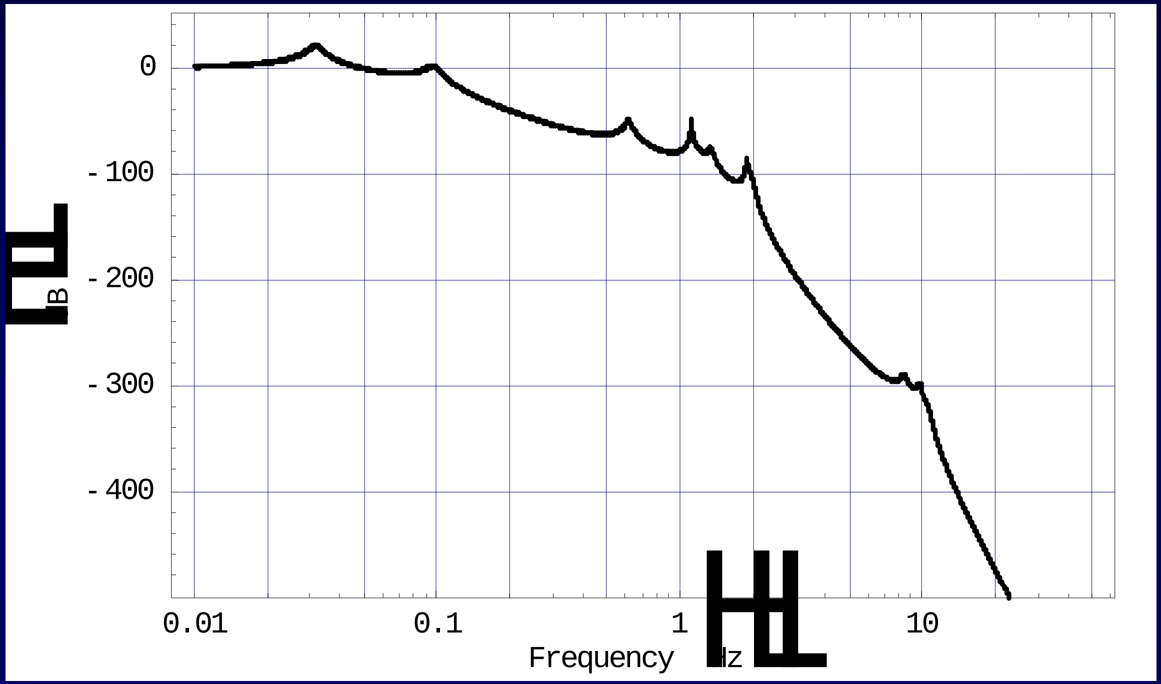


Talk by Ben Lee



Isolation System





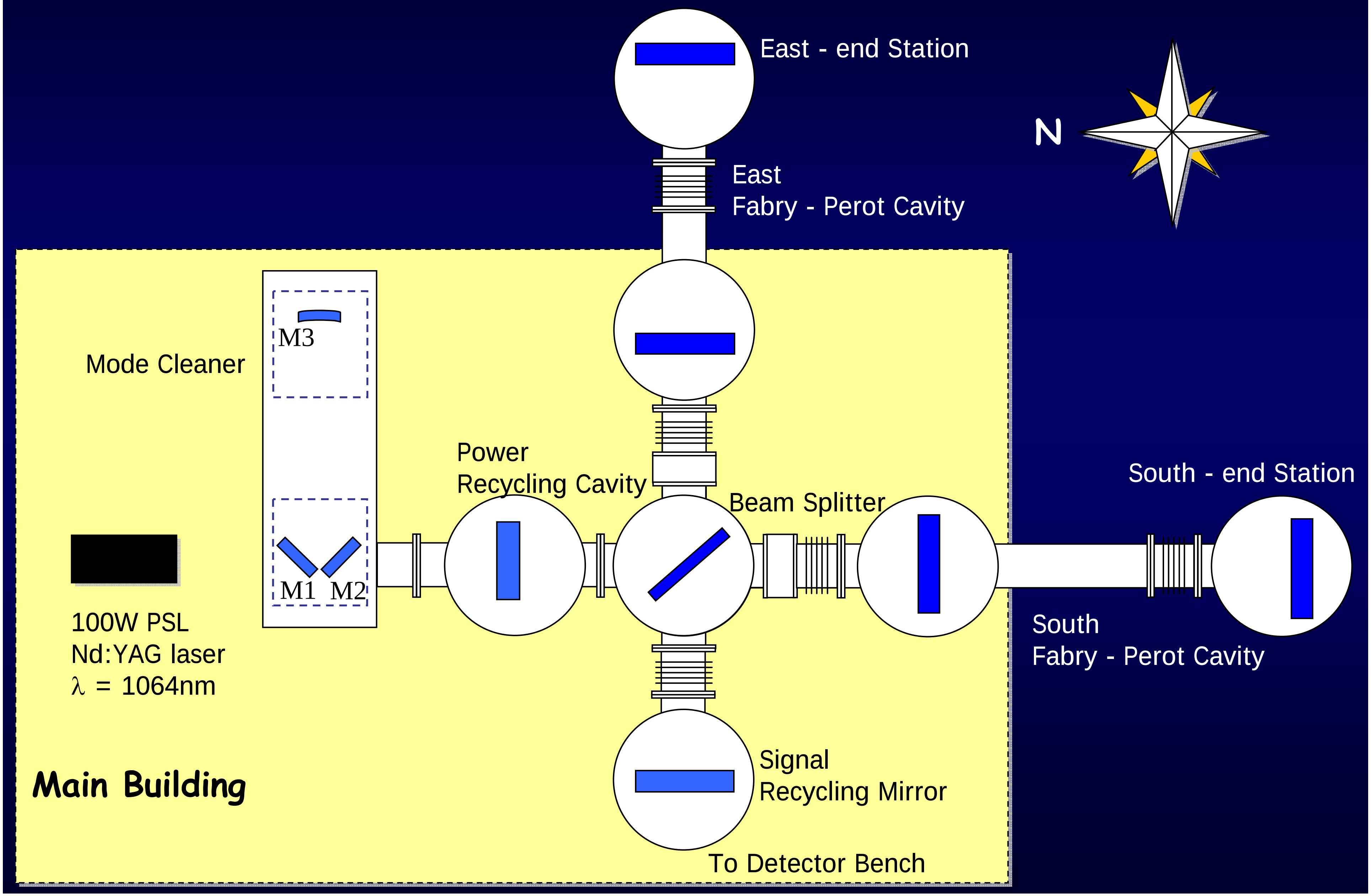
- Robust isolation system
- Built for heavy test masses

Talk by Jean Charles and Eu-Jeen

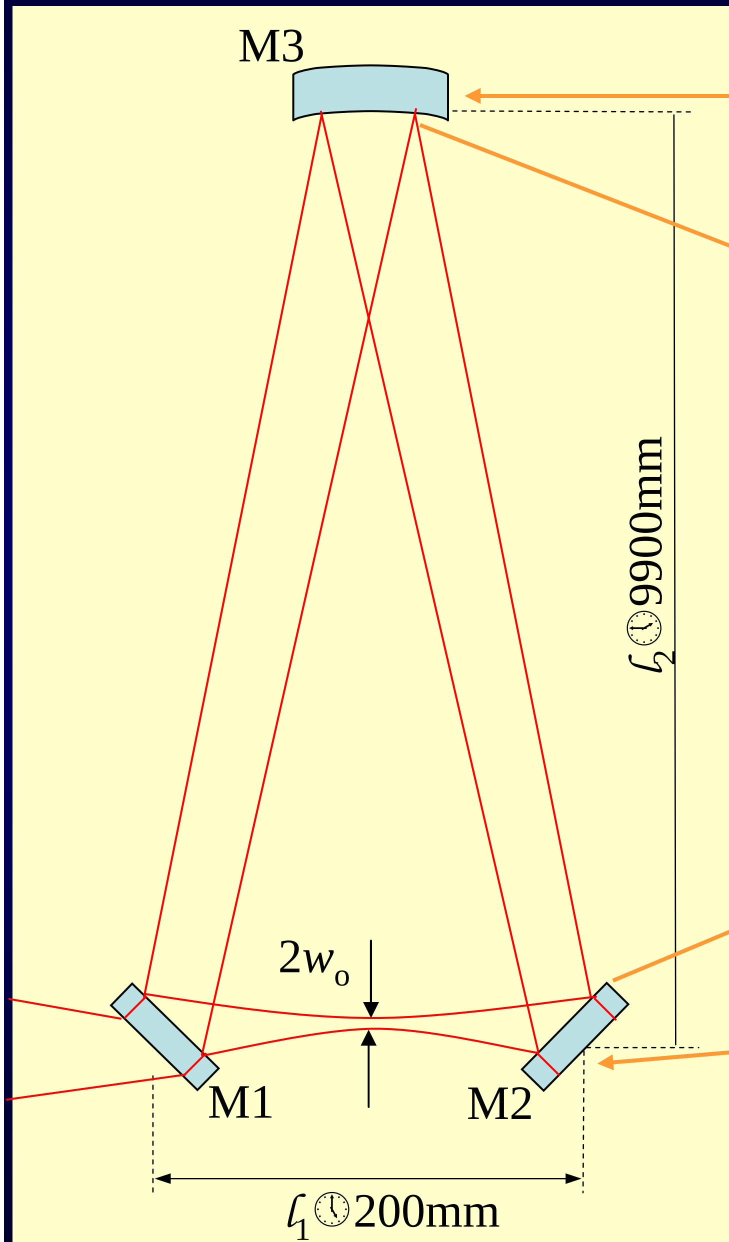
Digital Control

- Digital Control already under development.
- DSP based?
- LIGO EPICS?
- Is there a way of combining both?

AIGO Dual Recycling Interferometer

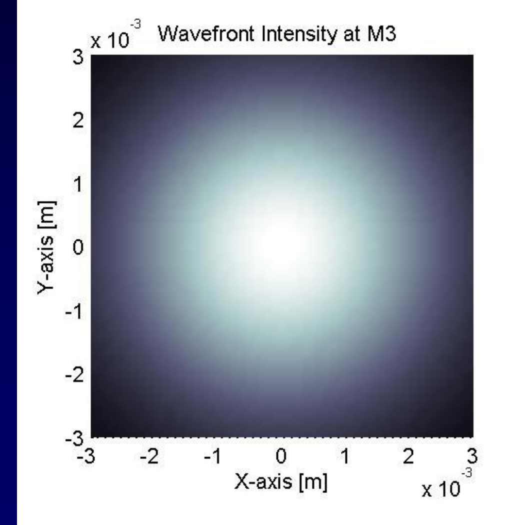


Mode-Cleaner Geometry



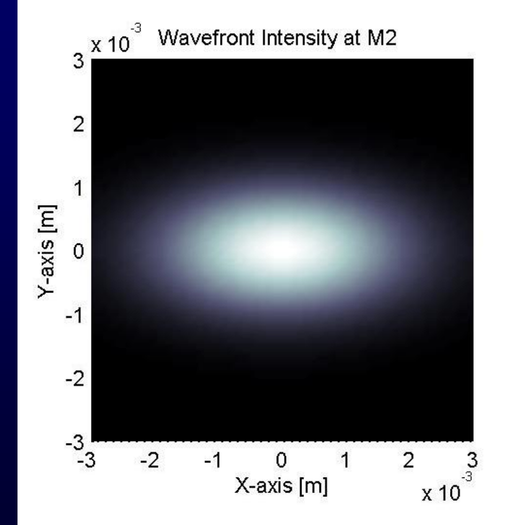
Concave end mirror

Incident angle 0.579°

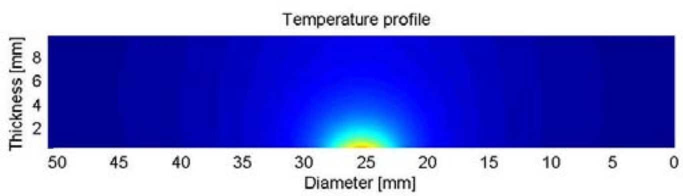


Incident angle 44.712°

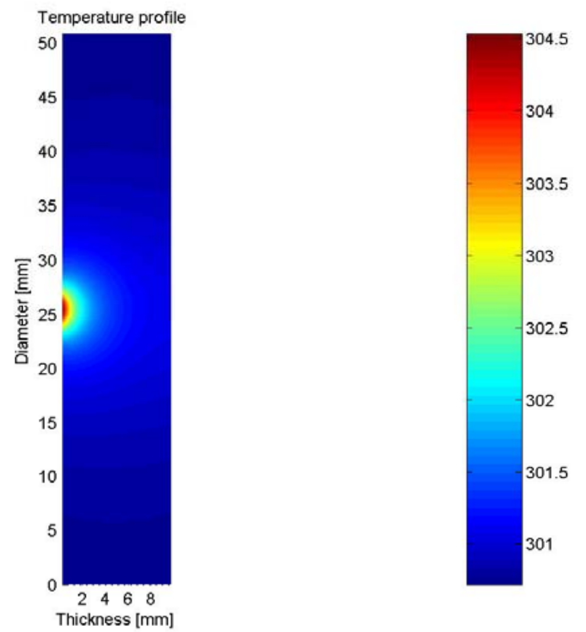
Flat Mirrors used as input and output couplers

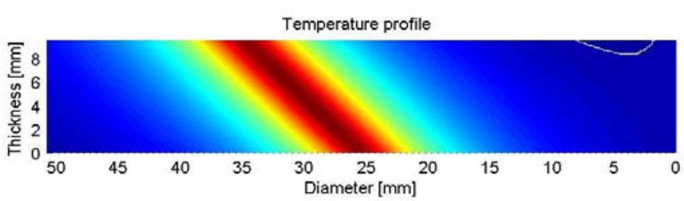


Coating and Substrate Absorptions

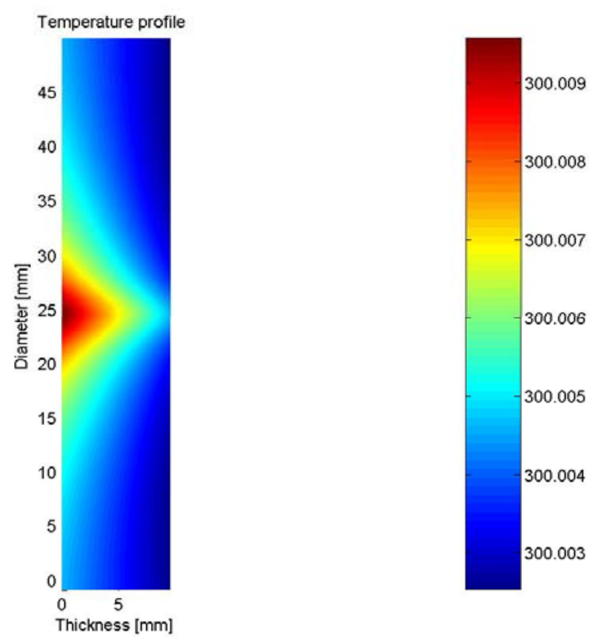


High reflectivity coating absorption produces astigmatic thermal lensing. The spot ellipticity produce different distribution between X and Y axis.

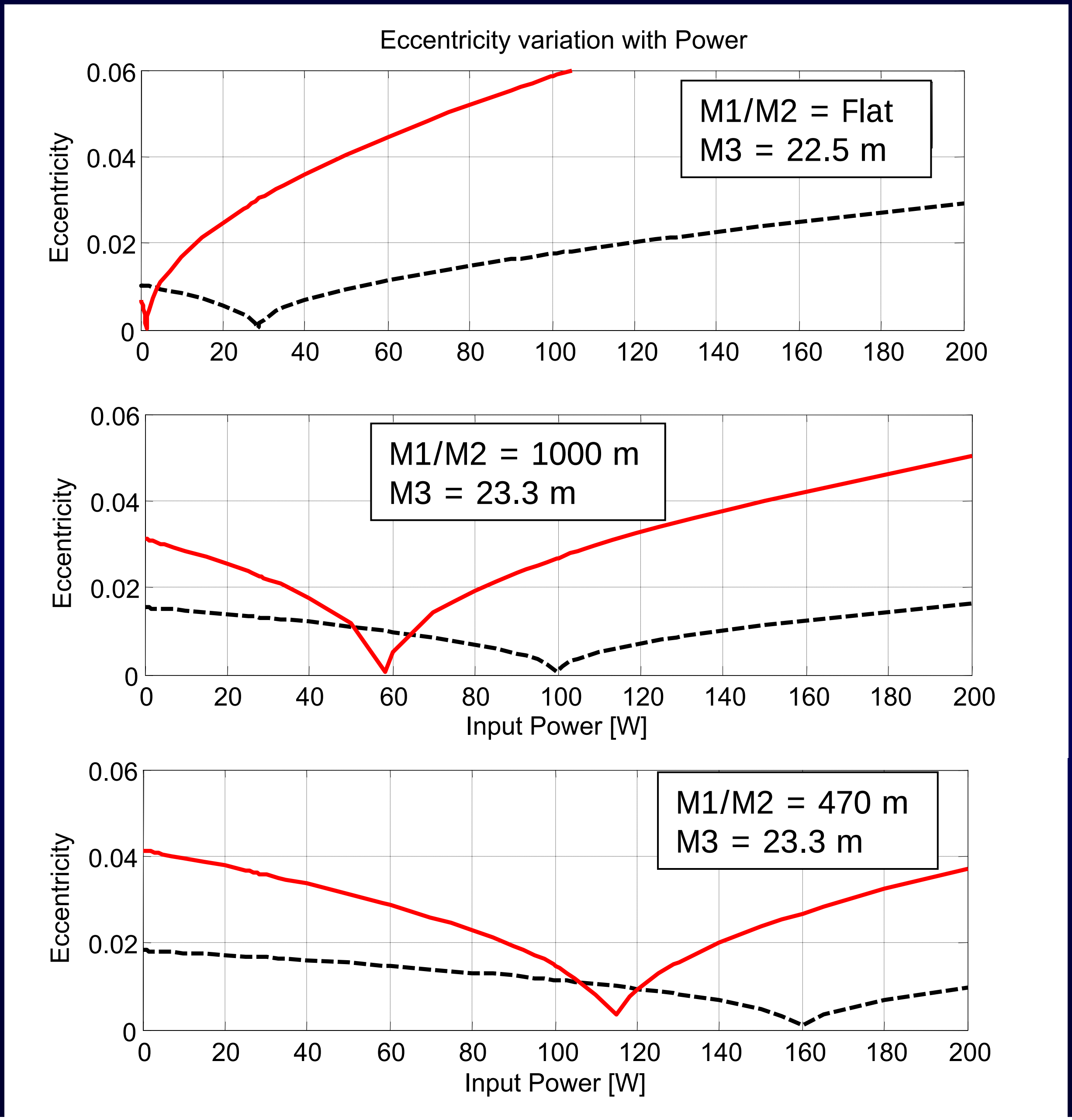




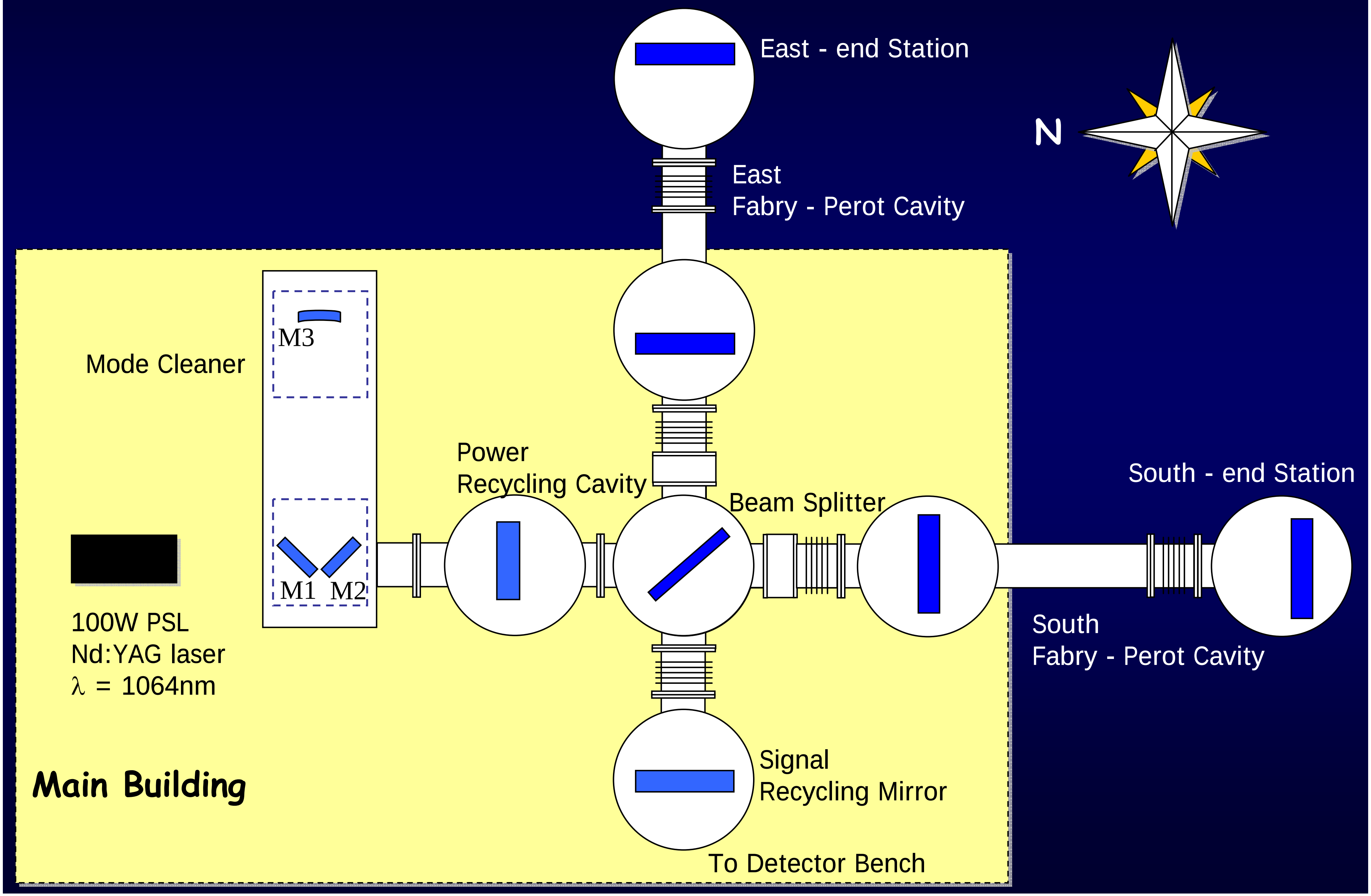
M2 used as output coupler the diagonally transmitted beam produces strong astigmatic thermal lensing.



Eccentricity variation with Power



AIGO Future Interferometer



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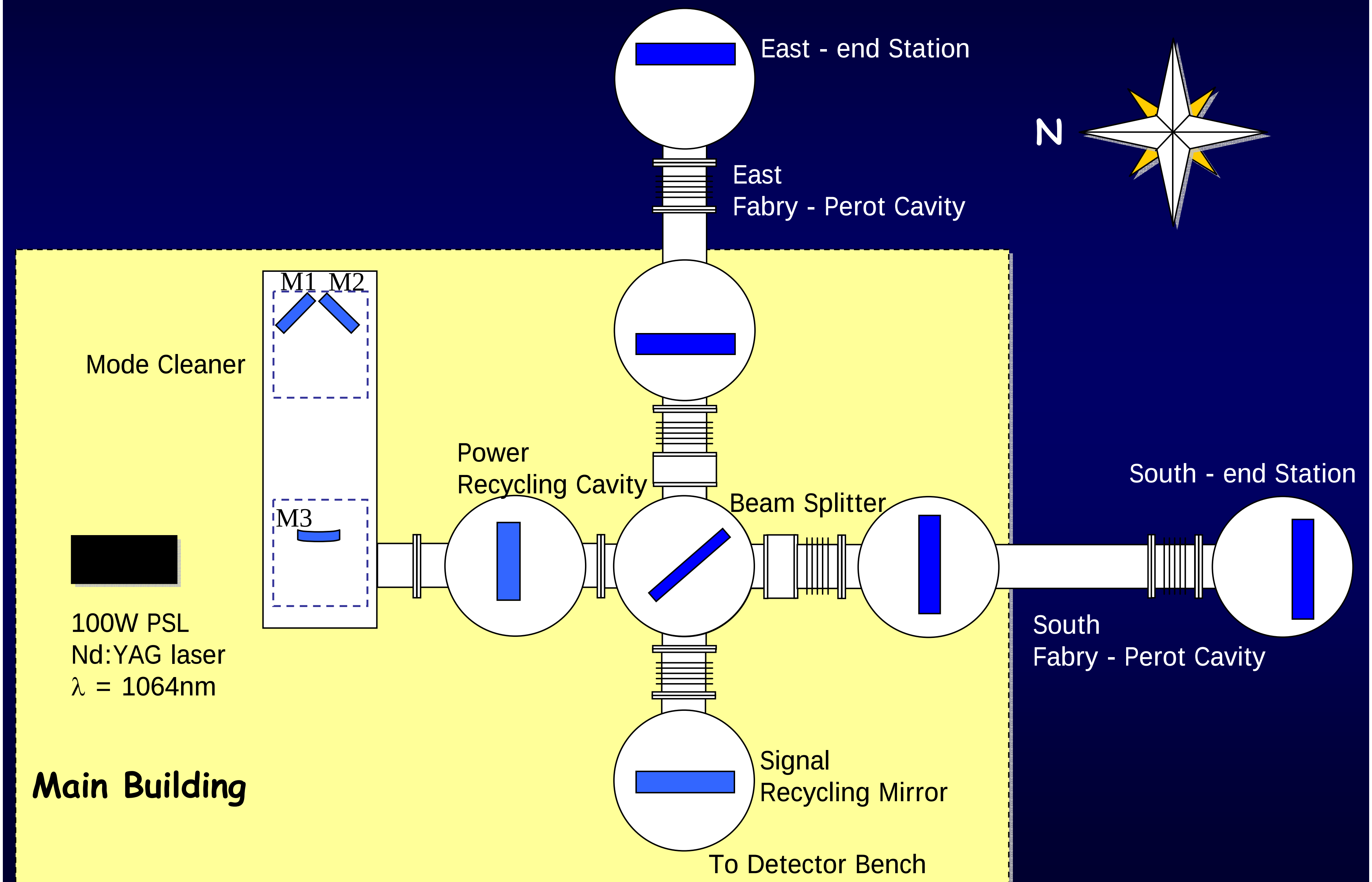

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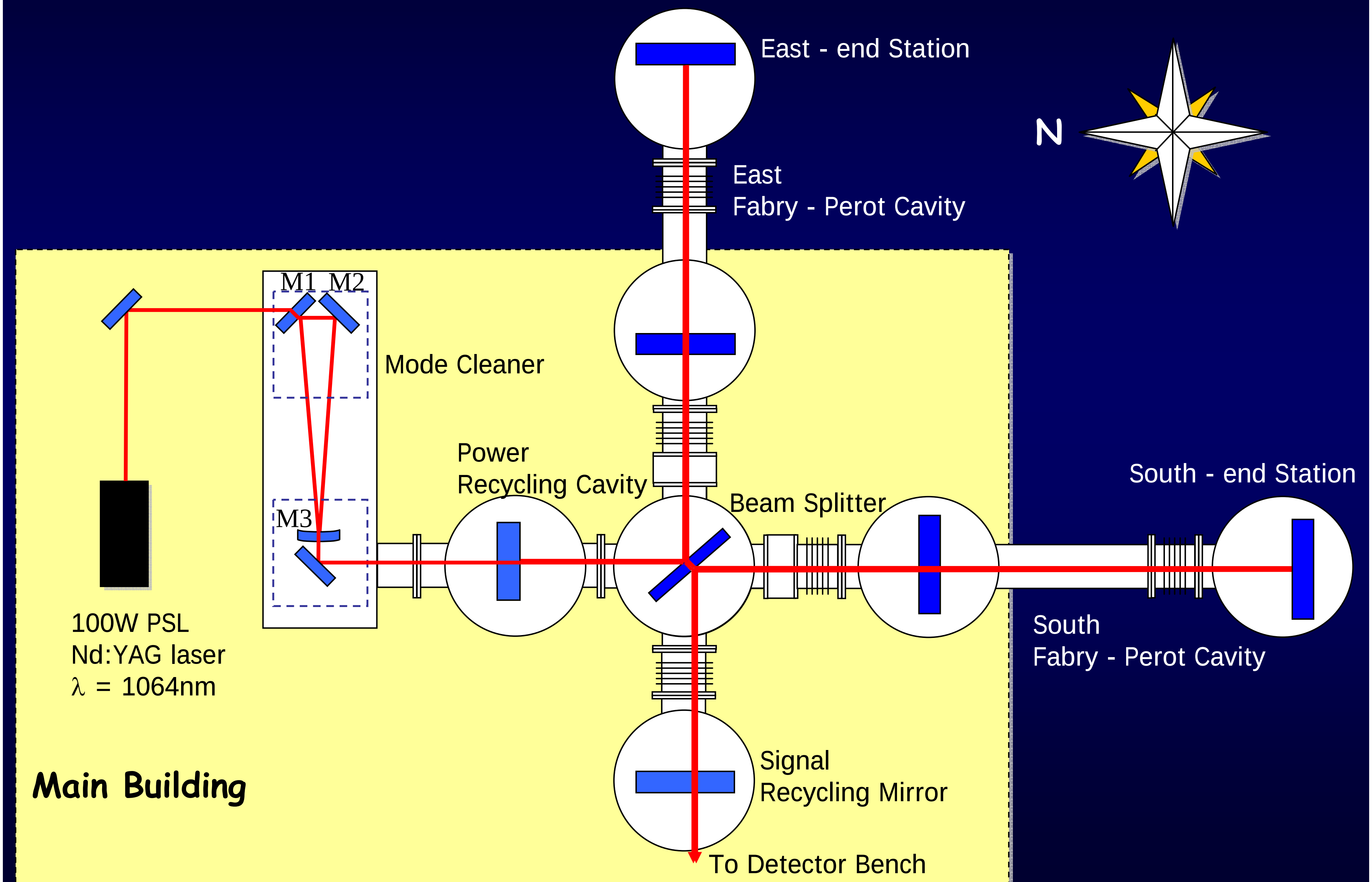

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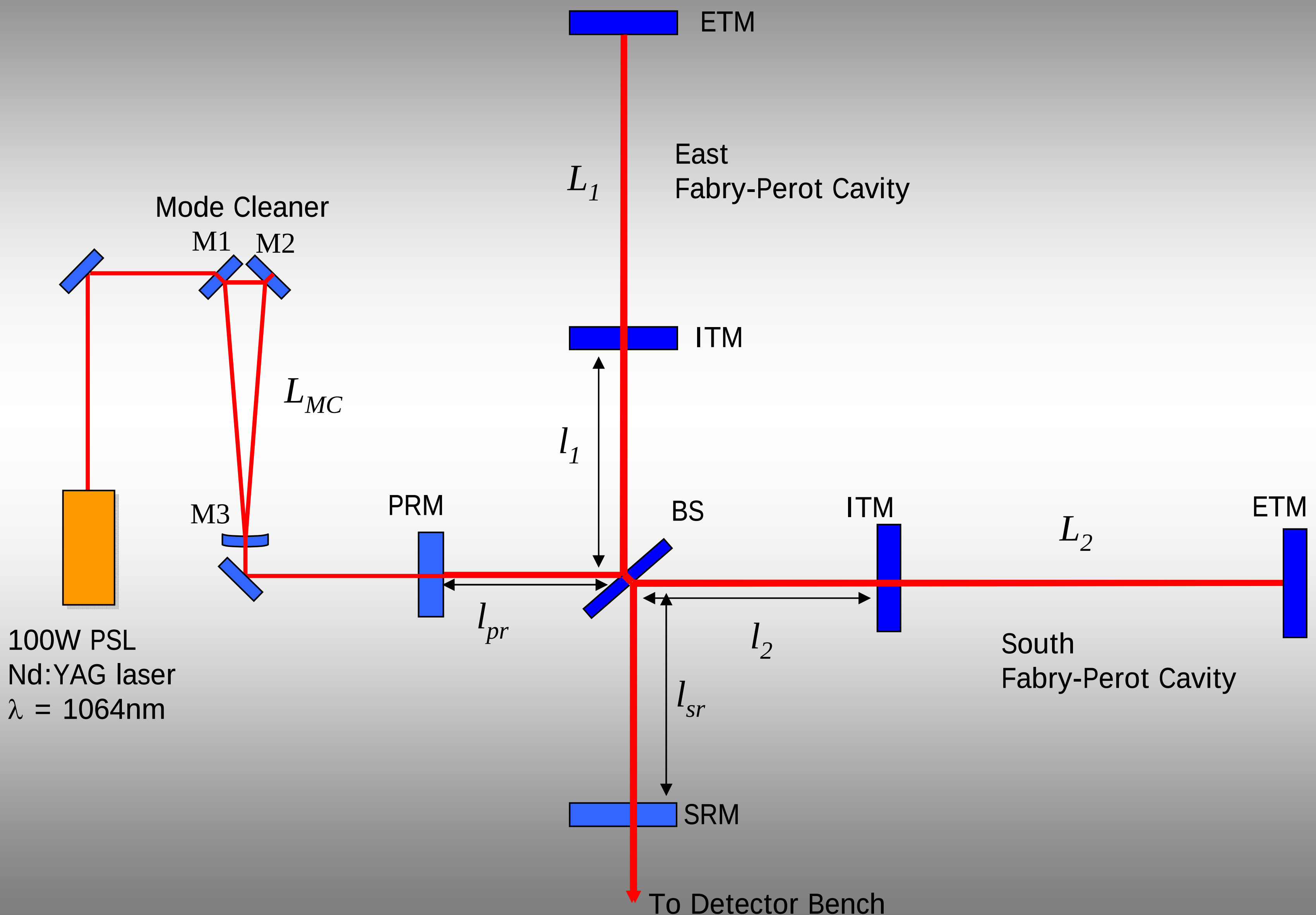
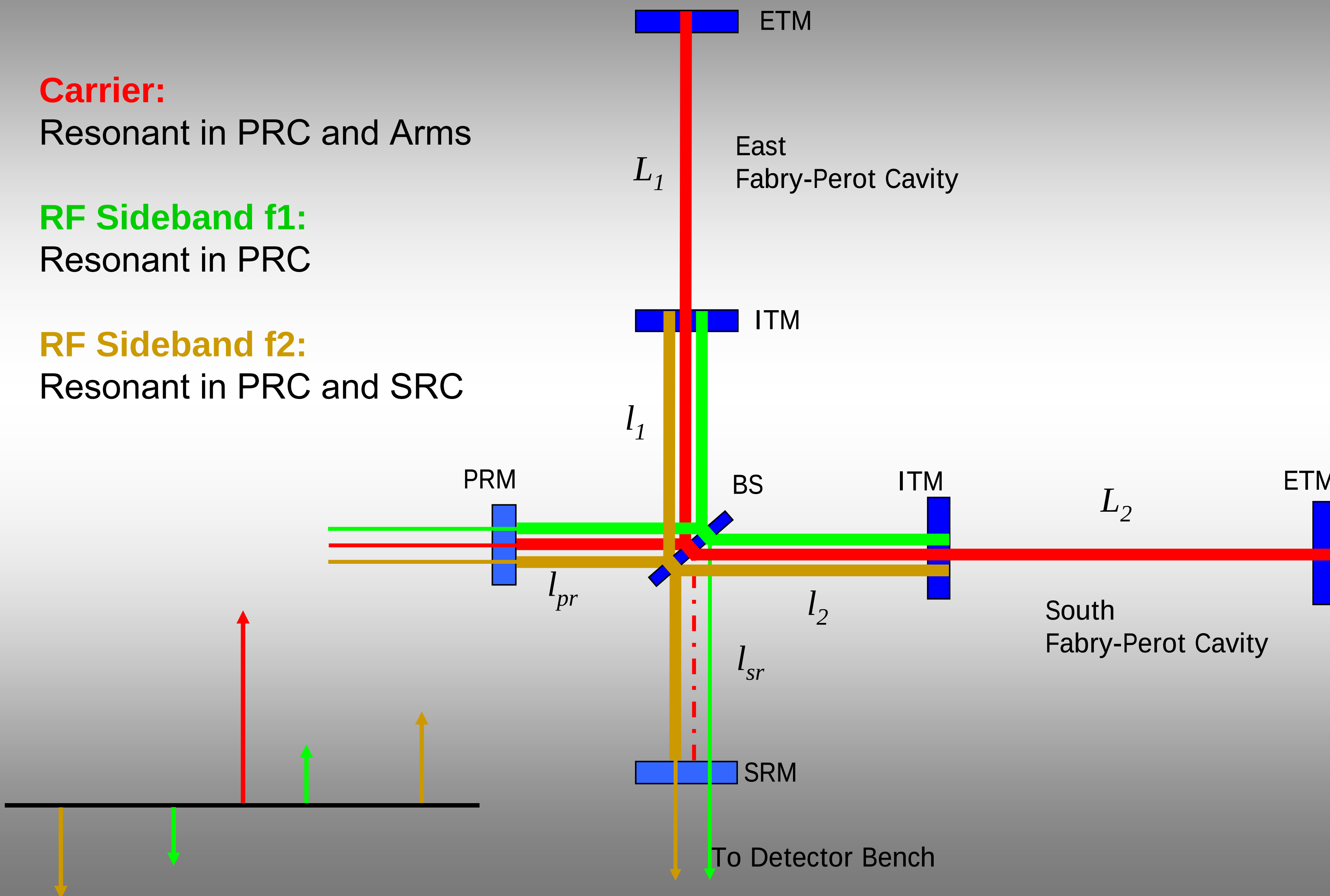


AIGO Future Interferometer

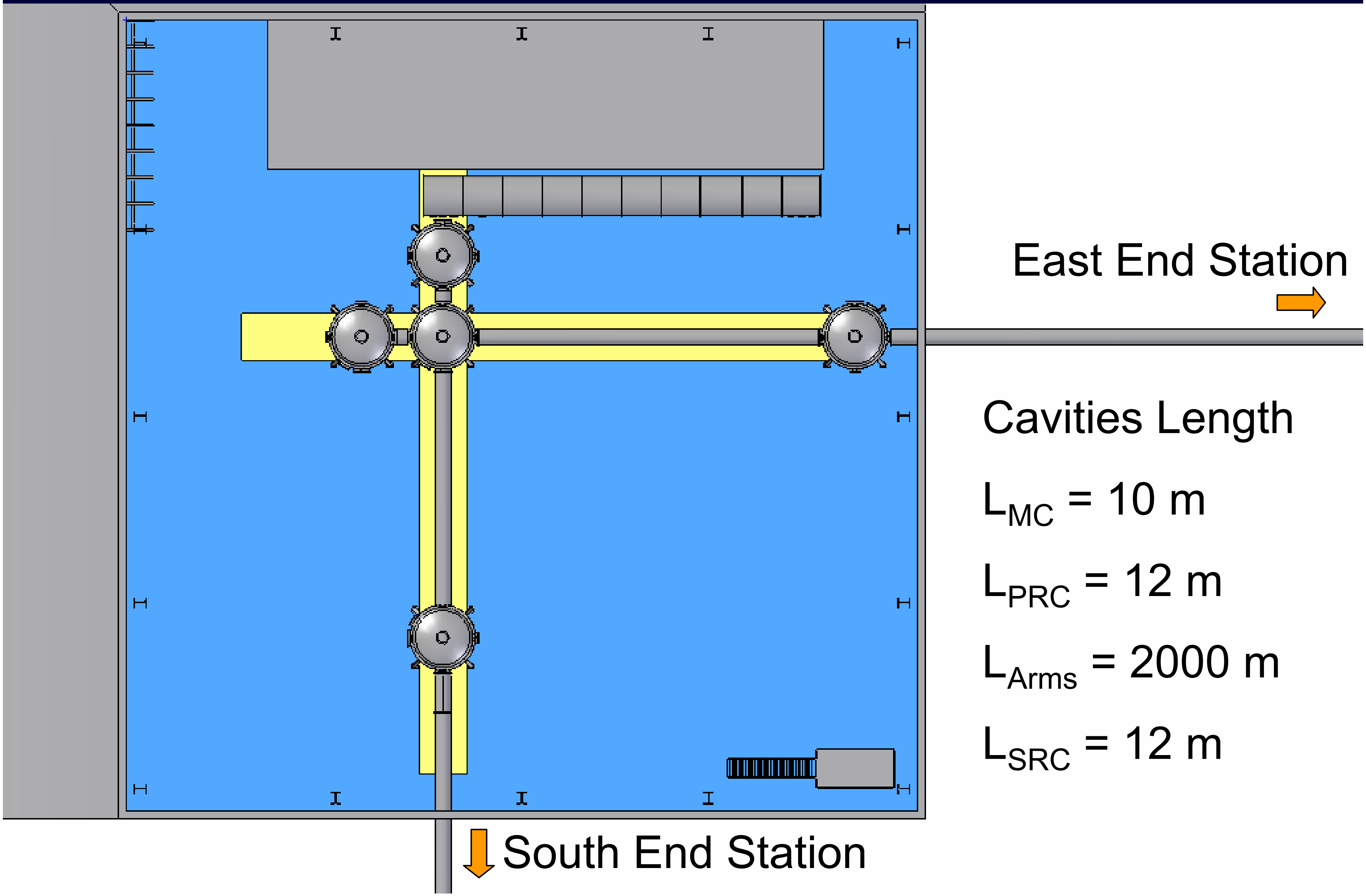
Carrier:
Resonant in PRC and Arms

RF Sideband f1:
Resonant in PRC

RF Sideband f2:
Resonant in PRC and SRC



Actual Interferometer Configuration



Cavities Length

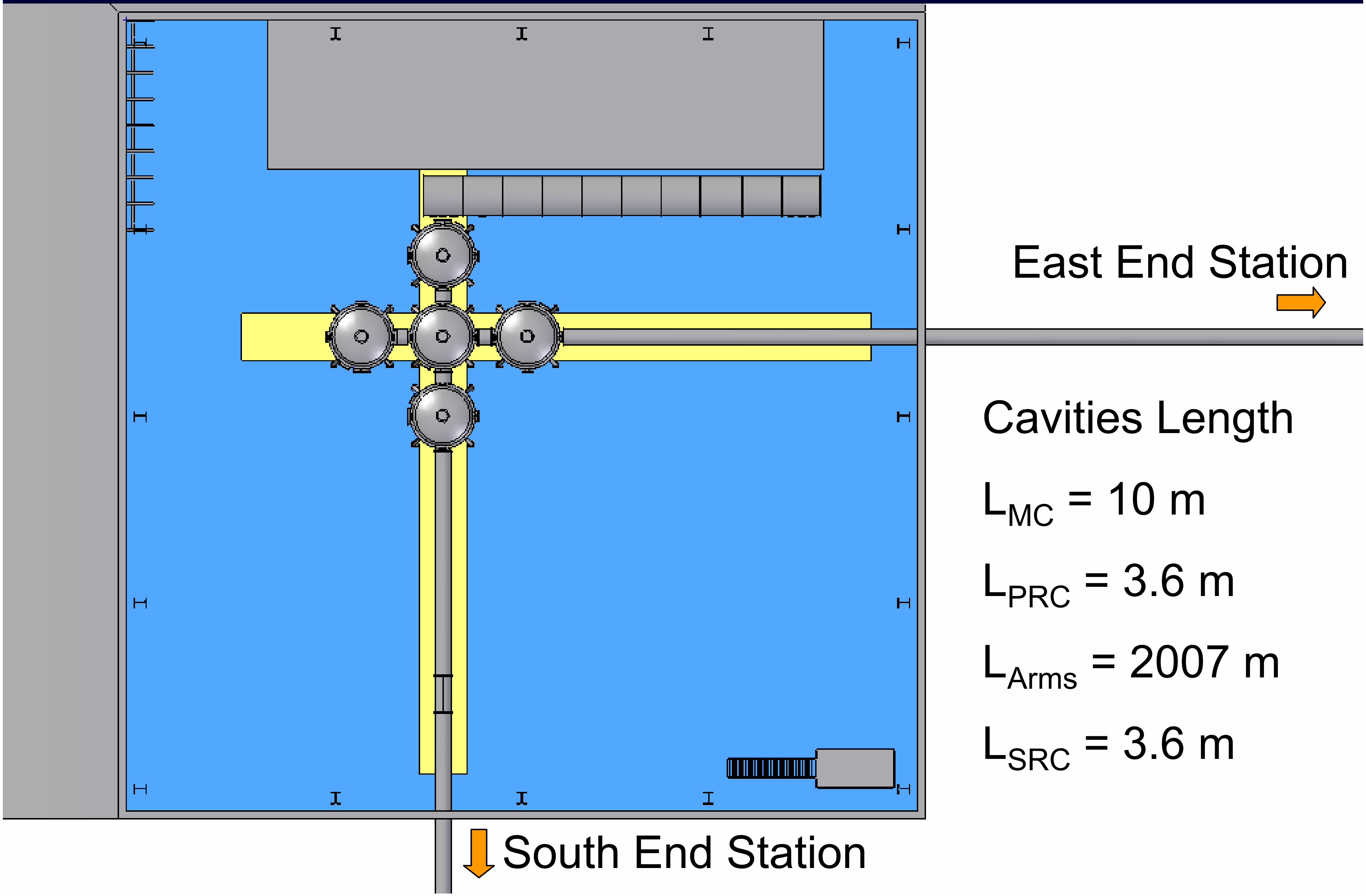
L_{MC} = 10 m

L_{PRC} = 12 m

L_{Arms} = 2000 m

L_{SRC} = 12 m

AIGO Proposed Configuration



Cavities Length

L_{MC} = 10 m

L_{PRC} = 3.6 m

L_{Arms} = 2007 m

L_{SRC} = 3.6 m

Rule of Thumb

- Carrier should be resonant in the arms and the PRC.
- Carrier resonant in the SRC for resonant sideband extraction (RSE), and anti-resonant for signal recycling.
- SB1 should be nearly anti-resonant in the arms, and resonant in the PRC.
- SB2 also nearly anti-resonant in the arms, and resonant in the PRC.
- One of the SB should be resonant in the SRC and the other nearly anti-resonant.

AIGO Constrains

Limiting values for the cavities length are defined by the vacuum envelop:

$$L_{MC} < 10000mm$$

$$3600mm < L_{PRC}, L_{SRC}$$

Integer ratios between the cavities are not recommended, in order to avoid harmonics sidebands to resonate in the recycling cavity.

Actual Configuration

- Length PRC = 11727 mm

$$L_{PRC} = l_{pr} + \frac{(l_1 + l_2)}{2}$$

- ❾ Mode Cleaner shorter than Recycling Cavities?
- PRC Free Spectral Range: 12.782 MHz
- PRC as a coupled cavity ❾ half integer of PRC FSR
- “Longest” Mode Cleaner 7818 mm ❾ FSR = 19.173 MHz

AIGO Interferometer Sidebands

For transmission of modulation sidebands by the mode-cleaner, L_{MC} and f_m must satisfy:

$$f_m = n_1 \frac{c}{2L_{MC}}$$

$$n_1 = 1$$

For sideband coupling into the recycling cavity, L_{PRC} and f_m must satisfy:

$$f_m = \left(n_2 + \frac{1}{2}\right)\frac{c}{2L_{PRC}}$$

$$n_2 = 1$$

Sideband must not resonate inside the main arms, but also not exactly anti-resonant:

$$n_3 = f_m\left(\frac{2L_{Arm}}{c}\right)$$

$$n_3 = 255.82$$

Sideband 1 = 19.173 MHz

AIGO Interferometer Sidebands

To choose the high frequency sideband we look to demodulate at:

$$f_1 + f_2 \leq 200MHz$$

Sideband 2 = 172.559 MHz

Schnupp asymmetry given by:

$$\delta l = \frac{c}{4 f_2}$$

$$\delta l = 434 \text{ mm}$$

For a peak frequency of 300Hz (Adv LIGO) the carrier phase shift will be:

$$0.0607\left(\frac{\pi}{2}\right)$$

$$L_{SRC} = 12569\ mm$$

Proposed Configuration

- Length PRC = 4450 mm

$$L_{PRC} = l_{pr} + \frac{(l_1 + l_2)}{2}$$

- PRC Free Spectral Range: 33.685 MHz
- PRC as a coupled cavity ❾ half integer of PRC FSR
- “Longest” Mode Cleaner 8900 mm ❾ FSR = 16.842 MHz

AIGO Interferometer Sidebands

For transmission of modulation sidebands by the mode-cleaner, L_{MC} and f_m must satisfy:

$$f_m = n_1 \frac{c}{2L_{MC}}$$

$n_1 = 1$

For sideband coupling into the recycling cavity, L_{PRC} and f_m must satisfy:

$$f_m = \left(n_2 + \frac{1}{2}\right)\frac{c}{2L_{PRC}}$$

$n_2 = 0$

Sideband must not resonate inside the main arms, but also not exactly anti-resonant:

$$n_3 = f_m\left(\frac{2L_{Arm}}{c}\right)$$

$n_3 = 225.55$

Sideband 1 = 16.842 MHz

AIGO Interferometer Sidebands

To choose the high frequency sideband we look to demodulate at:

$$f_1 + f_2 \leq 200MHz$$

Sideband 2 = 168.423 MHz

Schnupp asymmetry given by:

$$\delta l = \frac{c}{4 f_2}$$

$$\delta l = 445 \text{ mm}$$

For a peak frequency of 300Hz (Adv LIGO) the carrier phase shift will be:

$$0.0605\left(\frac{\pi}{2}\right)$$

$$L_{SRC} = 5313\ mm$$

AIGO, Adv LIGO and VIRGO

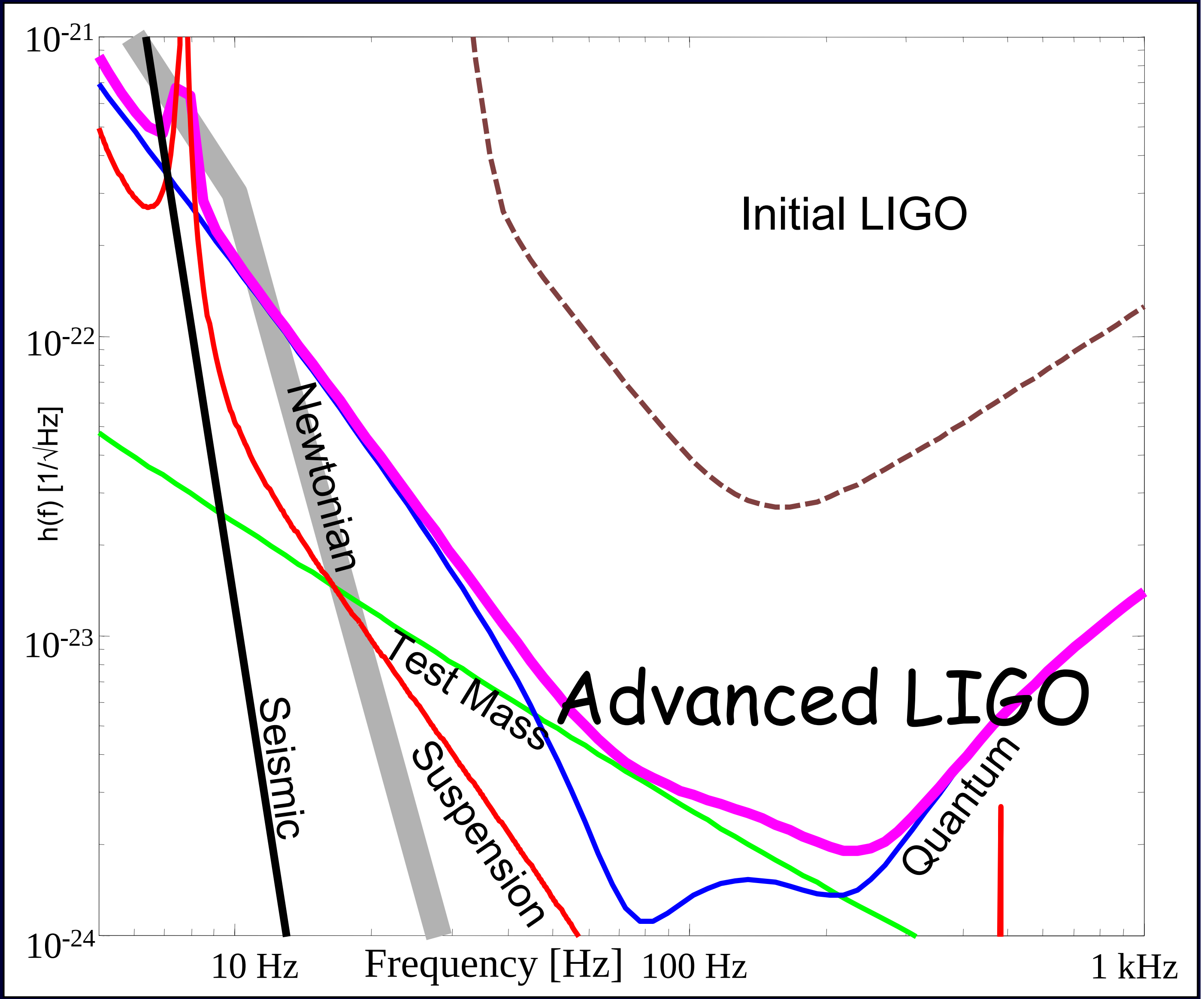
	Adv LIGO	VIRGO	AIGO 2K (sh)	AIGO 2K (lg)
PRM - BS	4	6	1.8	1.8
BS - ITM_{Inline}	4.536	6.4	2.873	10.144
BS - ITM_{Perp}	4.119	5.6	2.427	9.71
L_PRC_{Inline}	8.536	12.4	4.673	11.944
L_PRC_{Perp}	8.119	11.6	4.227	11.510
SRM - BS	4.821	5.562	2.663	2.642

AIGO, Adv LIGO and VIRGO

	Adv LIGO	VIRGO	AIGO 2K (sh)	AIGO 2K (lg)
L_MC	16.656	143.52	8.9	7.818
L_PRC	8.328	11.96	4.45	11.727
L_Arms	4000	3000	2007	2000
L_SRC	9.148	11.562	5.313	12.569
Asymmetry	0.416	0.399	0.445	0.434
SB 1 (MHz)	9	6.27	16.84	19.17
SB 2 (MHz)	180	188	168.42	172.56

High Optical Power

- Newtonian background
- Seismic 'cutoff'
- Suspension thermal noise
- Test mass thermal noise
- Unified quantum noise



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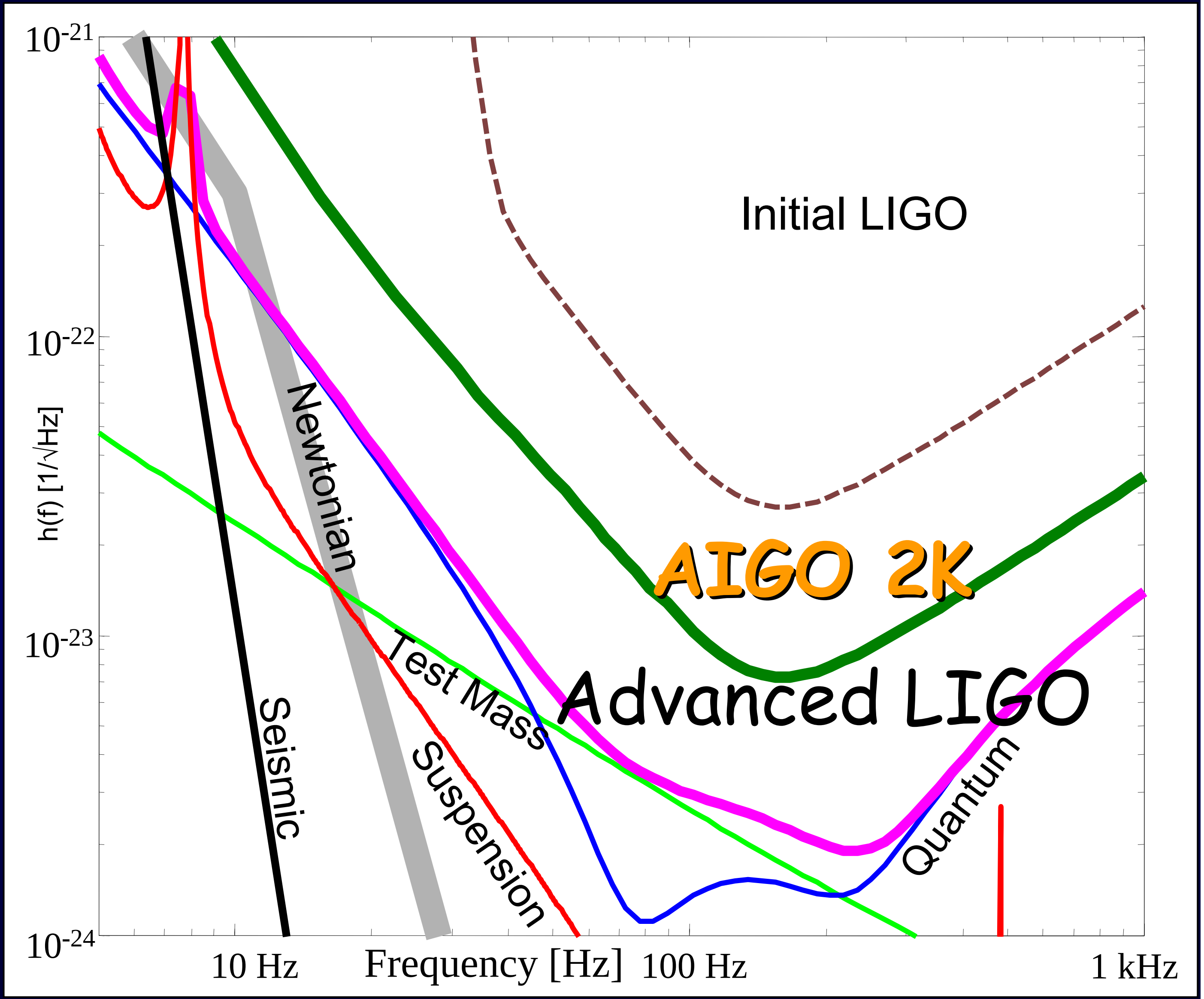

Conclusions

- AIGO 2K Dual Recycling Interferometer
- Test masses Fused Silica or Sapphire?
- Digital control system. EPICS, DSP or both?
- Short or long Recycling Cavities?

Conclusions

More information at:

ACIGA
http://www.anu.edu.au/Physics/ACIGA/

Australian National University
http://www.anu.edu.au/Physics/ACIGA/ANU/

University of Adelaide
http://www.physics.adelaide.edu.au/optics/res/hi_powerc.html

University of Western Australia
http://www.gravity.pd.uwa.edu.au/