ACIGA High Optical Power Test Facility

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for ACIGA

LIGO-G050515-00-Z

Contents

- Status of High Optical Power Test Facility (HOPTF)
- Planned Experiments

ACIGA

Australia Consortium for Interferometric Gravitational Astronomy

Primary Institutions:

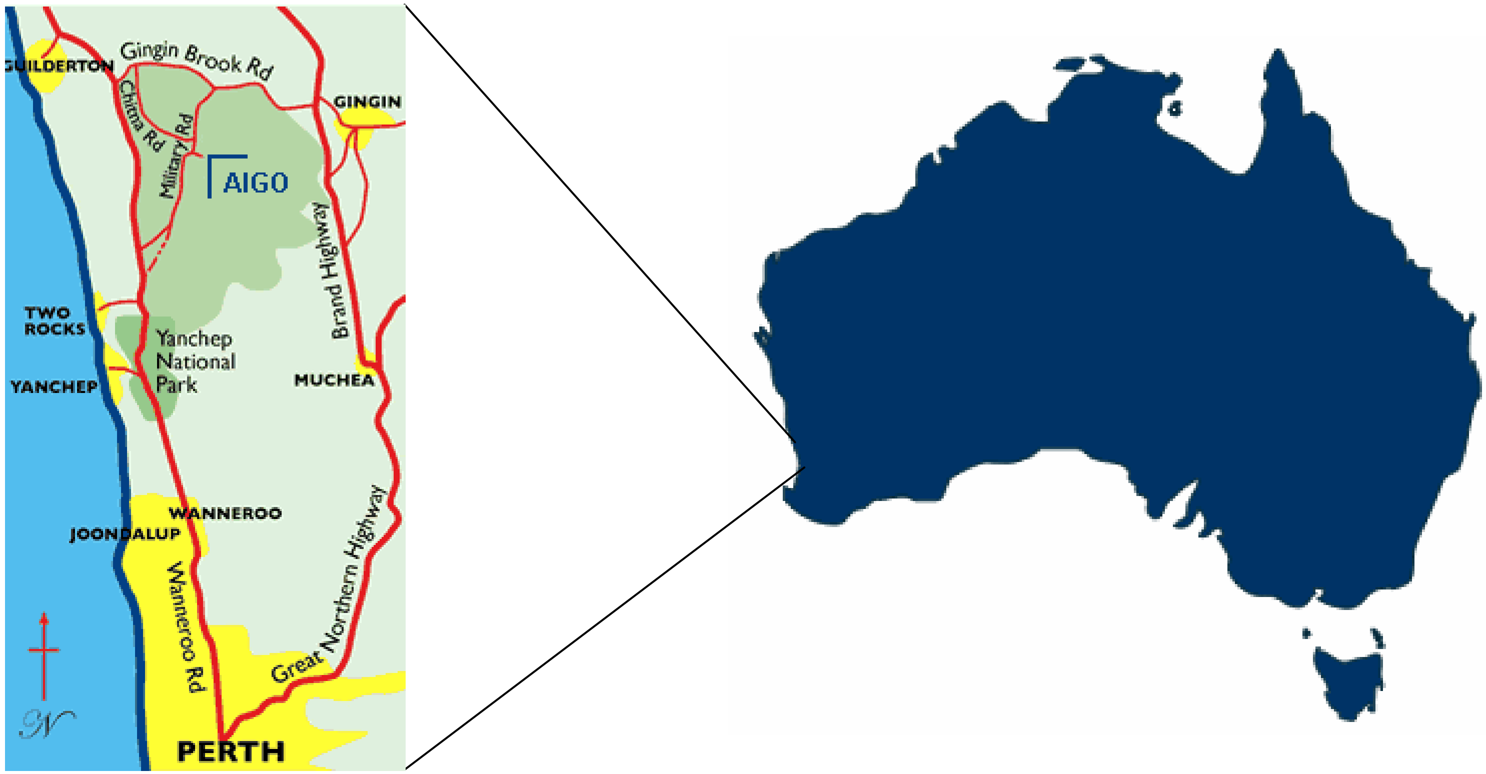
University of Western Australia
University of Adelaide
Australian National University

Affiliate Institutions:

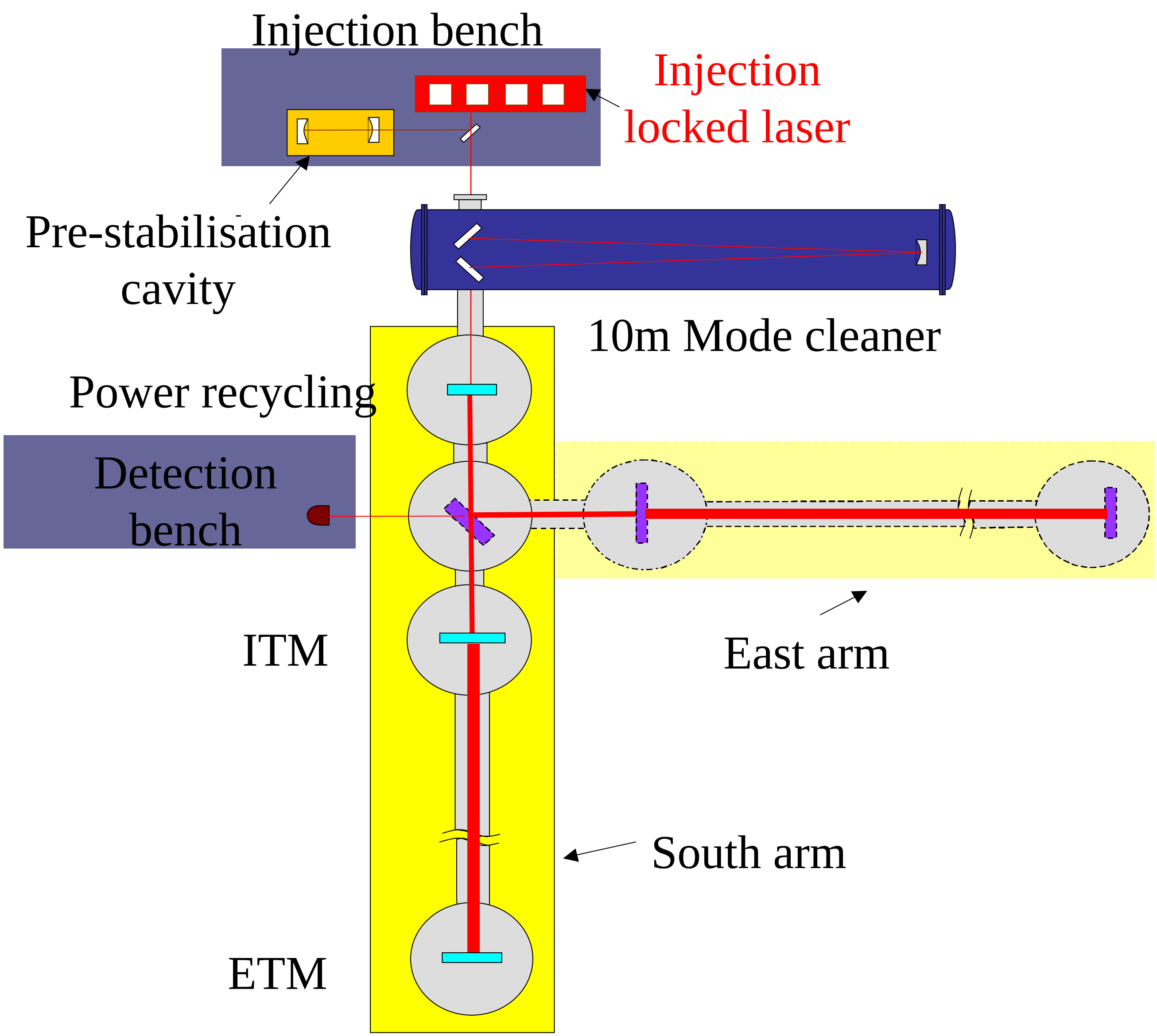
Monash University
CSIRO-Optics

AIGO Location

- AIGO is located 90km north of Perth in Western Australia



HOPTF Configuration



Central Station

- High power laser clean room near Class 100.

Objectives of ACIGA HOPTF

- **Investigating problems associated with high optical power GW detectors**
  - **Thermal lensing and compensation**
  - **Parametric instabilities and control**

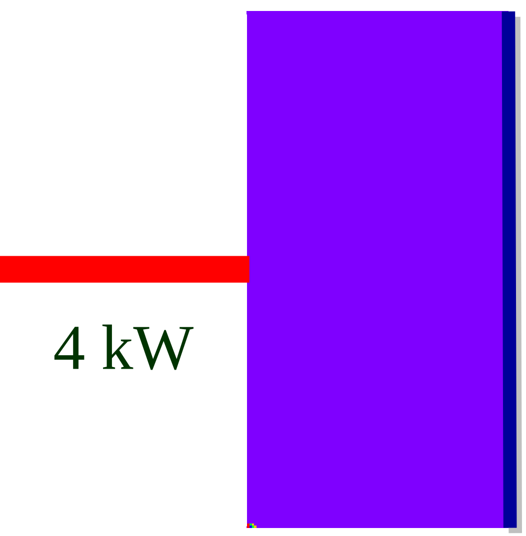
- **Low noise 80m base line advanced interferometer**
  - **Demonstrate noise performance of high power interferometers**
  - **Evaluate thermal compensation**
  - **Determine noise limit set by the control of parametric instabilities**

- **Advanced gravitational wave interferometer detector**

AIGO — the Southern Hemisphere link in the global network

First Problem: Thermal Lensing

- Absorption in mirror substrate and coating creates thermal gradient
- Thermal gradients distort refractive index of substrate ⇒ lens effect



Power Absorbed Substrate = 1W

- Thermal expansion changes mirror curvature ⇒ lens effect

Power Loss and Reduced Sensitivity

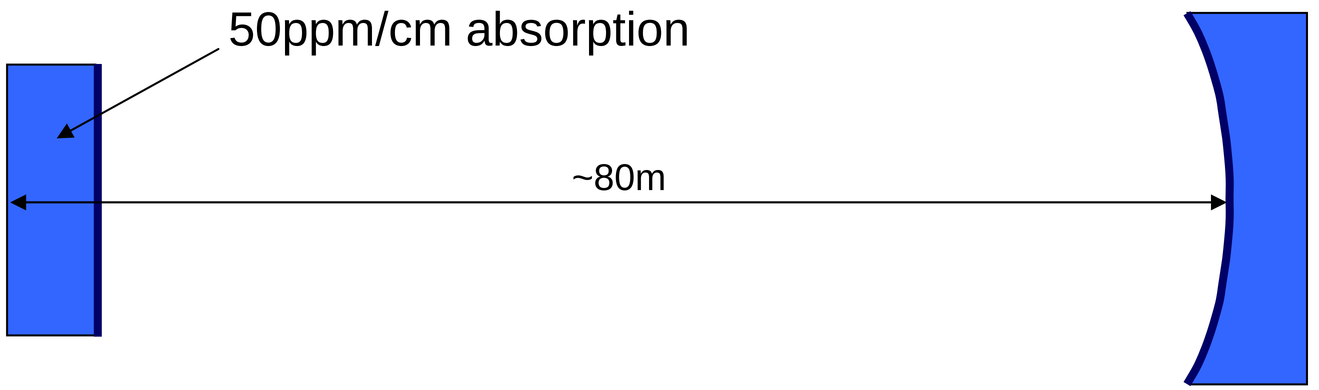
Simulation: Jerome Degallaix

ACIGA's high optical power facility

- 100W input power
- Up to 500kW circulating power with power recycling
- Sapphire test mass
- Fused silica thermal compensation plate

HOPTF Test 1: Reverse Substrate

- Placement of the ITM Sapphire substrate inside the cavity



Input Test Mass
a-axis Sapphire
100mm diameter
46mm thickness

End Test Mass
m-axis Sapphire
150mm diameter
80mm thickness

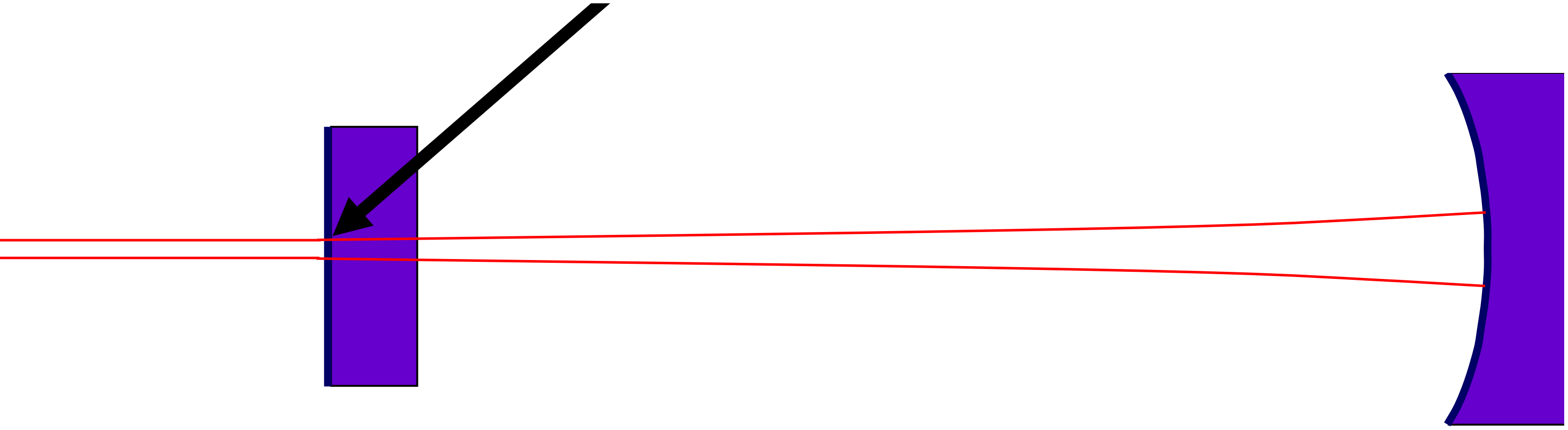
HOPTF Test 1: Cold Cavity

Half-symmetric resonator

Input Power: ~7W

Cavity Waist size: ~8.7mm

Cavity Waist Position: 0m



Input Test Mass

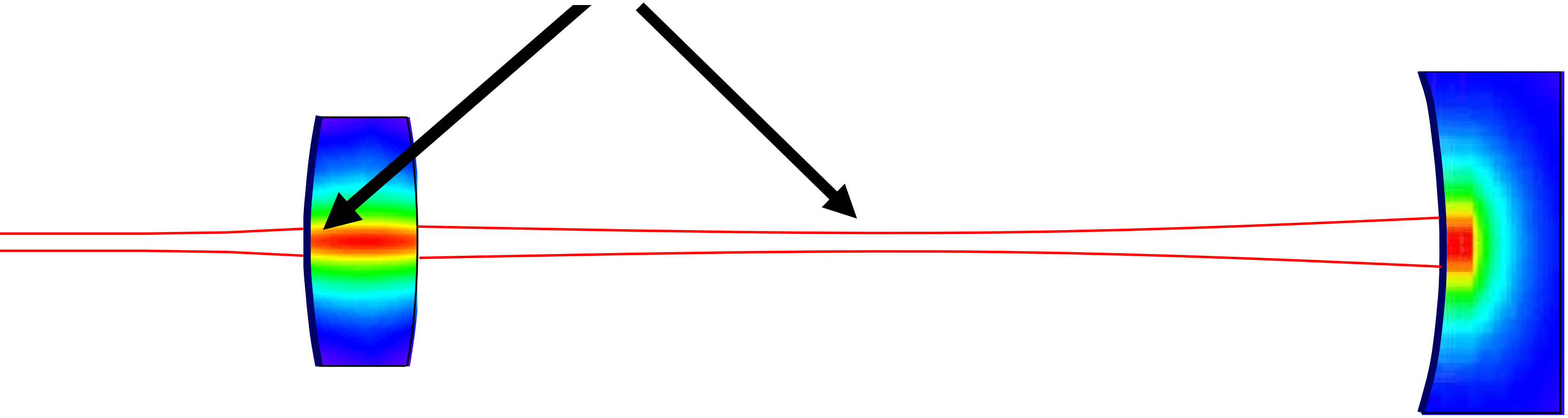
ROC = ◎

End Test Mass

ROC = 720m

HOPTF Test 1: Hot Cavity

Power Intra-Cavity: ~4.4kW
Cavity Waist Size: ~6.6mm
Cavity Waist Position changed: 47m

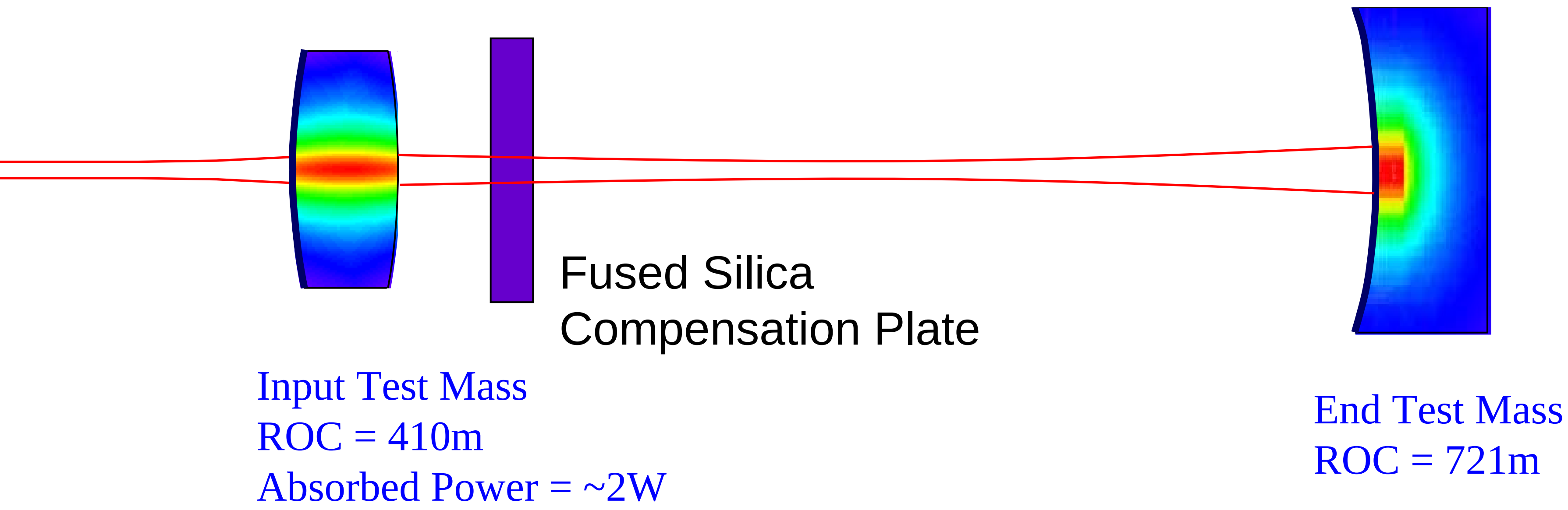


Input Test Mass
ROC = 410m
Absorbed Power = ~2W

End Test Mass
ROC = 721m

Thermal Gradient: Jerome Degallaix

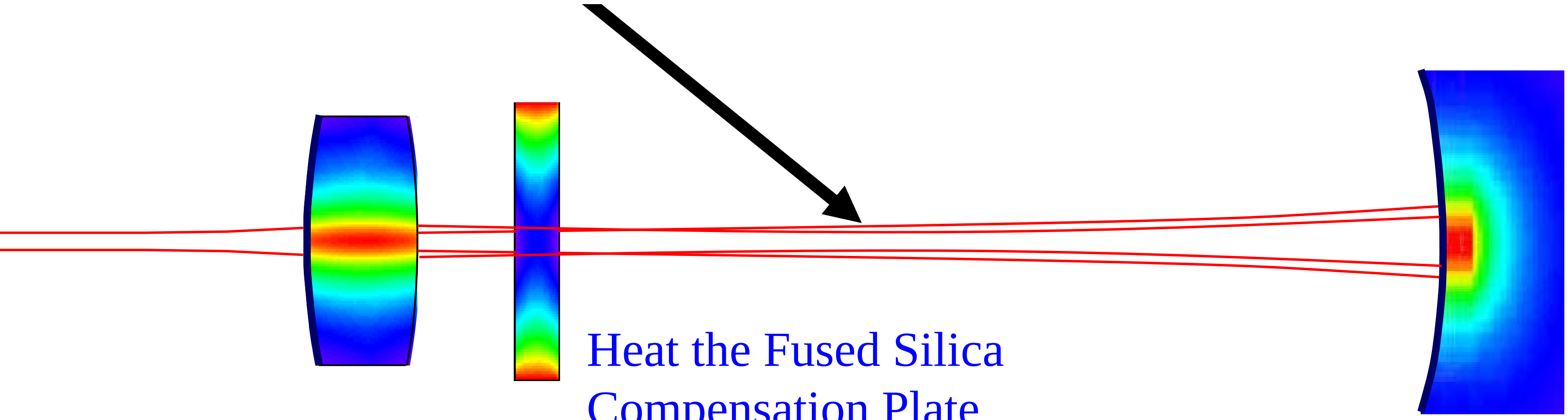
Thermal compensation



Thermal Gradient: Jerome Degallaix

HOPTF Test 1: thermal compensation

Power Intra-Cavity: ~4.4kW
Cavity Waist Size: ~6.6mm
Cavity Waist Position: 47m



Heat the Fused Silica Compensation Plate

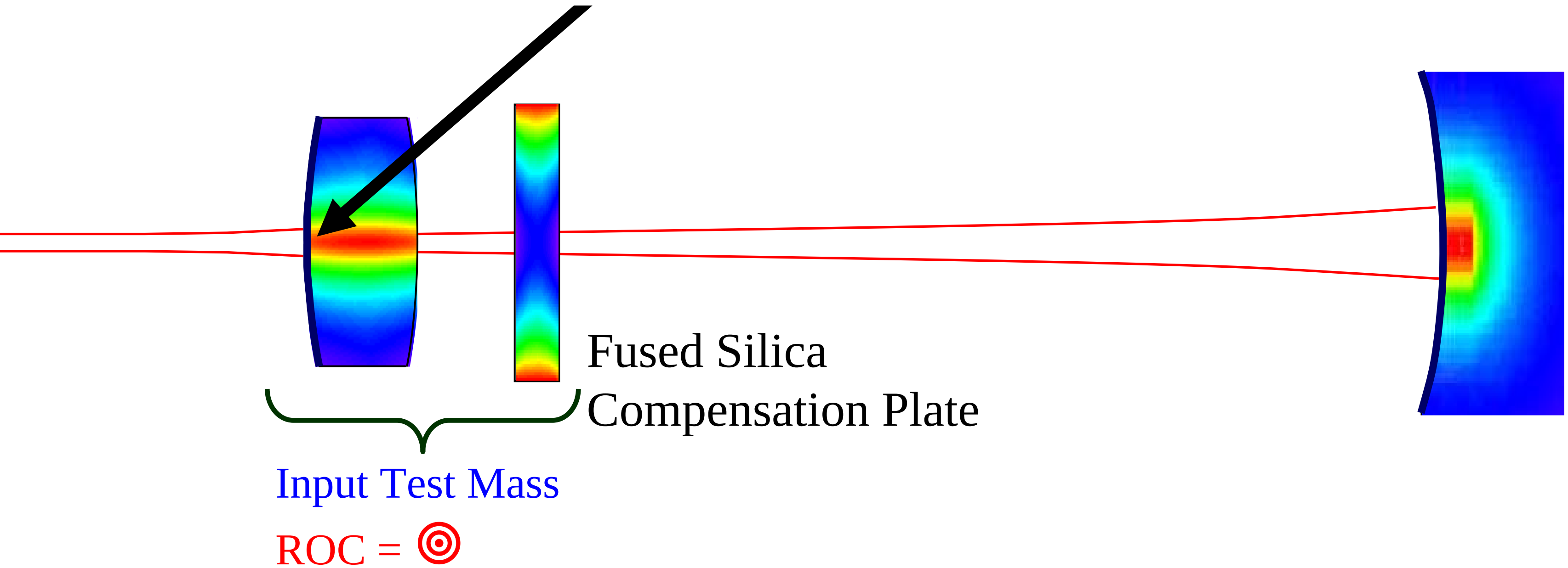
Input Test Mass
ROC = 410m
Absorbed Power = ~2W

End Test Mass
ROC = 721m

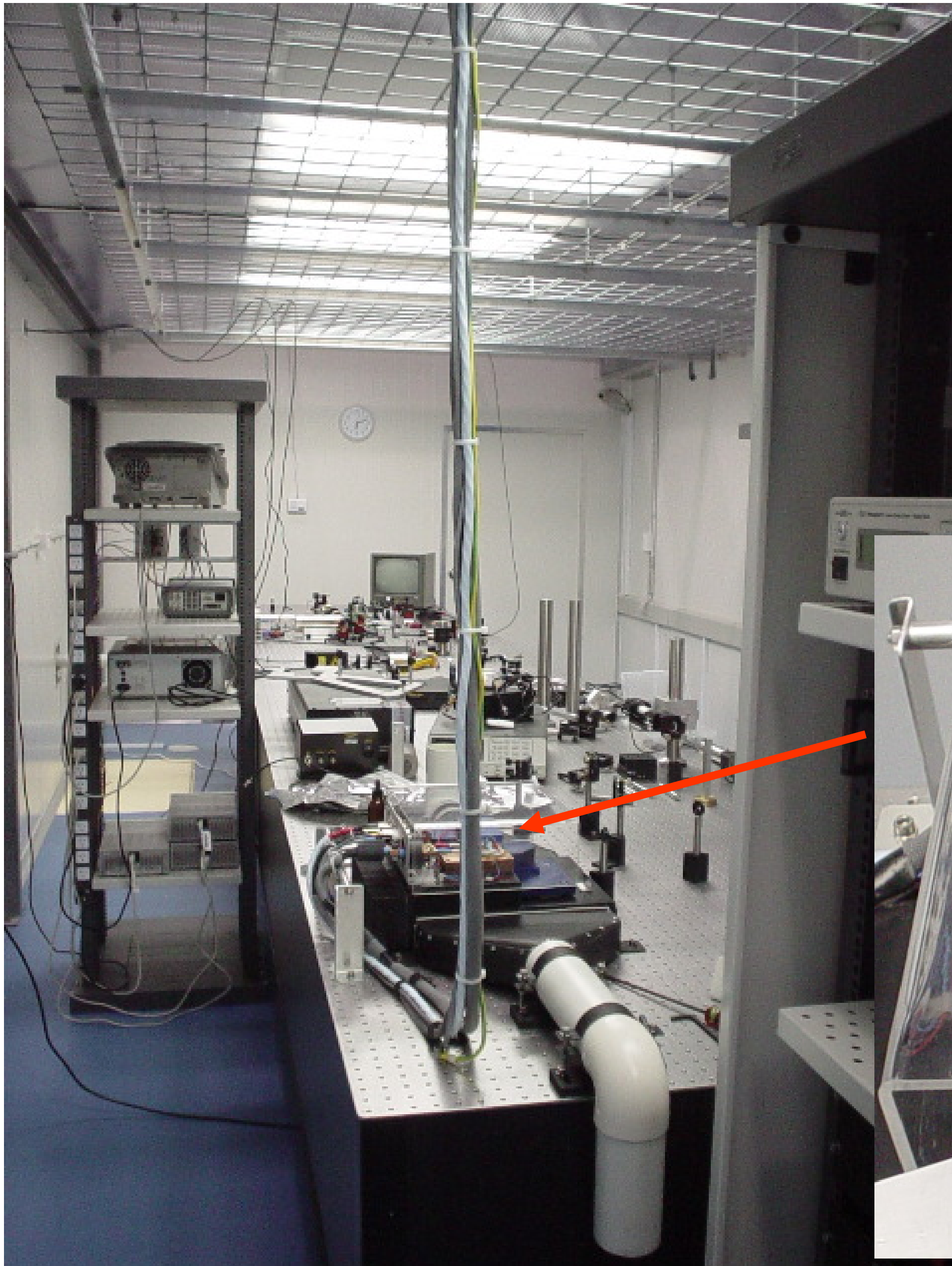
Thermal Gradient: Jerome Degallaix

HOPTF Test 1: Thermal compensation

Power Intra-Cavity: ~5kW
Cavity Waist Size: ~8.7mm
Cavity Waist Position: 0m

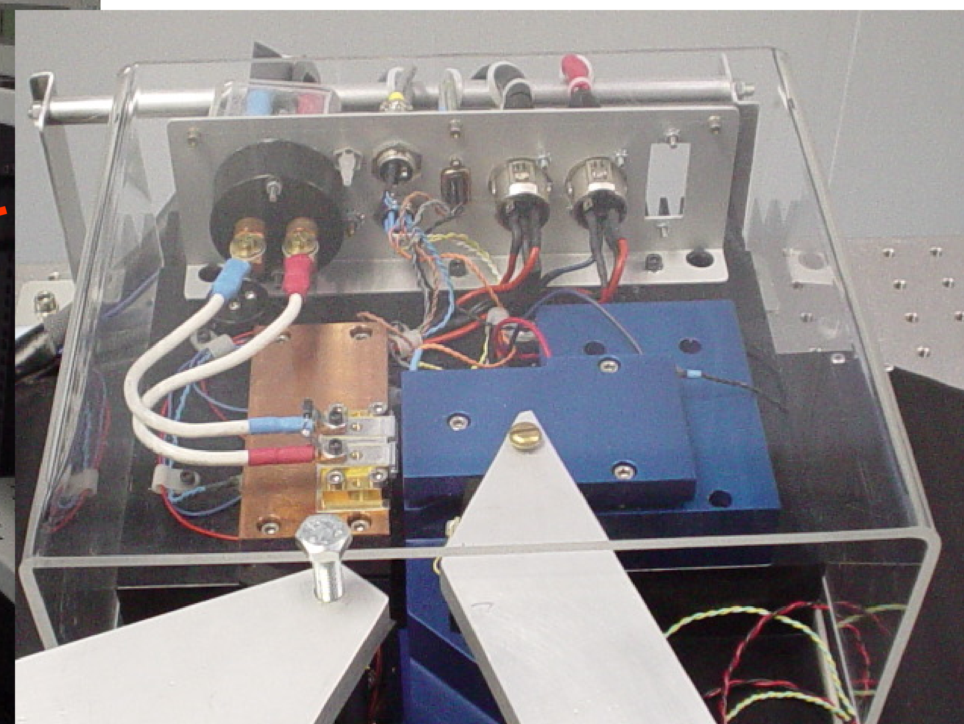


Thermal Gradient: Jerome Degallaix



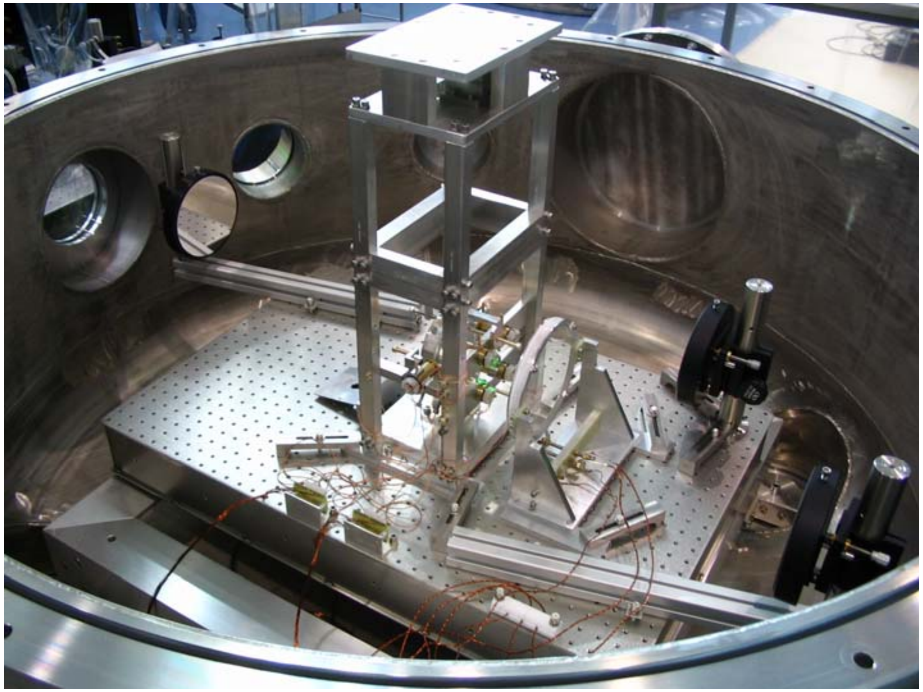
- 10 W injection locked laser developed by Adelaide installed

- The 80-meter cavity has been locked to the laser

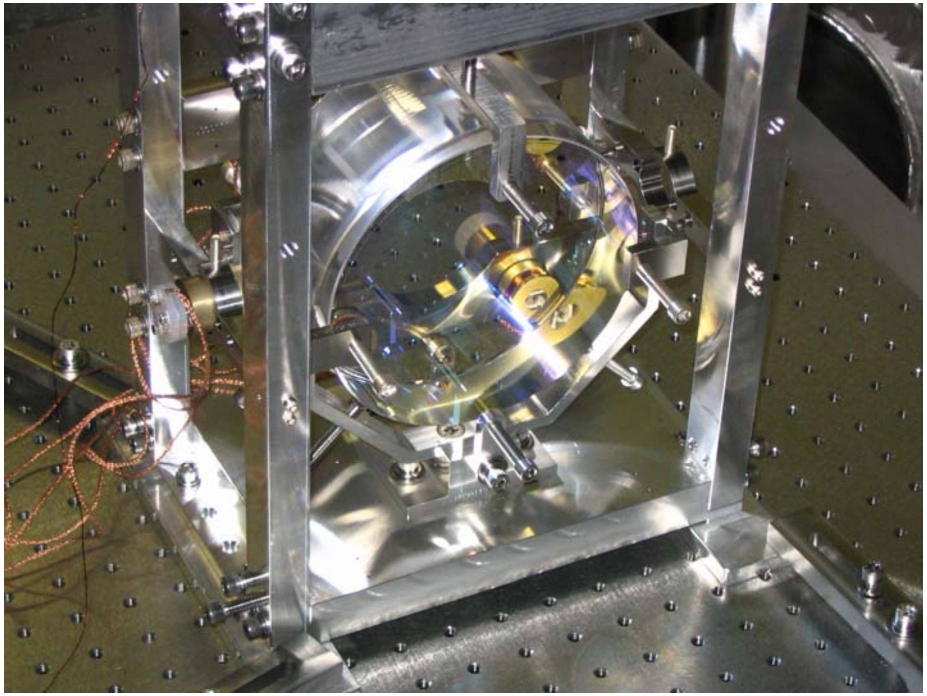


HOPTF Test1

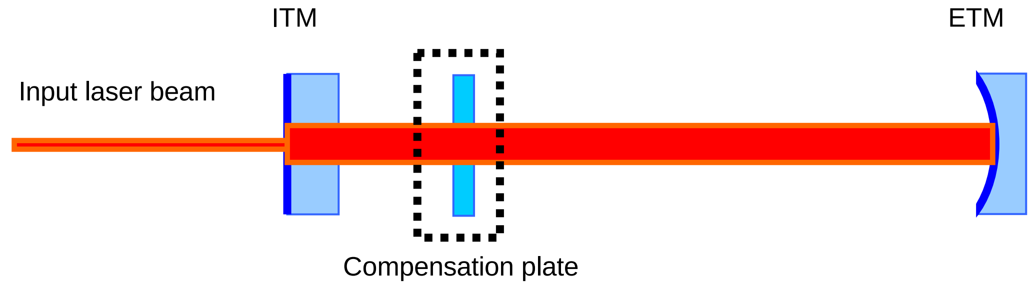
- Simple Suspension with sapphire ITM

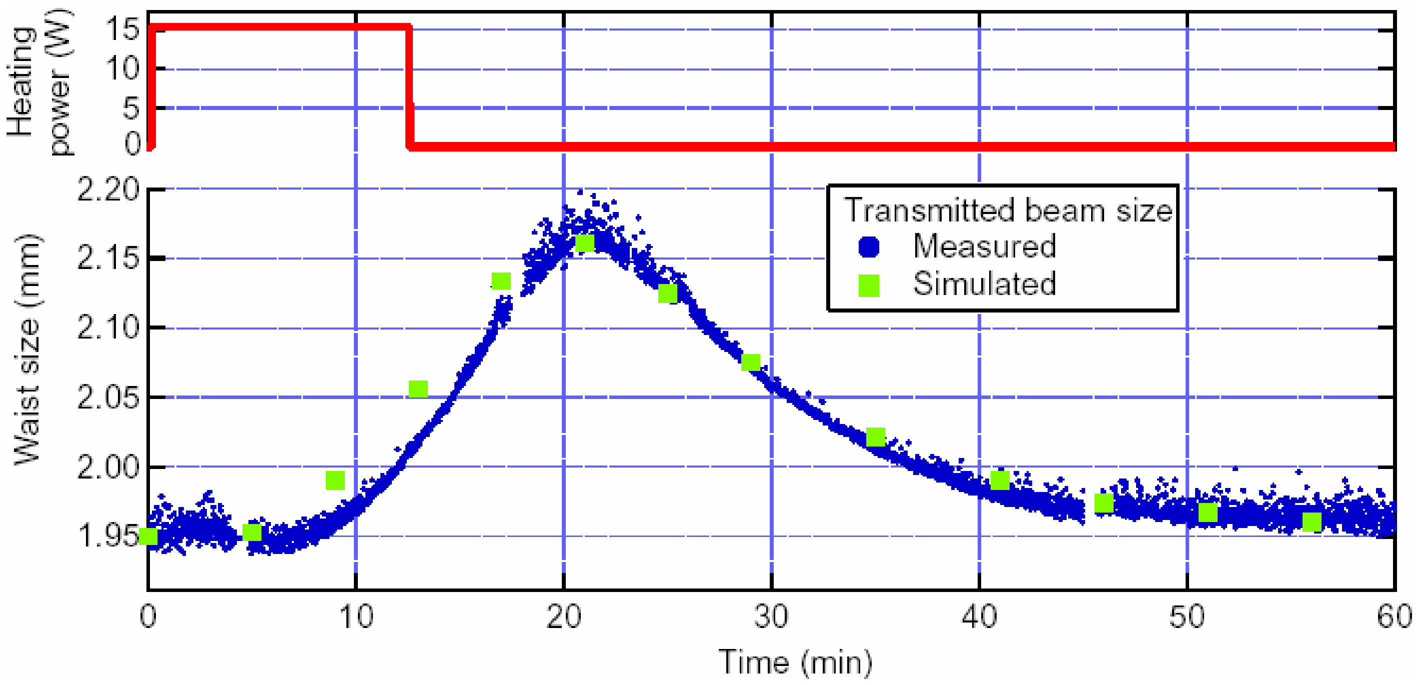


- Simple Suspension with sapphire ETM



Measured beam size after the ETM as a function of the heating power to the CP



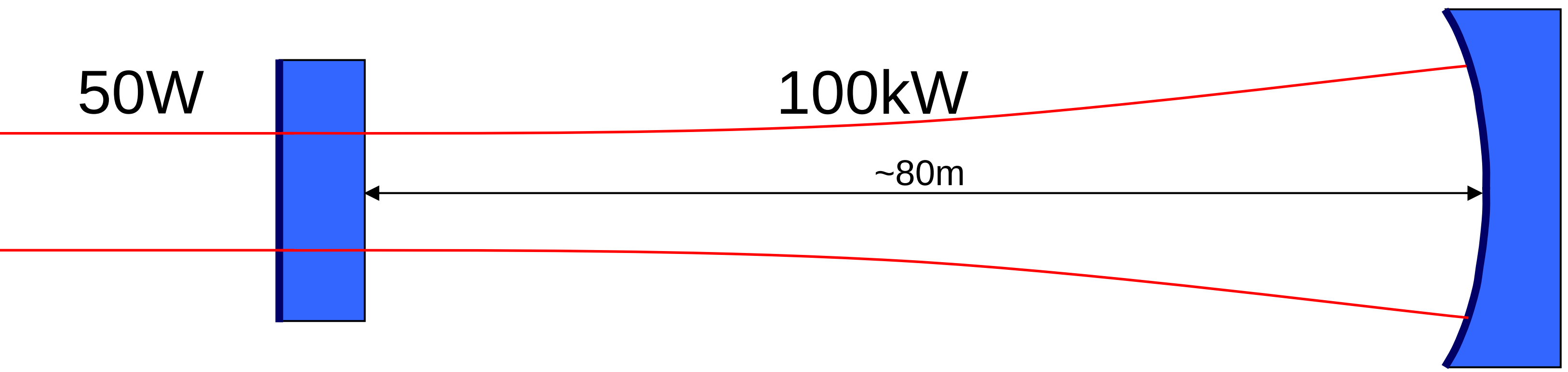


Next Step of Thermal Lensing Experments

- Input full power into the 80-meter cavity
- Detect the wavefront distortion using the Hartmann sensor installed
- HOPTF Test 2
- HOPTF Test 3

HOPTF Test 2

- TEST 2: ITM substrate is outside the high power cavity
- Optical distortion will be dominated by the absorption in the HR coatings on the ITM and ETM

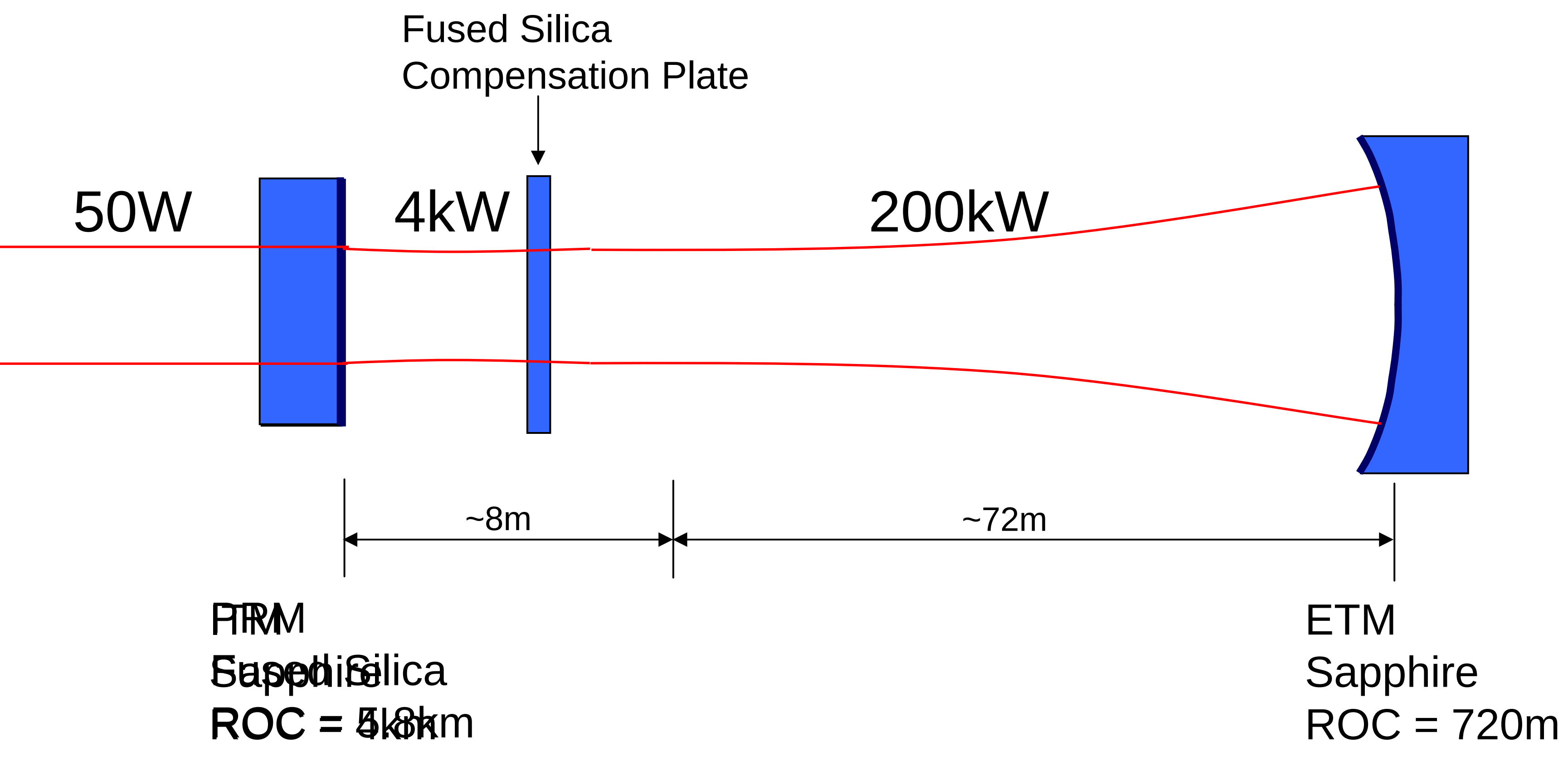


Input Test Mass
a-axis Sapphire
100mm diameter
46mm thickness
ROC = ◎

End Test Mass
m-axis Sapphire
150mm diameter
80mm thickness
ROC = 720m

HOPTF Test 3

- TEST 3: Power Recycling Mirror to increase the power inside the cavity

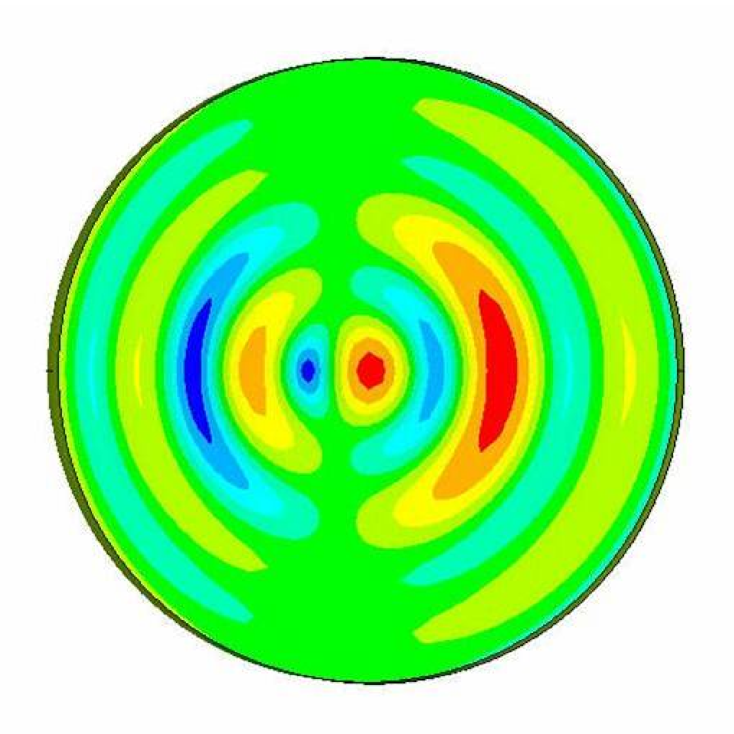


Second Problem: Parametric Instabilities (PI)

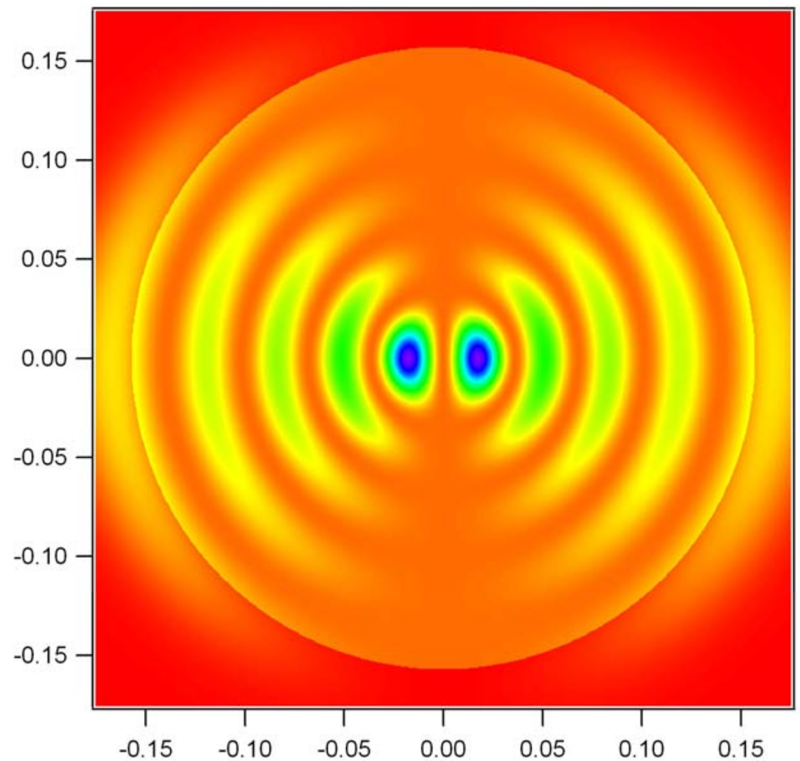
- PI depends on a product of:
  - Optical Q-factor
  - Mechanical Q-factor
  - HOM Q-factor
  - Optical Cavity Power

Gingin HOPTF Prediction

Acoustic Mode 160kHz



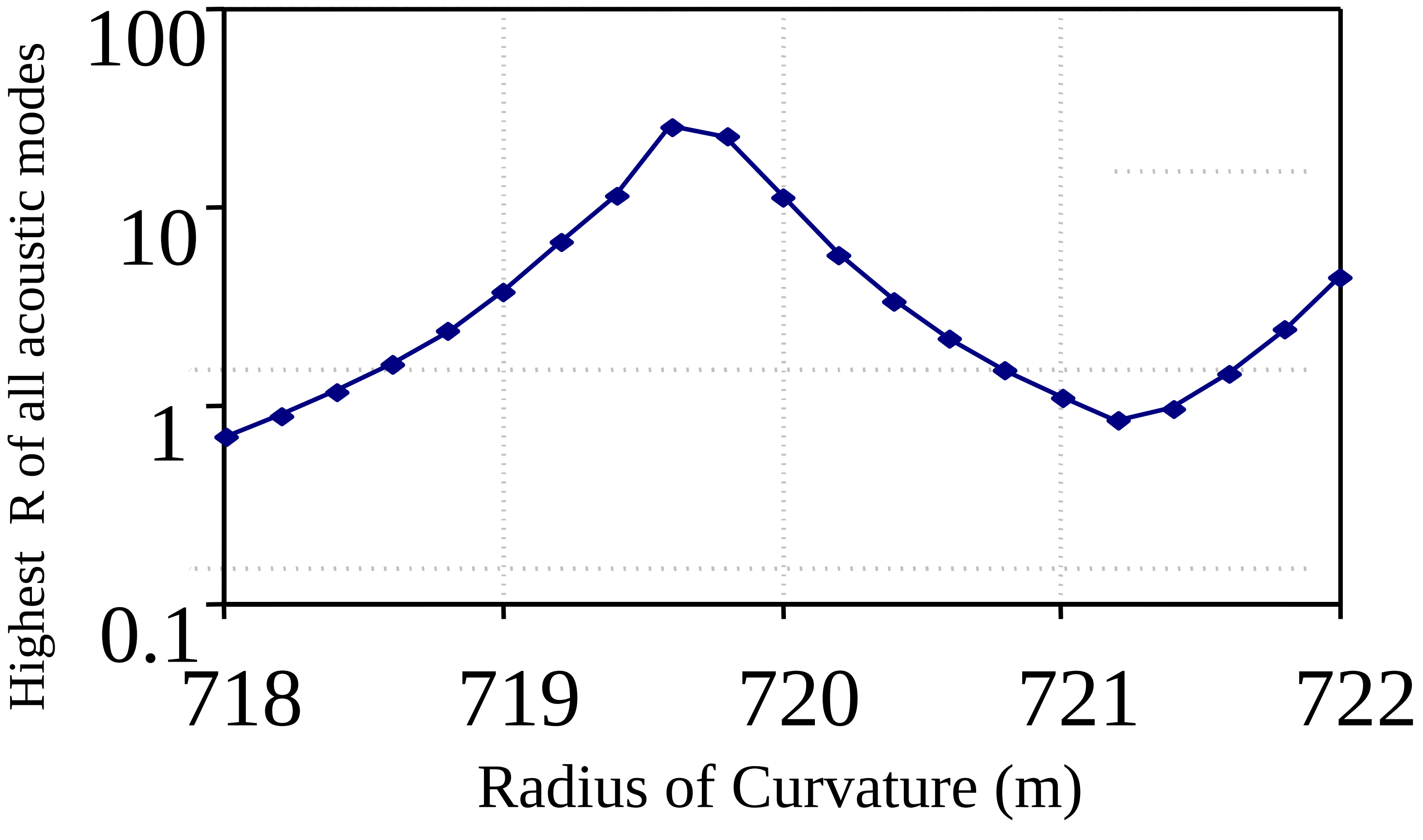
Optical mode, LG41



Overlap Factor Λ = 0.174

Gingin HOPTF Prediction

- HOPTF 80m cavity should observe parametric instability if sapphire test mass Q-factor is $2x10^8$.

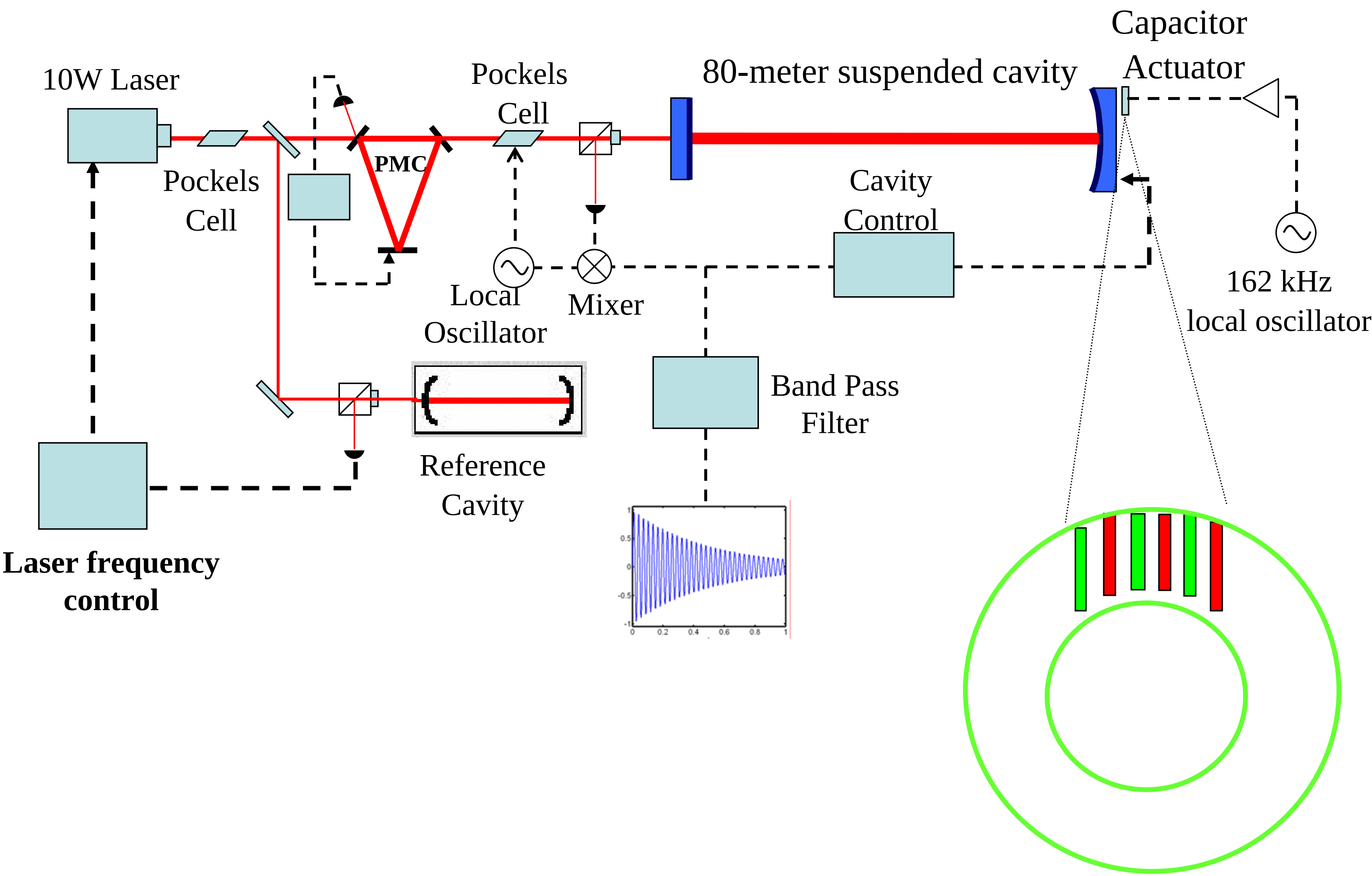


What do we expect to see

R=1	**Q= infinity**	**Unstable**
R=0.1	**~10% increase in Q_m**	**Detectable**
R=0.01	**~1% increase in Q_m**	**Hard to detect**

First goal: detect modes, measure Q, predict R

How can we do


10W Laser
Pockels
Cell
PMC
Pockels
Cell
80-meter suspended cavity
Capacitor
Actuator
Cavity
Control
162 kHz
local oscillator
Local
Oscillator
Mixer
Band Pass
Filter
Reference
Cavity
Laser frequency
control

Expected at HOPTF

Current set up (internal substrate, magnets glued on): F=1000, 5W into cavity:

ΔQ=1% if $Q=10^7$,

ΔQ=10% if $Q=10^8$

Test 2: (external substrate) F=2000,

ΔQ=7% if $Q=10^7$,

ΔQ ~ 40% if $Q \sim 5.\ 10^7$.

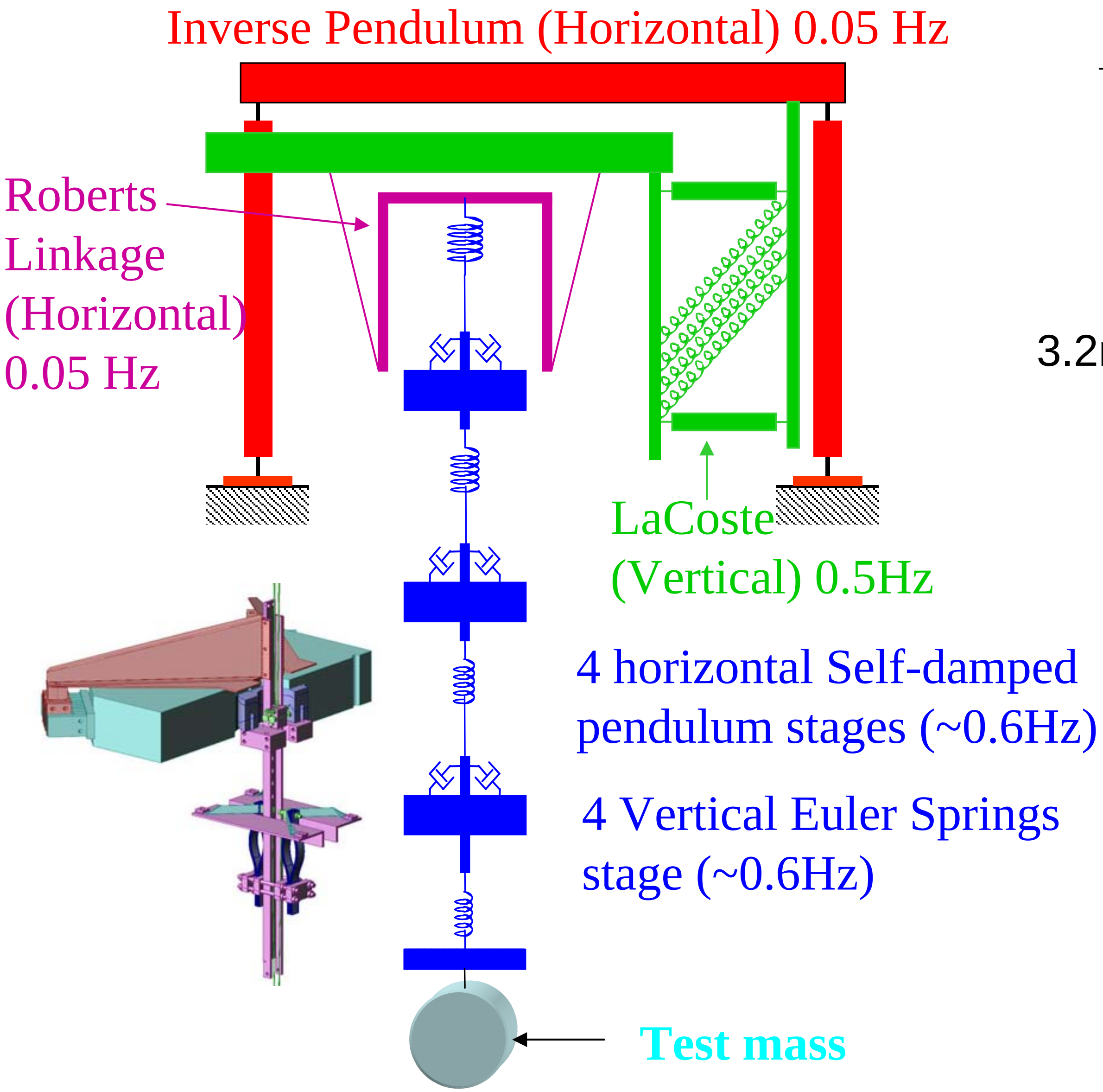
East Arm PI Test: (capacitive actuation), $Q=10^8$,

R>1 at 10W input power

Advanced Vibration Isolation

- 2 stages of ultralow frequency horizontal pre-isolation
- vertical ultralow frequency pre-isolation
- self damping
- Euler springs
- Best isolation system in the world!

UWA Vibration Isolation and Suspension System



AIGO Future—long base line detector