ACIGA Status Report: Gingin High Power Test Facility

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HPTF Test Objectives

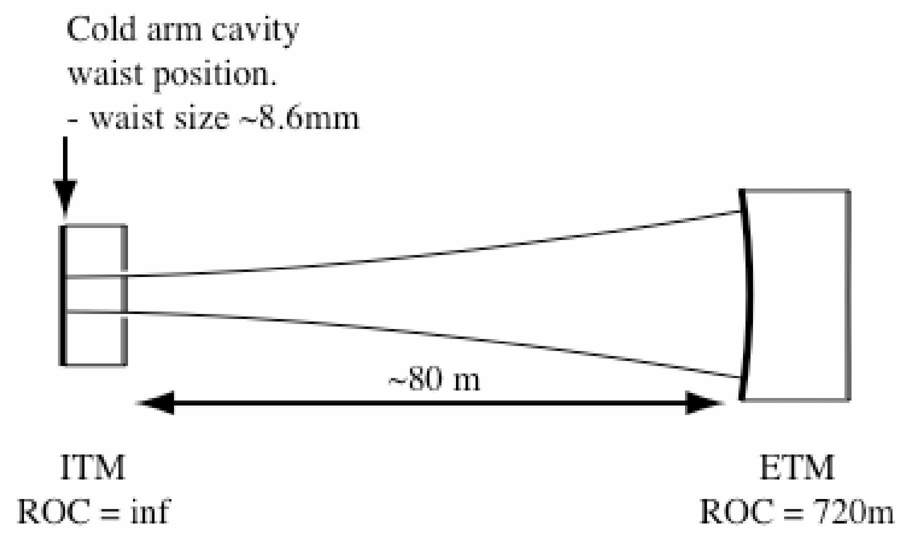
- Measure optical distortions in ITM substrate and coatings
- Test wavefront sensors
- Test wavefront actuators
- Investigate control of power recycled FP cavities.

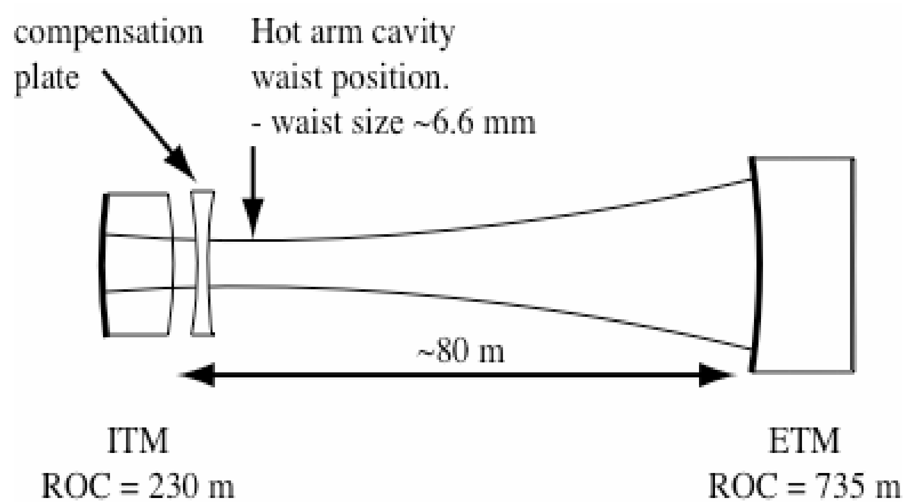
  Test 1: Substrate absorption as in Adv LIGO
  Test 2: High Reflectivity ITM coating absorption
  Test 3: Power recycled FP with unstable recycling cavity
  at low power as in Adv LIGO

HPTF Test 1: Measure substrate absorption

Cavity parameters:

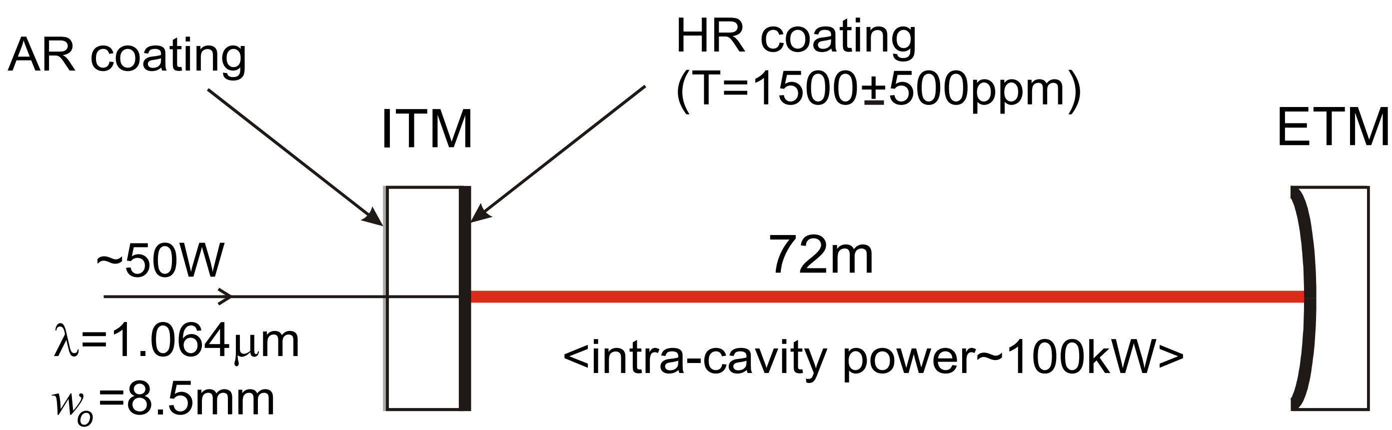
- Circulating power with 7W input: ~5.5 kW.
- Cavity waist (hot): ~6.6 mm.
- Thermal lensing induced ROC of Input Test Mass: ~230m.
- Waist position with thermal lensing will be moved away from the ITM towards the End Test Mass.
- Use of a Fused Silica thermal compensation plate to compensate the thermal lensing in the ITM.





HPTF TEST 2: Measure wavefront distortion due to absorption in mirror coating

- Reverse ITM
- Measure degradation of finesse with increasing stored power
- Use Hartmann wavefront sensor to characterize distortion.



- Use same optics, reversing ITM.
- Higher input power (~50W).
- Higher intra-cavity power (~100kW).

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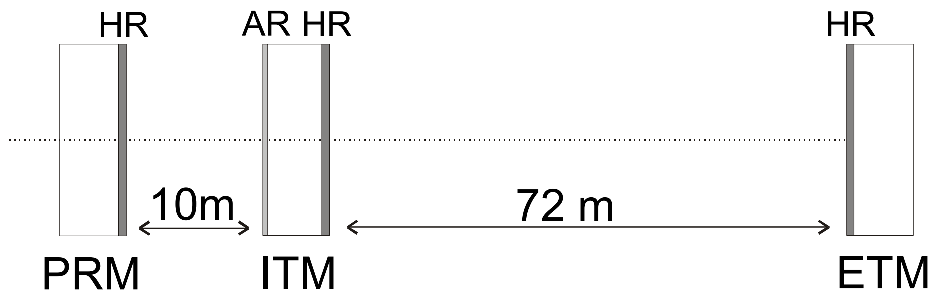
HPTF TEST 3: Coupled cavity test



Recycling cavity unstable at low power as in LIGO 1, and AdLIGO
Radii of curvature: PRM: 5.8 km, ITM: 4.0 km, ETM: 720m

Transmittances: PRM ~ 5%, ITM ~ 8%

Input power = 100 W, recycling cavity power 4 kW, arm cavity power 200 kW

At above powers: recycling cavity stable, and same eigenmode as FP

Spot radius similar to test 1, w_0 = 0.9cm

Detailed modeling in progress

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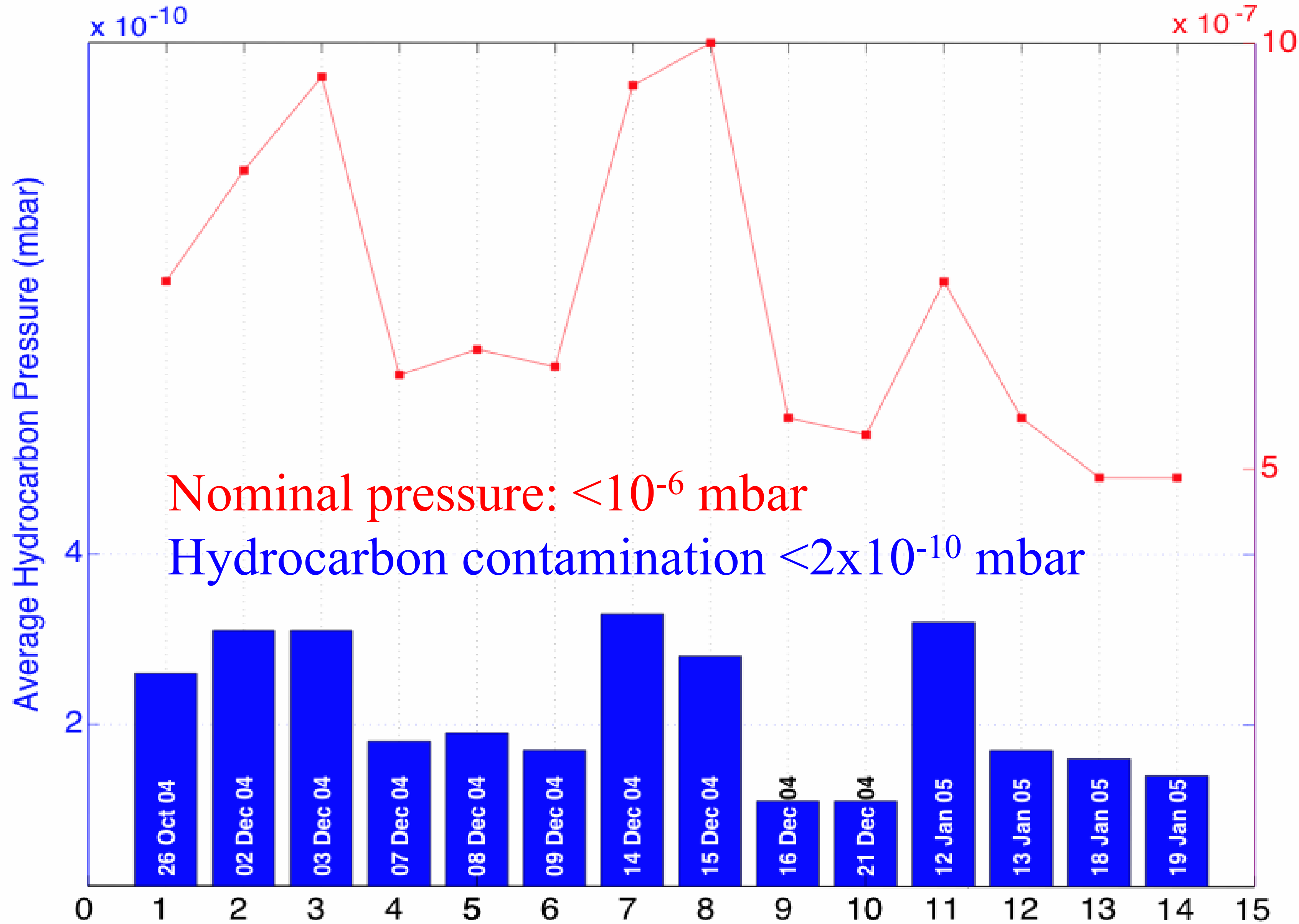
Basic Facility

- Laser lab with vacuum tanks, vacuum pumps running 24/7.
- 80m beam tube between main lab and end-station.

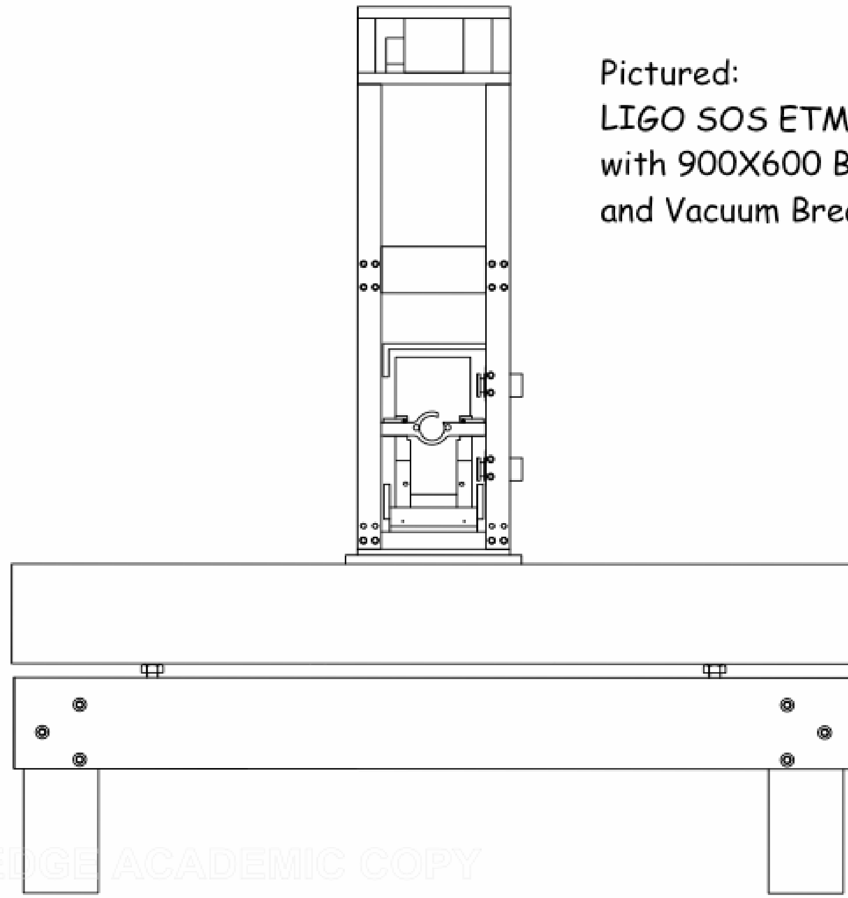
- Class 100 and 1000 Clean rooms.
- Facility to incorporate a suspended power-recycled Fabry-Perot cavity.
- Initial 10W Nd:YAG laser.
- Incorporation of thermal lensing, sensing and compensation.

Vacuum pressure and contamination



Initial Suspended Cavity

- Using BK7 optics to initial try to lock the suspended cavity.
- LIGO SOS, placed on top of a 900mm x 600mm breadboard
- Breadboard leveled by 4 bolts, with no further isolation
- Replace BK7 optics by the Sapphire, once system is running reliably: NOW!



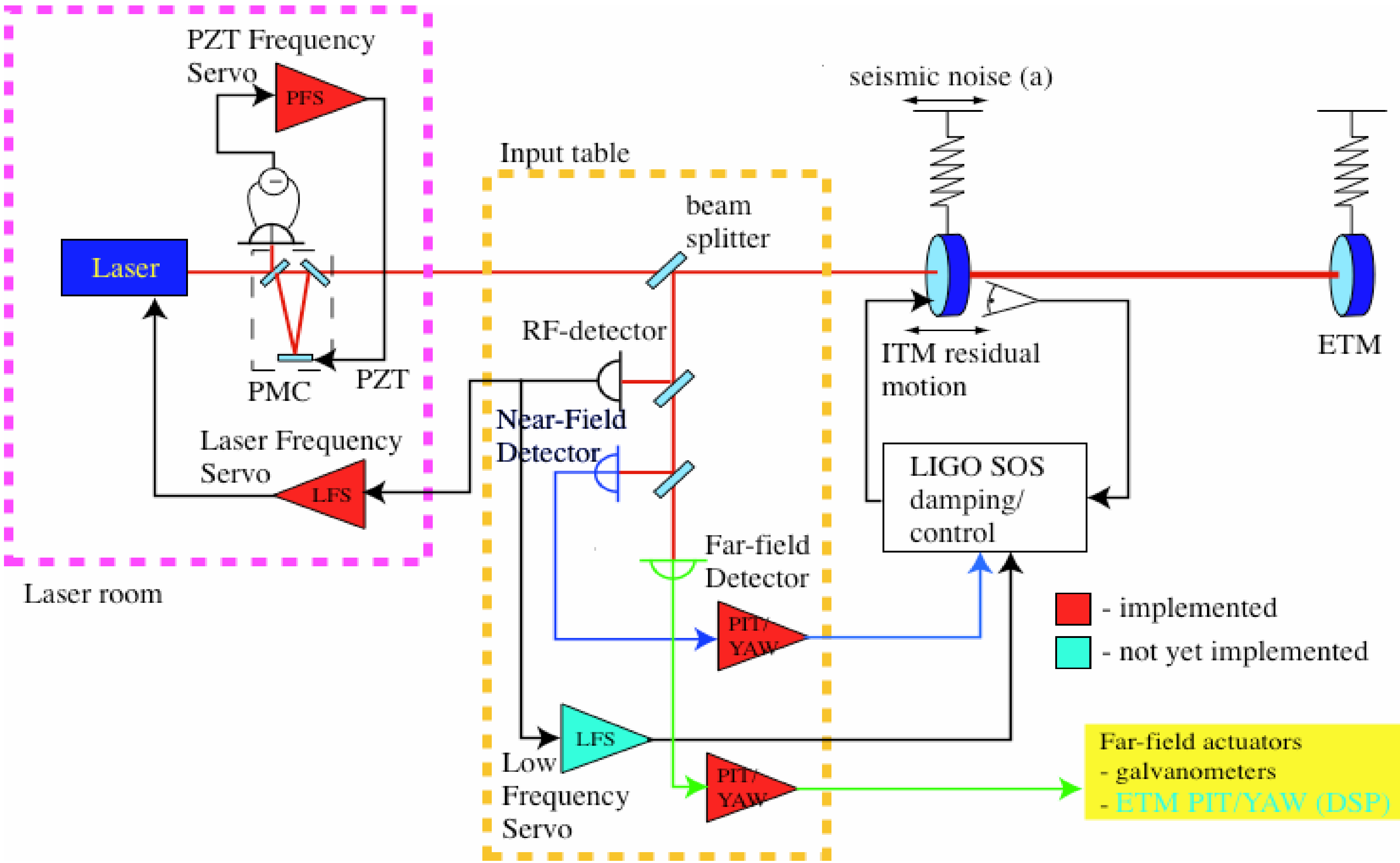
Pictured:
LIGO SOS ETM
with 900X600 Breadboard
and Vacuum Breadboard Stand

Drawing: Tim Slade

Initial lock

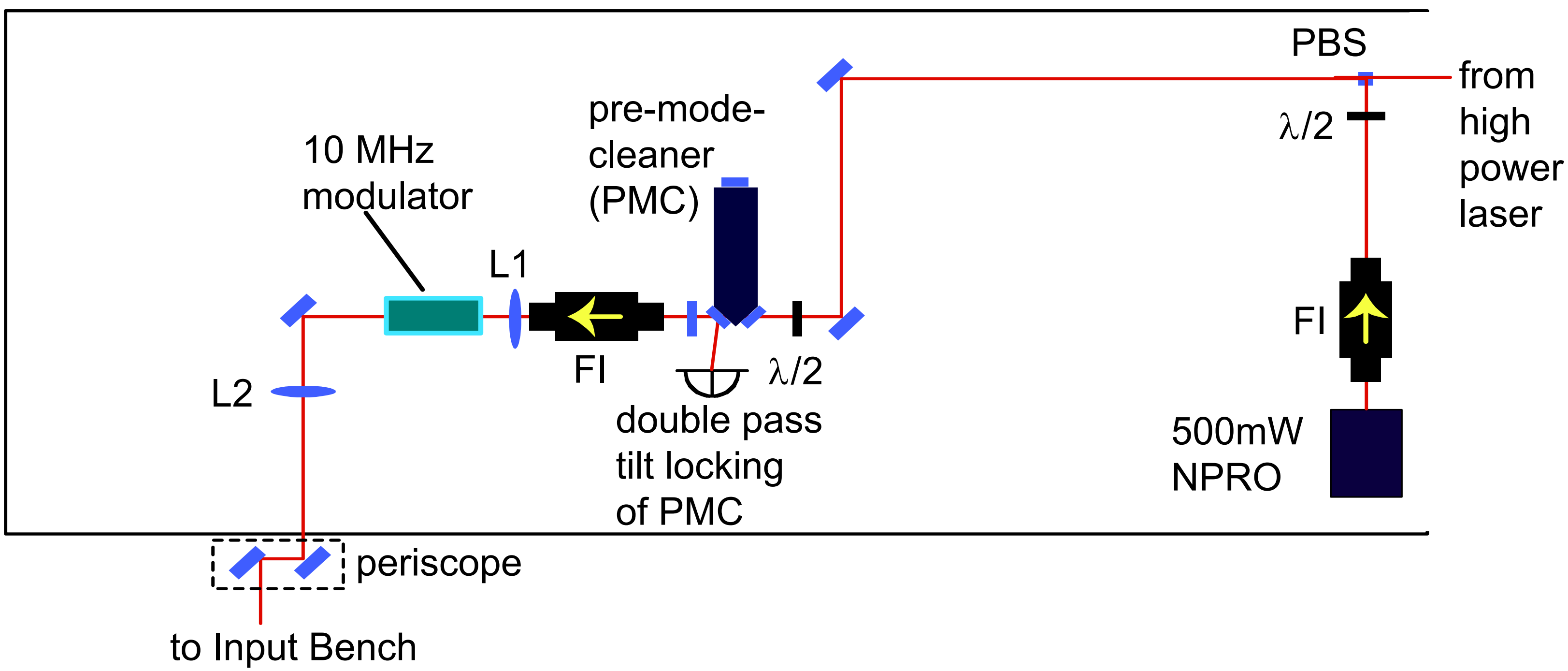
- BK7 Test Masses, R~99.8% (F~500).
- Use of 500mW NPRO, ~250mW incident on arm cavity.
- 10MHz sidebands used for locking.
- Laser locked to the arm cavity.
- LIGO SOS damping of TM.
- Remote DC control of TM position off-set.

Global Cavity control



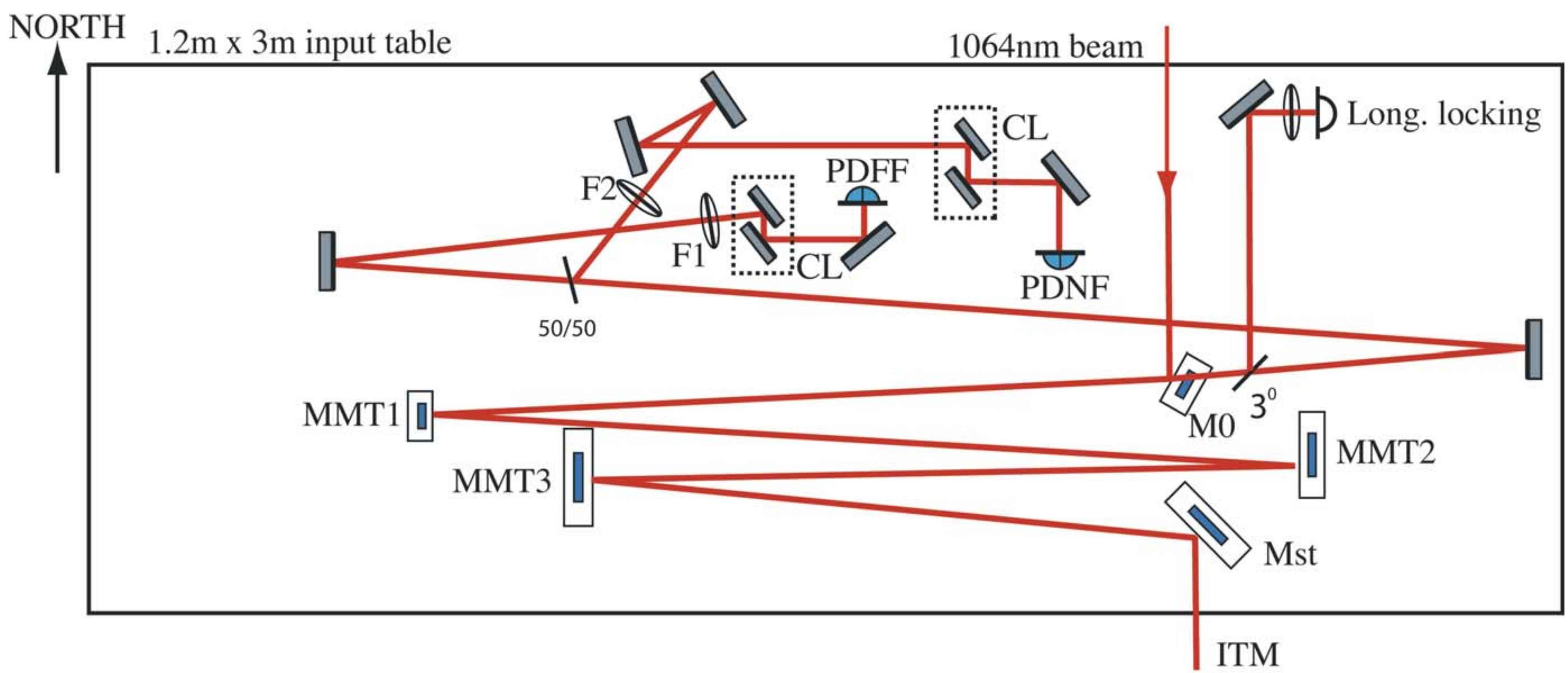
Laser Room

- Preliminary cavity alignment with 500mW NPRO
- PMC transmission (F=200), 85%
- Faraday Isolator(1&2), T=91%

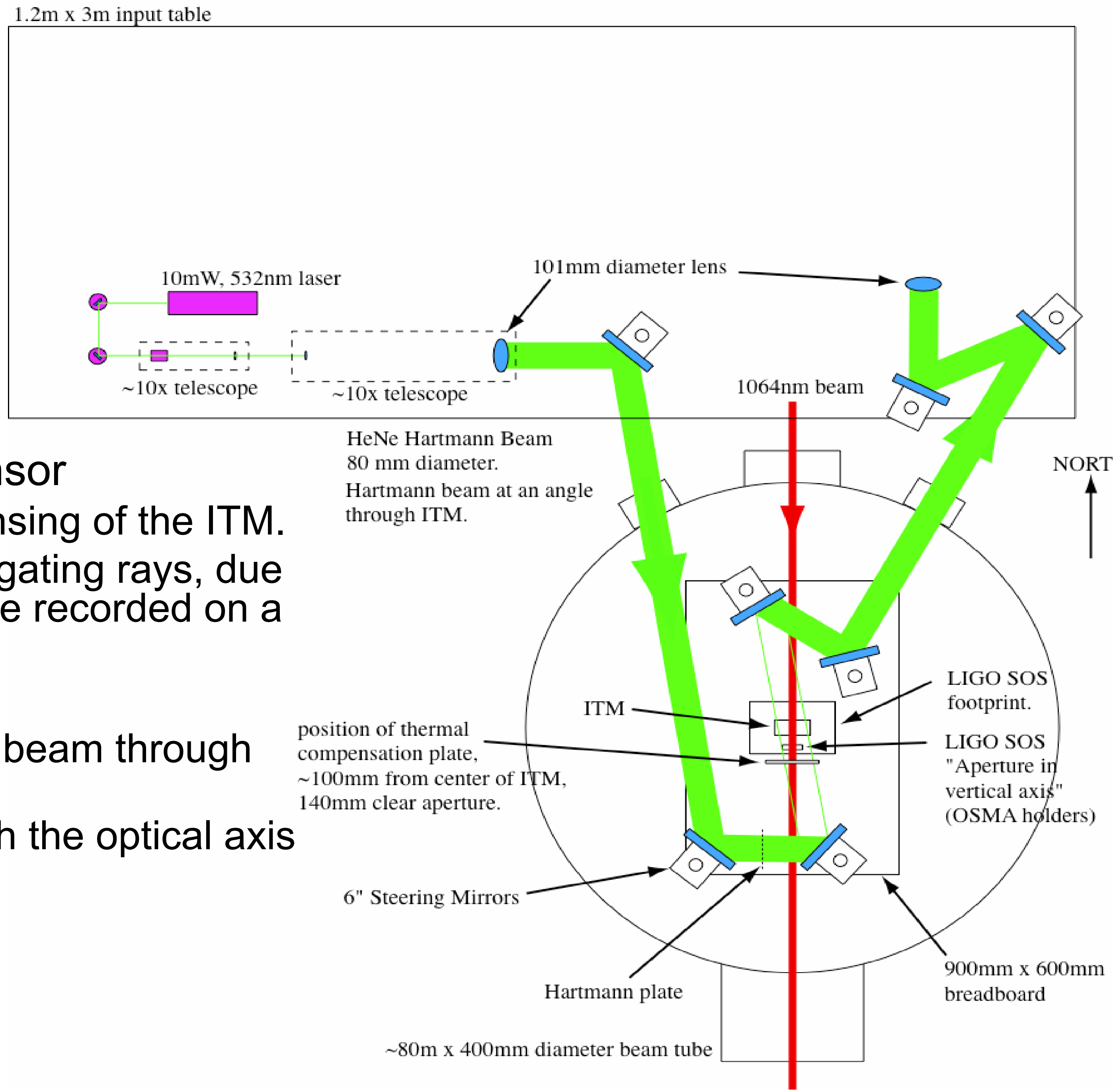


Input-table

- Input-table accommodates the suspended cavity mode-matching telescope, longitudinal sensing and auto-alignment sensing.
- Also the Hartmann Wave-front Sensor.



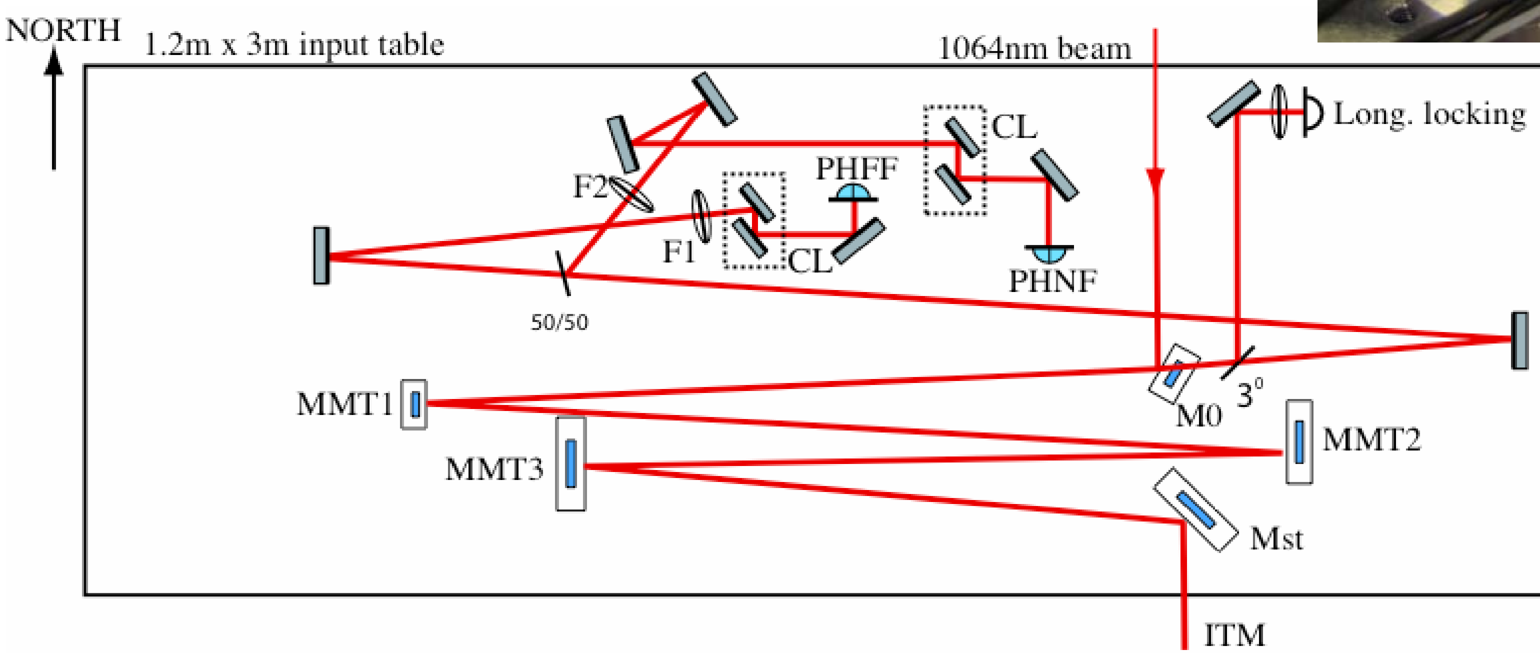
Input-table (cont.)



- Hartmann Wave-front Sensor
  - Measures the thermal lensing of the ITM.
  - The change of the propagating rays, due to the thermal lensing, are recorded on a CCD.
- Hartmann Sensor Beam
  - ~80mm diameter sensor beam through ITM.
  - Sensor beam at ~10º with the optical axis of the cavity.

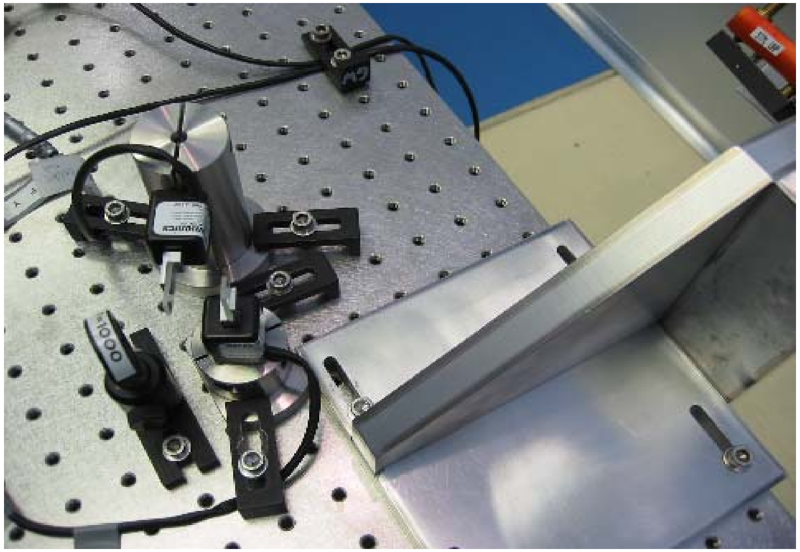
Auto-alignment installation

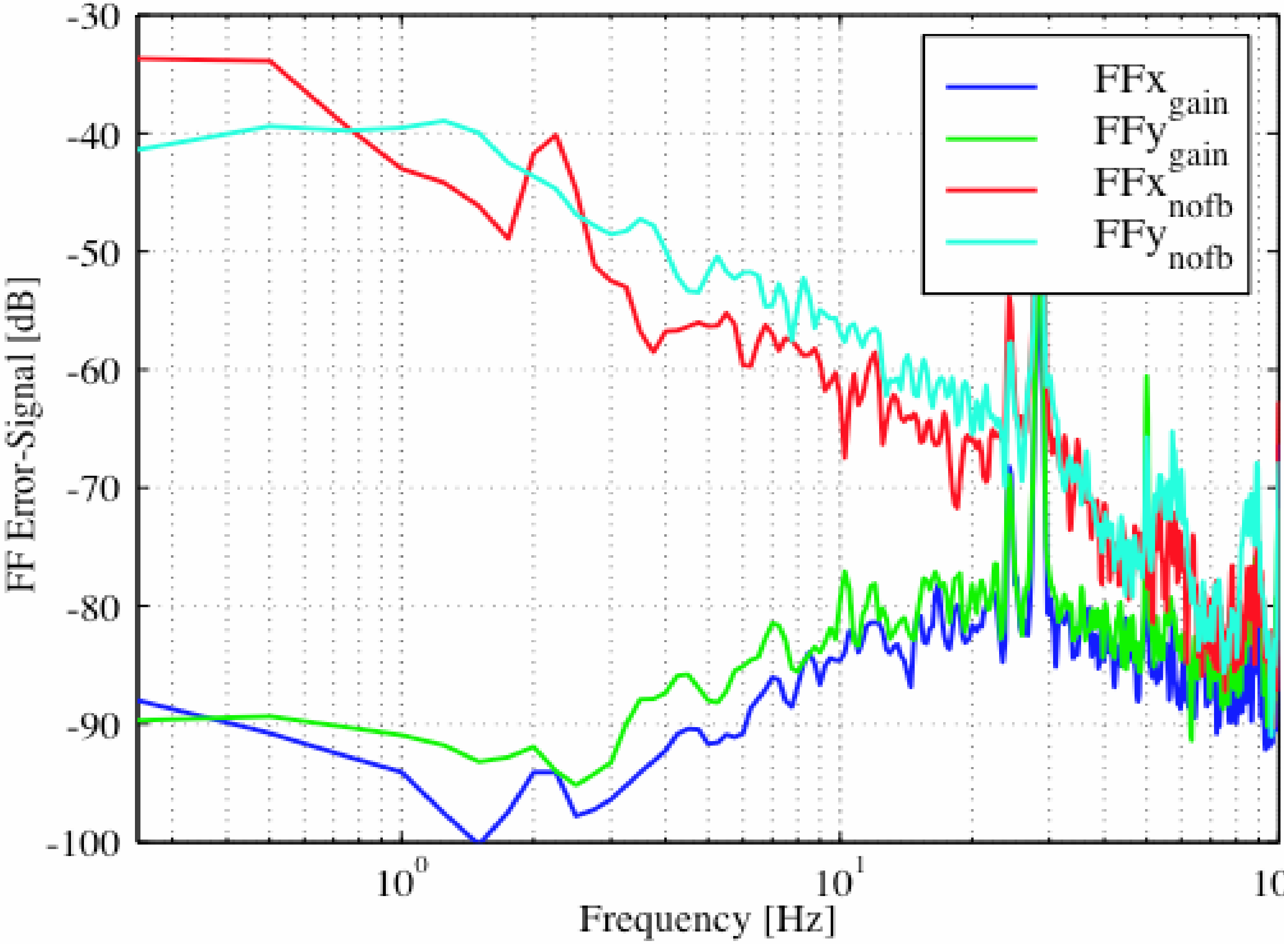
- Wave-front sensing is employed in the auto-alignment system.
- Galvanometers actuate for off-set in the far-field, while the ITM is actuated for tilt in the near-field.
- QPD centering loops have a unity gain bandwidth of 100Hz, with a suppression of 60dB @1Hz.



X/Y beam-offset (Far-Field)

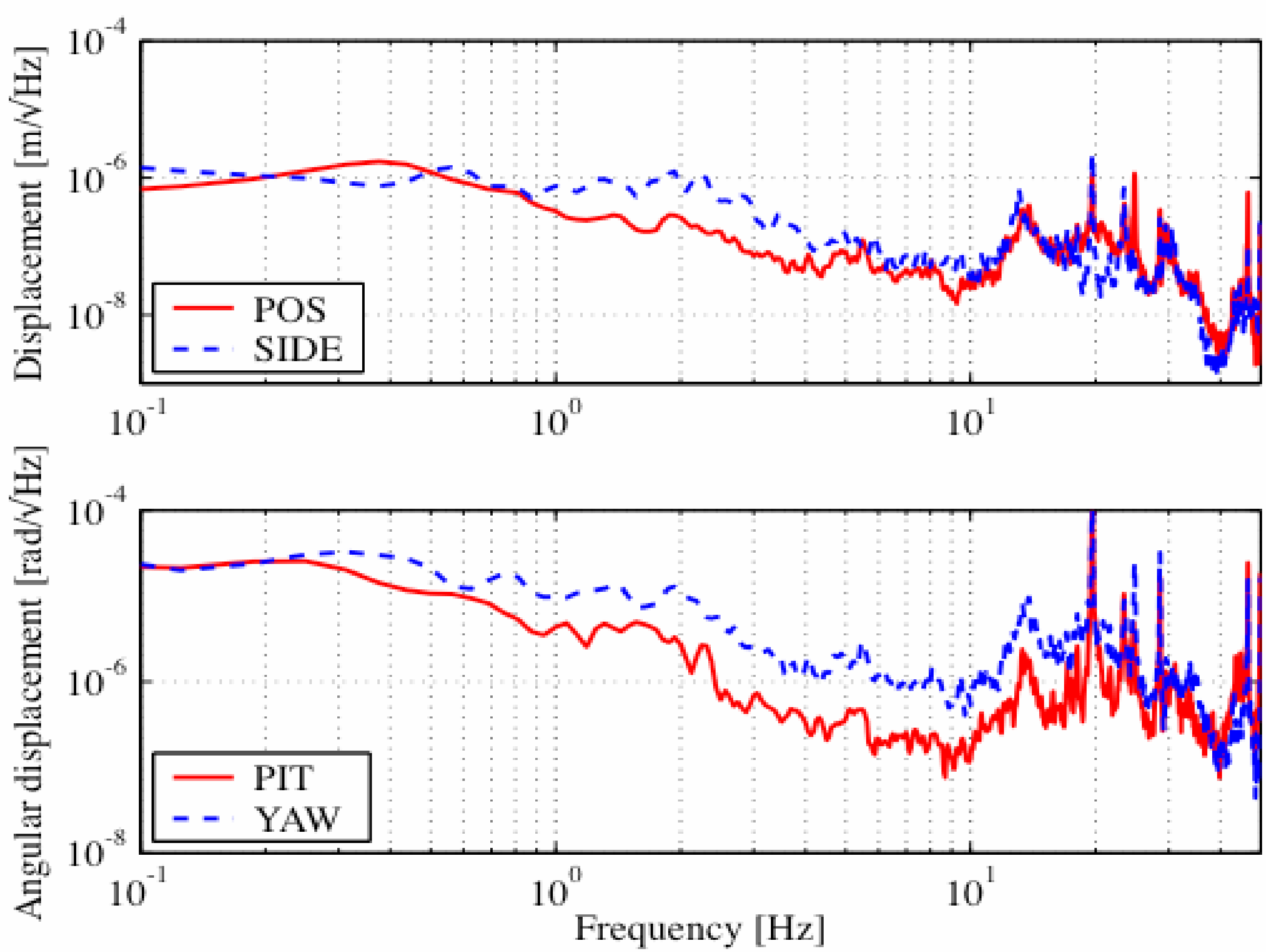
- 2 galvanometers with small mirrors steering the beam in X/Y onto the ITM.
- Far-Field unity gain bandwidth ~80Hz, with a suppression of ~50dB @1Hz.





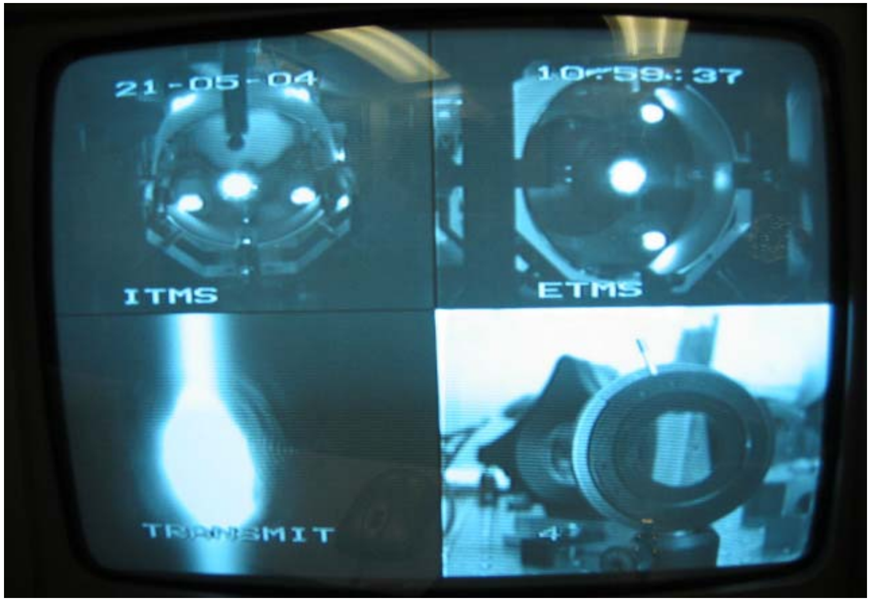
ITM residual motion

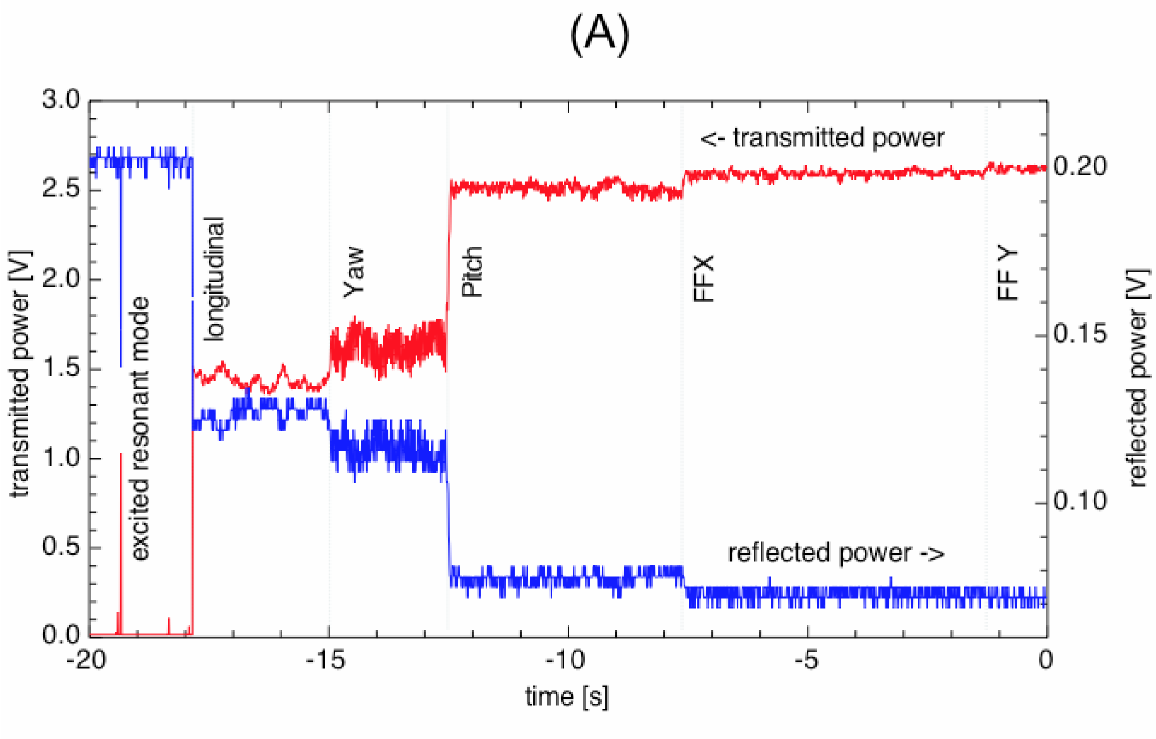
- Test masses have local damping.
- ITM SOS is placed on a breadboard, providing no advanced seismic isolation.
- Even so, the system can be locked.
- ITM residual motion, from the OSEMs.

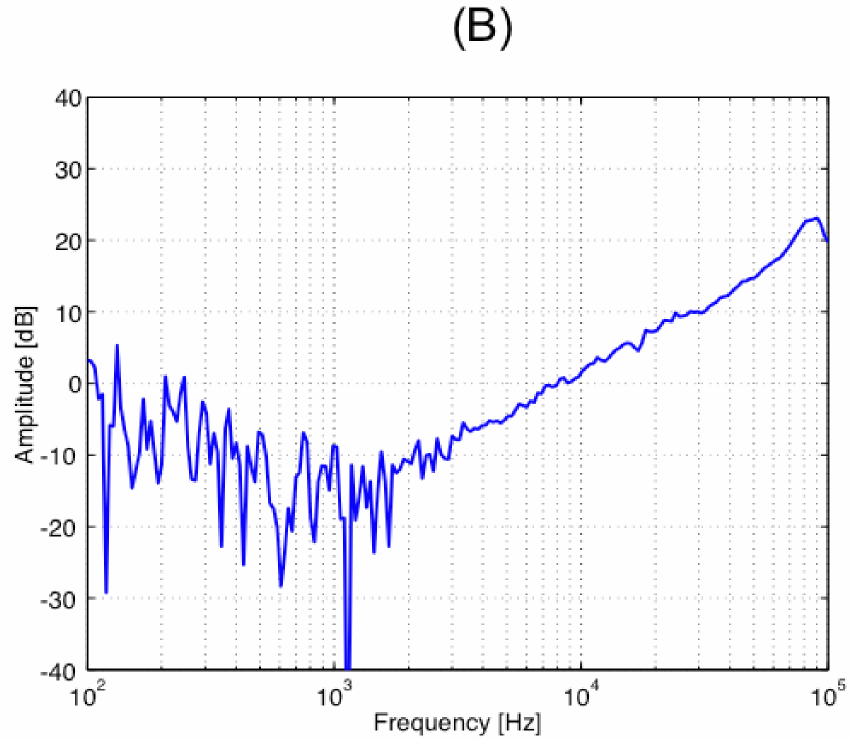


Longitudinal and auto-alignment lock

- (A) Auto-alignment -> increased and stabilised the transmitted power.
- (B) Longitudinal lock -> bandwidth of ~9kHz.







Current operational status

- Longitudinal lock reliable (without PMC).
- Change over of the near-field actuation to the Alignment Sensing Control (ASC) inputs complete.
- Set up of the digital signal processor (DSP) for auto-alignment feedback still in progress.
- Significant electronic noise present in the end-station.
- Tracking noise in the system.
- Bandwidth of the control signal to the end-station, large enough?

Future work

- Finalise the analog input and output filterboards to the DSP.
- Installation of the far-field alignment feedback to the ETM (debugging and streamlining software feedback filter implementation).
- Incorporate the near-field DSP feedback filter (use of the ASC-input).
- Distribute far-field feedback to the galvanometers and the ETM.
- Perform long term lock stability measurement (longitudinal and alignment control).
- Re-incorporate the PMC.
- Installation of the Sapphire test masses.
- Commissioning of the 10W laser.

Laser Development for HPTF

10 W laser

Injection-locked 10 W Nd:YAG production laser for HPTF (and TAMA).

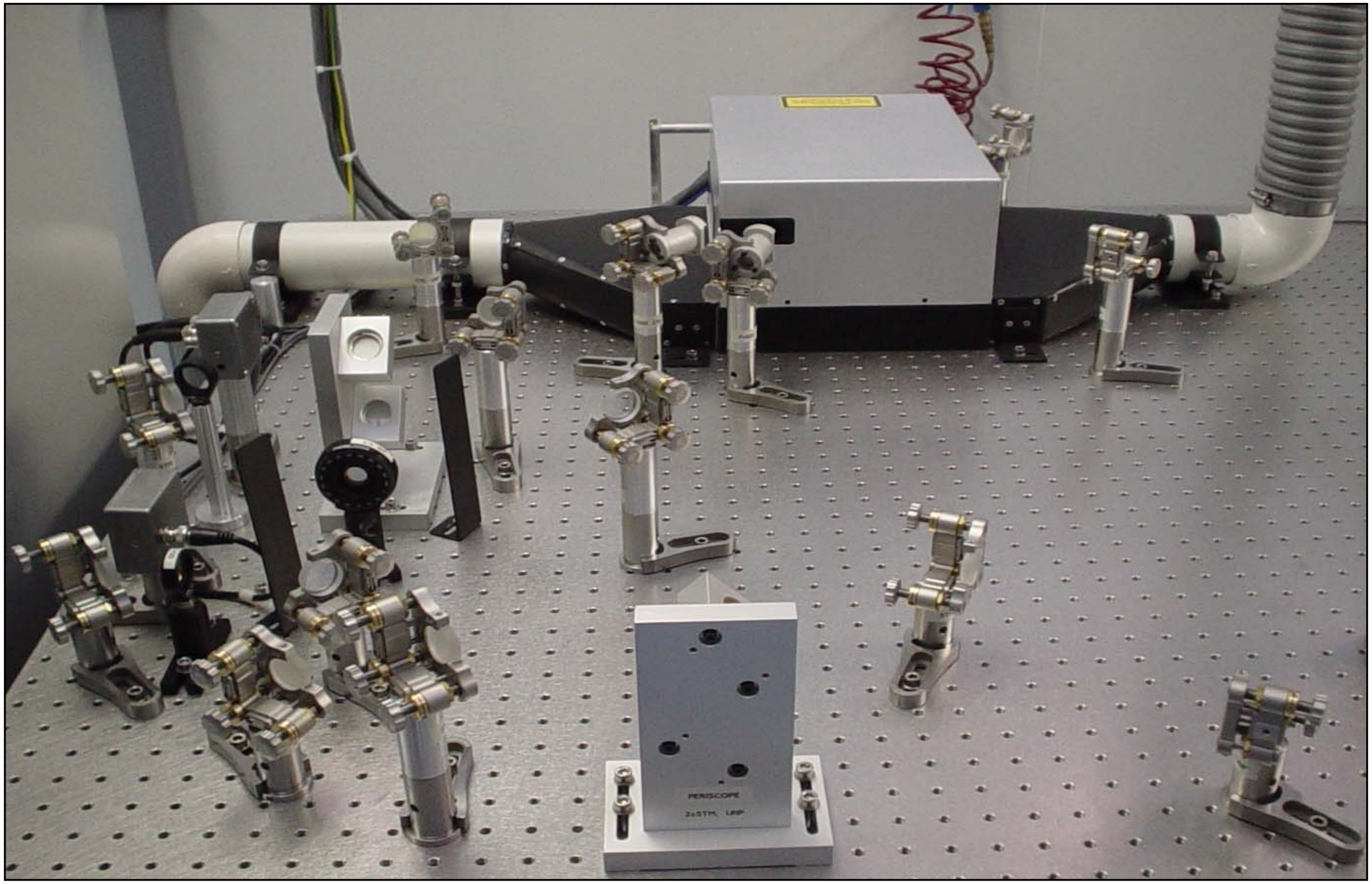
Operational.

100 W class laser

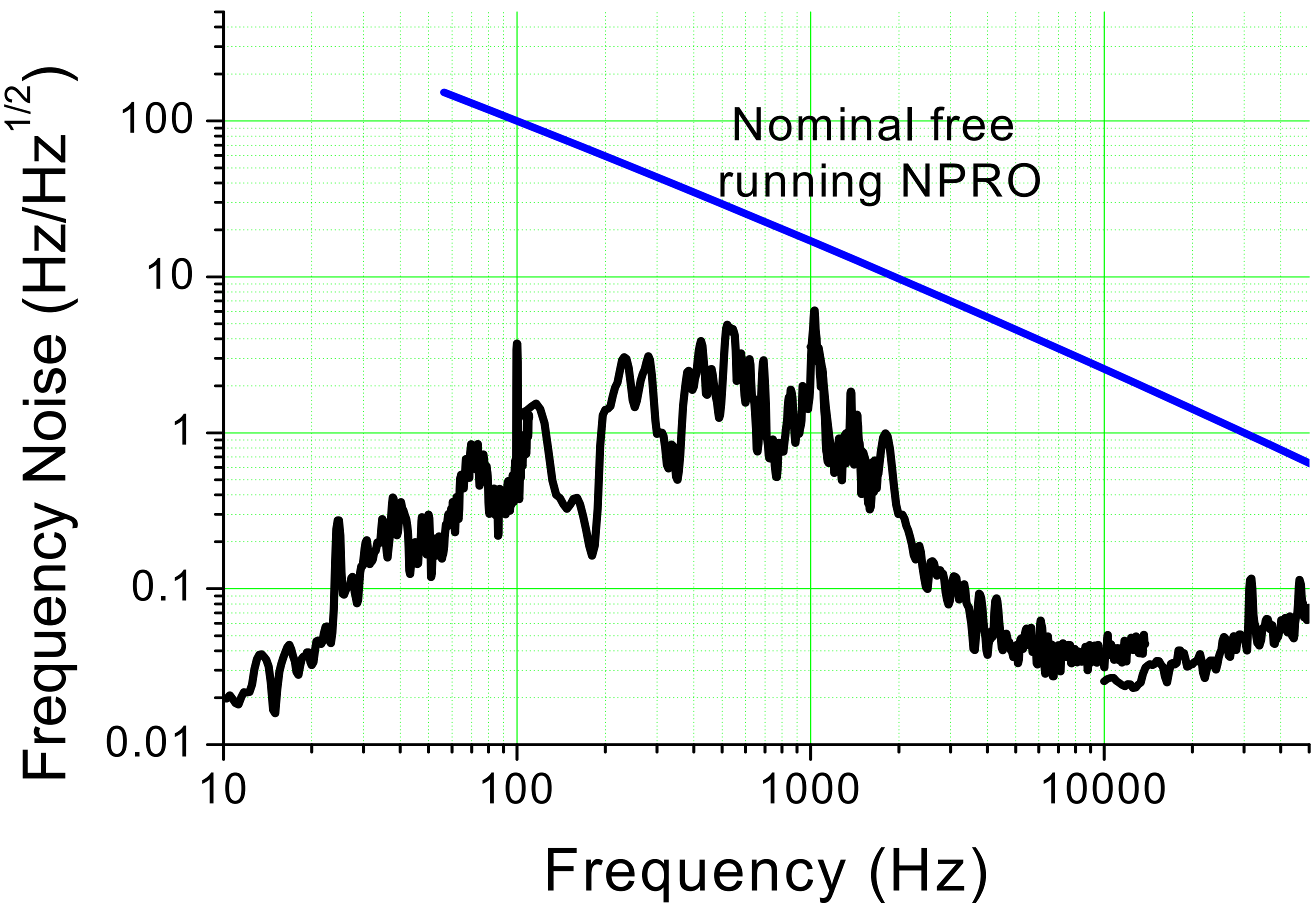
New improved laser architecture for laser oscillator to 100W and beyond.

Designed to solve all problems of previous design.

10W Injection-locked Laser at Gingin



Preliminary Frequency Noise Measurements

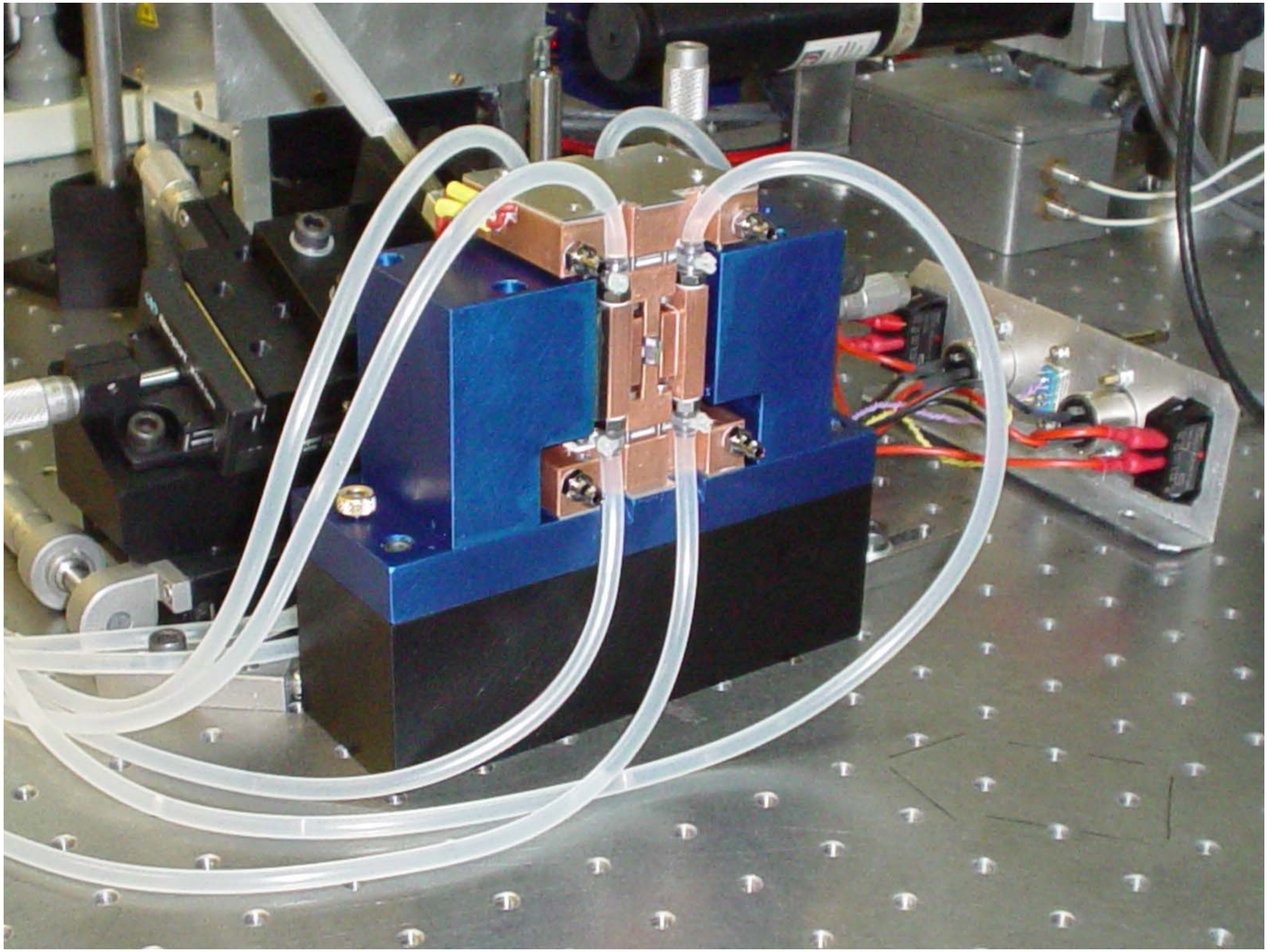


10W Laser Status

Progress to date:
- Efficient robust compact design
- Robust thermal control system
- $M^2_{x,y} < 1.1$ with 9.8W output in travelling-wave
- Injection-locking achieved

Future plans:
- Increased output power
- Long-term injection-locking
- Commissioning at ACIGA
- Further characterisation of noise
- Delivery of injection-locked laser to TAMA in mid-2005

New 100W Laser Head

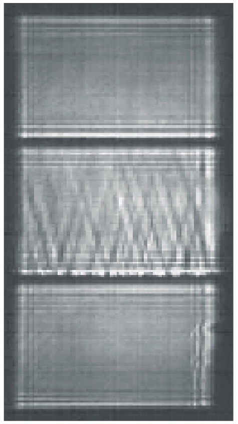


100W Laser Design

Design features for GWI Laser:

- Single laser head with simple, robust resonator, good alignment stability
  - Repeatable turn-on stability
- Thermal lens control, less sensitive to pump power
- Vary laser power by varying pump power: not point design
- Efficient cooling: less water, less vibrations, less noise
- Design does not pump through cooling water:
  - less pump noise

While we have not proven all this yet, preliminary measurements on faulty laser crystal support these design aims.



100W Laser Status

using faulty crystal

Thermal properties of design have been verified experimentally:

- horizontal and vertical thermal lens controlled
- heat is efficiently removed from laser crystal

Robust engineering, coatings: reproducible laser behavior

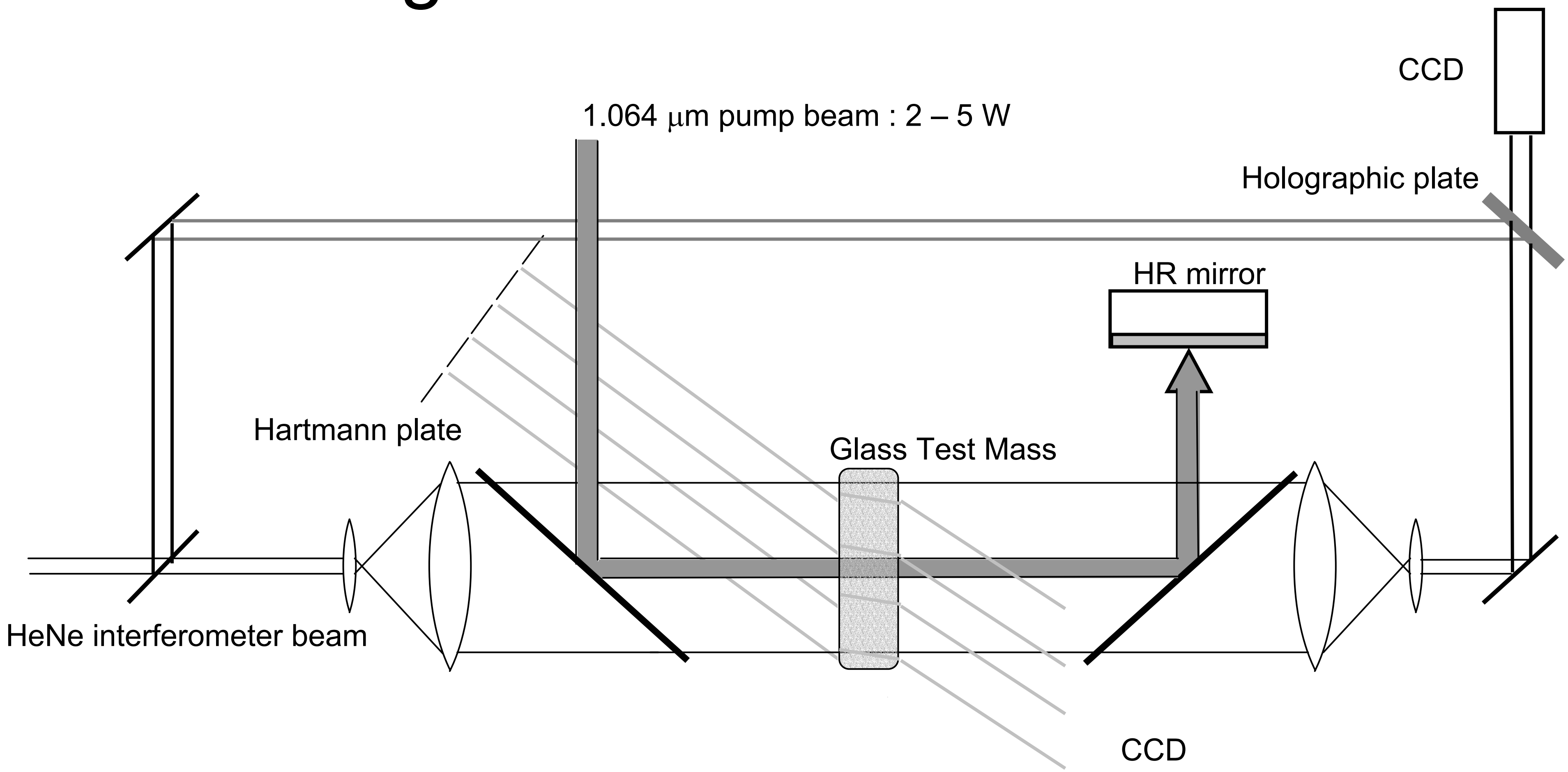
Pump efficiency verified: ~ 90% pump power absorption

(35W measured out with 155W pump)

Replacement slabs fabricated, polished & Coated:

→ delivery expected March 2005.

Measure the thermally-induced aberration using off-axis Hartmann sensor



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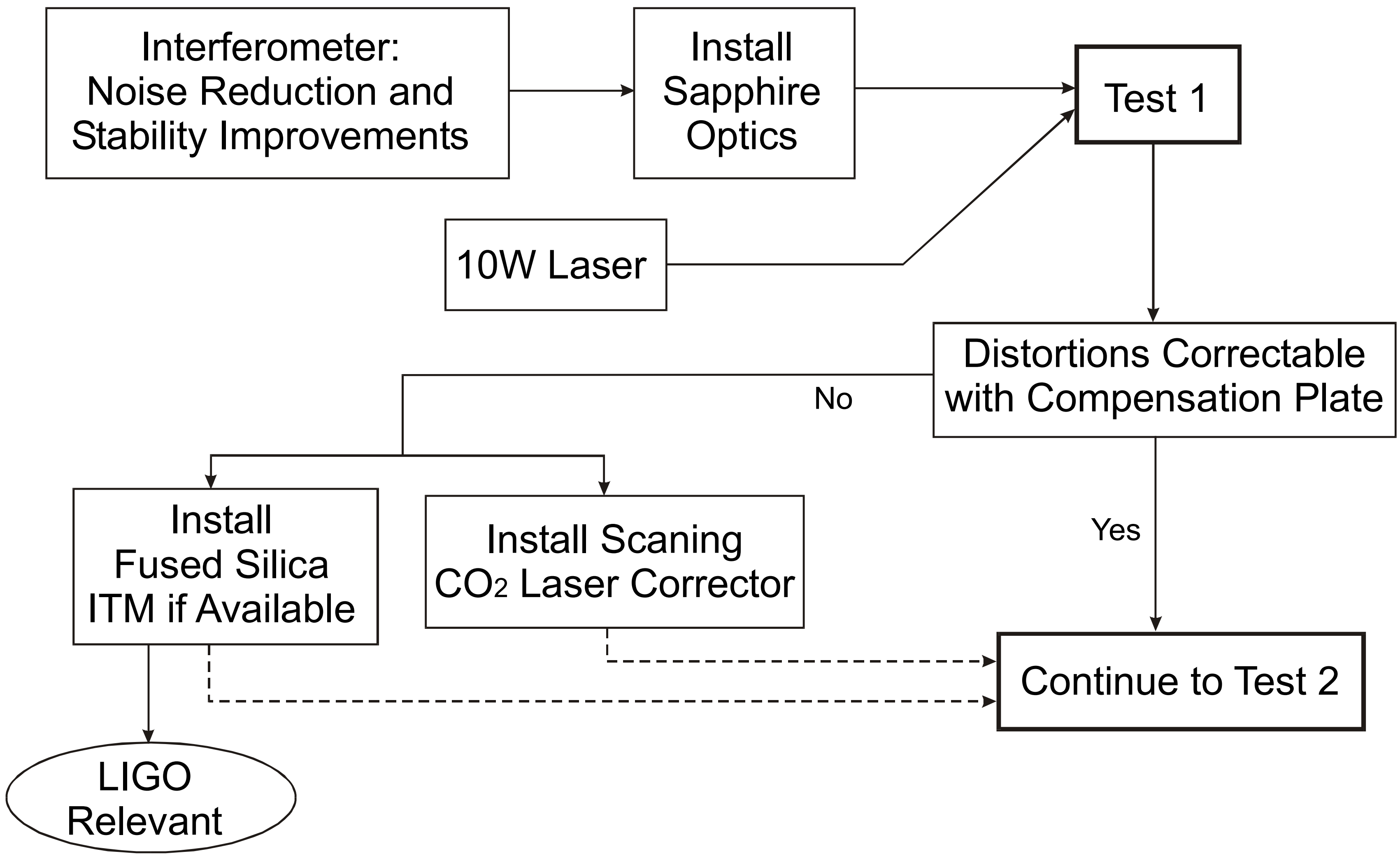
Experiment Plan



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