THE UNIVERSITY OF ADELAIDE AUSTRALIA

Gingin High Power Test Facility Review: Optics and Lasers

J. Munch, P. Veitch, D. Mudge, A. Brooks, D. Hosken, T Kelly

Optics and Lasers Group
Department of Physics and Mathematical Physics
The University of Adelaide

LSC, Livingston, March 2003
LIGO-G030073-00-Z

Contents

Review HPTF test sequence

Modeling of test 1

Status of laser development for HPTF

Hartmann wavefront sensors

High power optical components

HPTF Test Objectives

- Measure optical distortions in ITM substrate and coatings, validate MELODY

  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 AdL

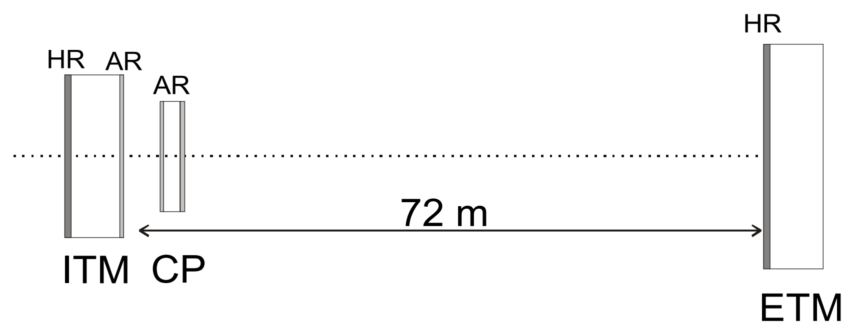
- Test wavefront sensors
- Test actuators for control in cavity
- Investigate control of power recycled FP cavities.

THE UNIVERSITY OF ADELAIDE AUSTRALIA

HPTF test #1

Wavefront distortion due to absorption in ITM substrate:

Use back surface ITM:



ITM: g_{ITM} = 1, T = 1800 ppm, substrate abs. = 500 ppm (50 ppm/cm),
AR coat abs.= 1 ppm, HR coat abs. = 1 ppm, AR coat reflectivity < 100 ppm

ETM: g_{ETM} = 0.9 (RoC_{ETM} = 720 m), T < 50 ppm, HR coat abs. = 1 ppm

w_o = 0.86 cm

CP: compensation plate, fused silica, 5 cm diameter, 1 cm thick, radiantly heated

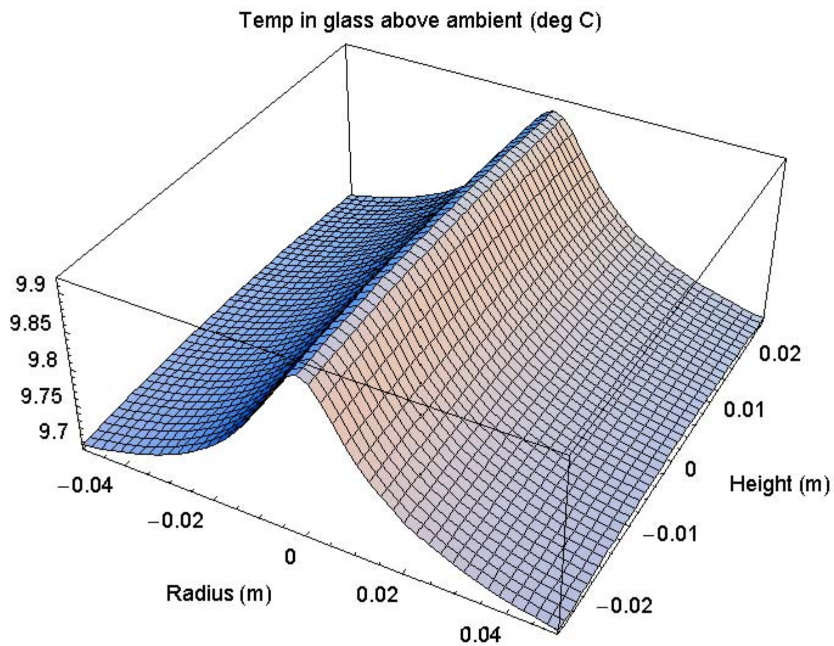
$P_{incident}$ = 4 W -> $P_{cavity} \approx$ 3.0 kW

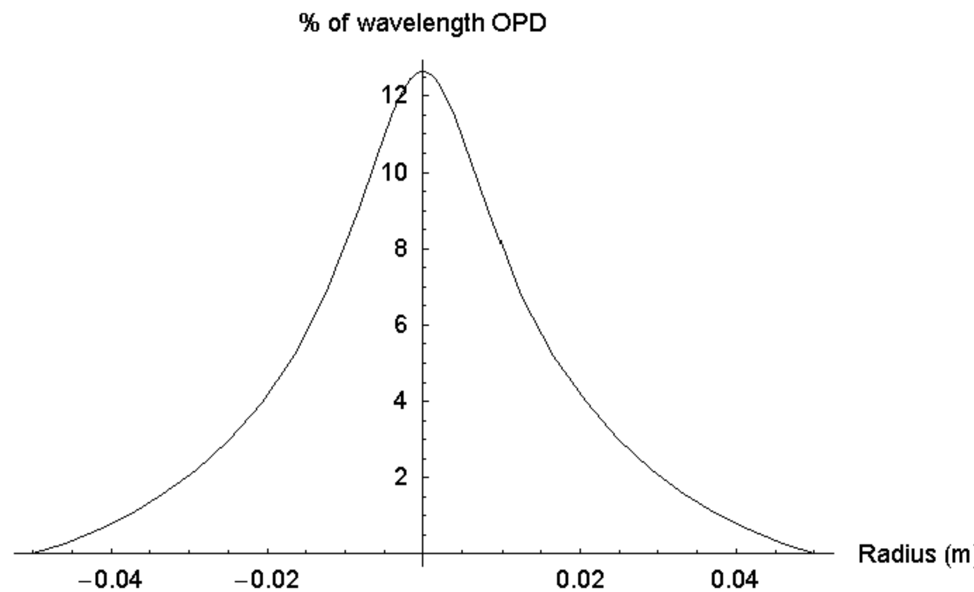
P absorbed in ITM substrate = 1.5 W – similar to AdvLIGO

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Expected wavefront distortion in test 1

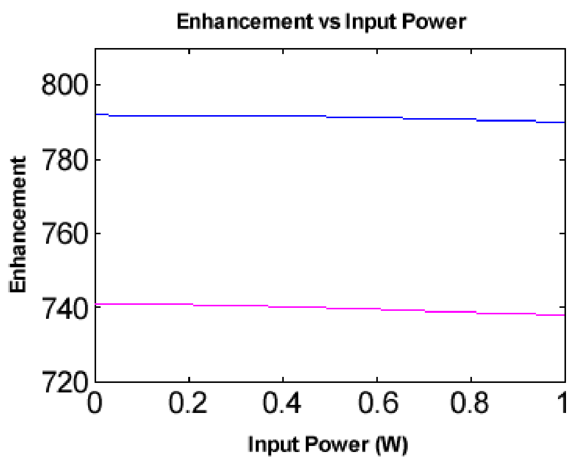
Using Hello-Vinet model and 4 kW intra-cavity power:



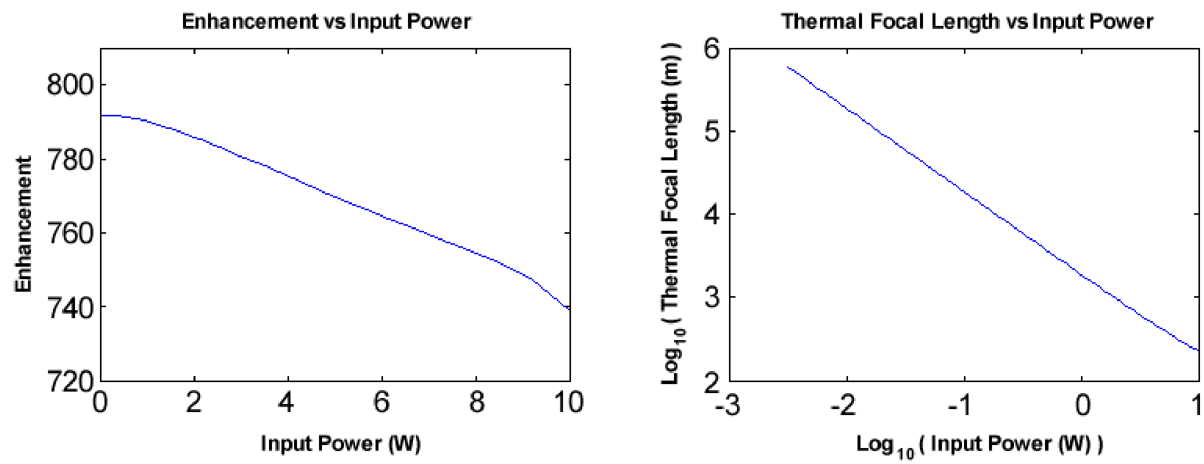


THE UNIVERSITY OF ADELAIDE AUSTRALIA

MELODY predictions for test 1



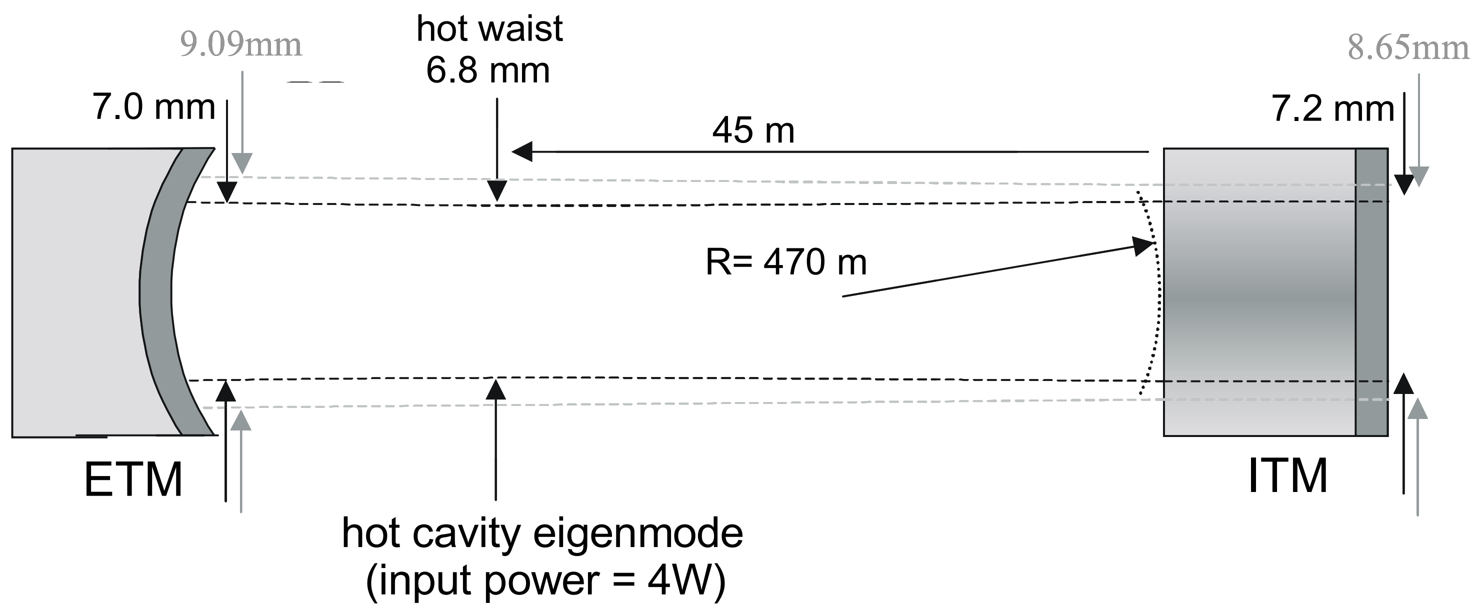
(a)



(b)

(a) Effect of ITM substrate inhomogeneity, low power
(b) Effect of absorption, no inhomogeneity

MELODY prediction for test 1 – mode change



HPTF test #2

Coating absorption test: reverse ITM to yield front surface mirror.

Optical distortion primarily in HR coating

$P_{incident}$ = 50 W $\rightarrow$ $P_{cavity} \approx$ 65 kW

P absorbed in ITM substrate = 25 mW

P absorbed in ITM HR coating = 65 mW – assuming 1ppm absorption

(cf ~ 200 mW in AdvLIGO)

Need 100W laser for more AdvLIGO-like test

Same optical parameters as initial Test 1

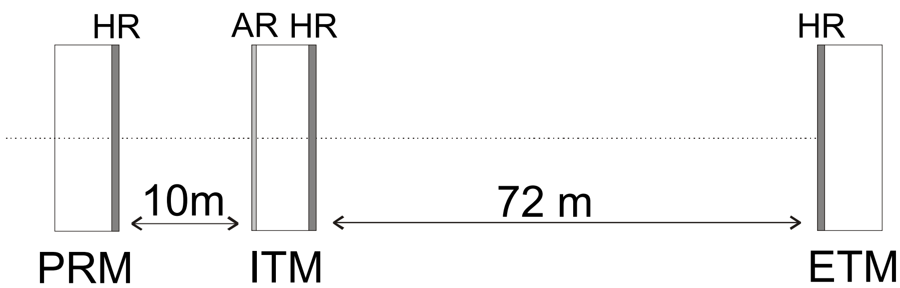
Modeling in progress

Add actuator to null effects of coating absorption

THE UNIVERSITY OF ADELAIDE AUSTRALIA

HPTF test #3

Coupled cavity test:



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

Transmittances: PRM ~ 5%, ITM ~ 8%

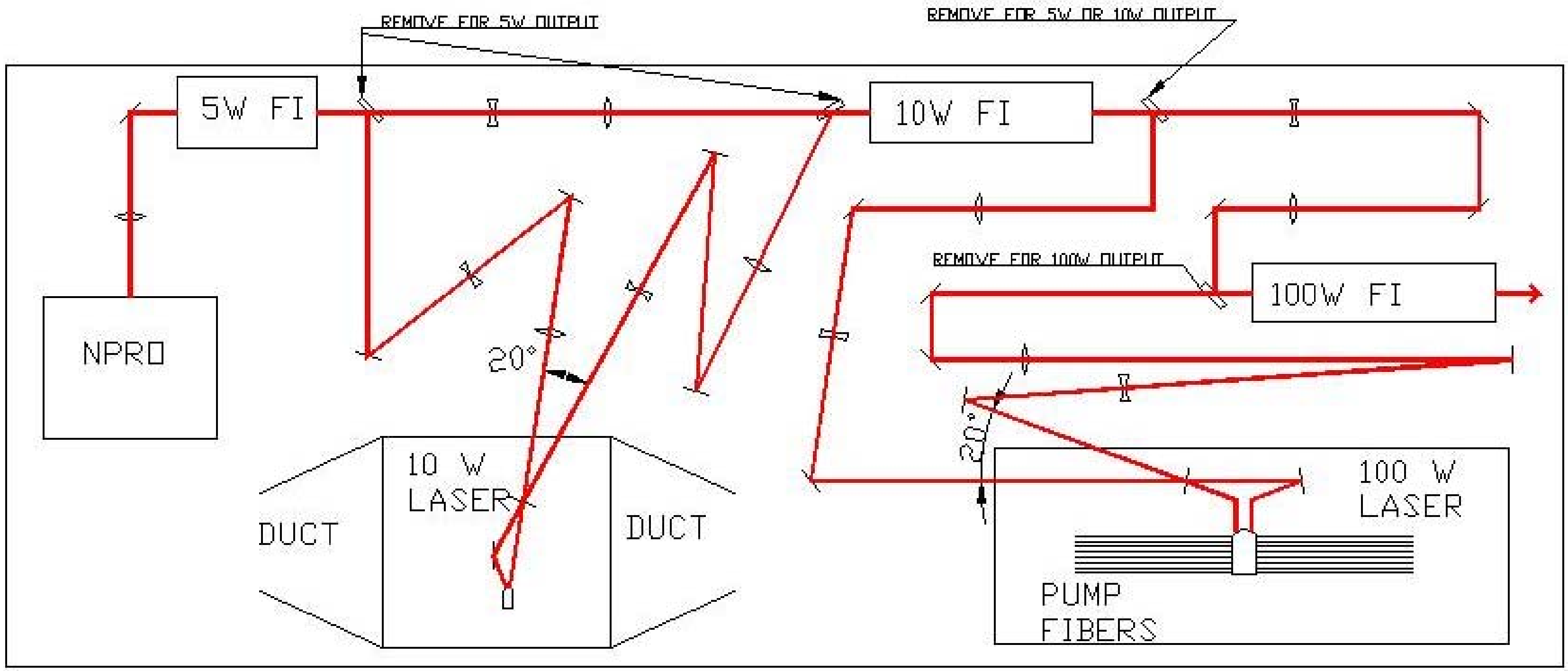
Input power = 100 W → recycling cavity power ≈ 4 kW, arm cavity power ≈ 200 kW

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

Gingin HPTF laser table



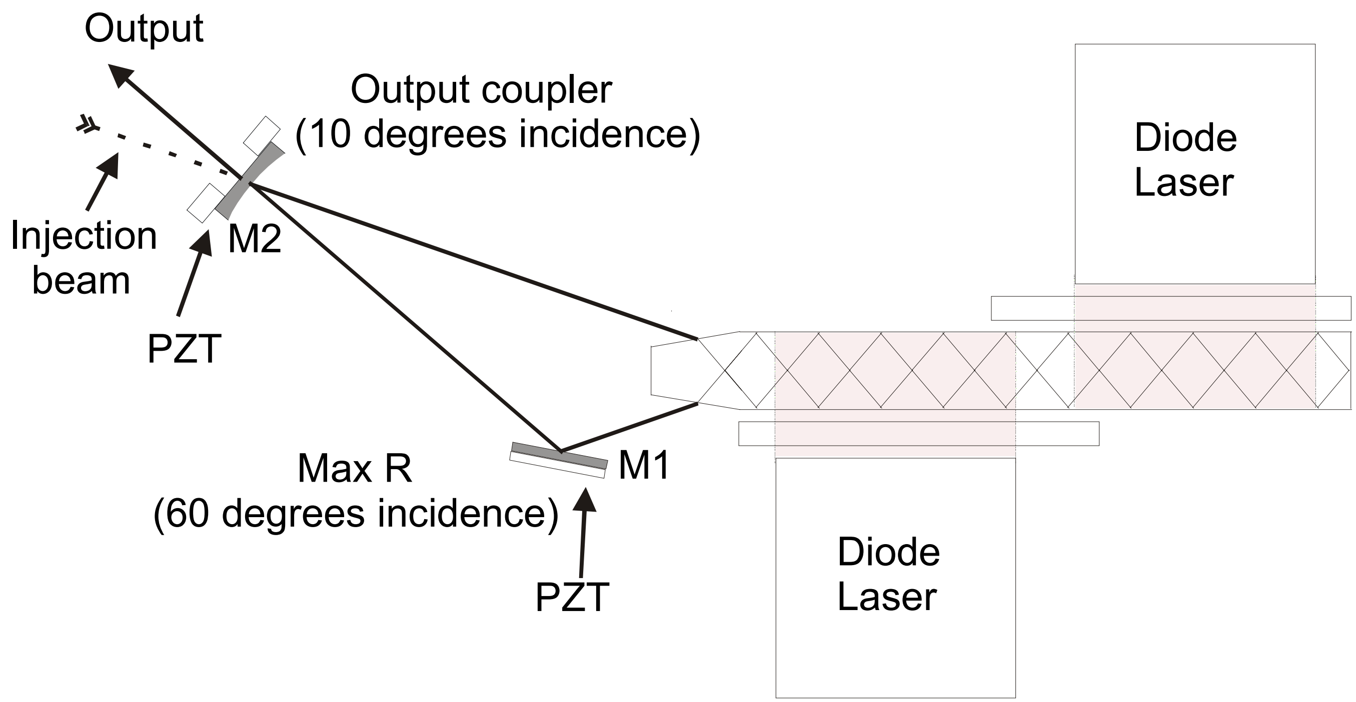
Laser Development for HPTF

10 W laser
Aim: to produce an injection-locked 10 W Nd:YAG brass-board laser for HPTF (and TAMA)
Strategy: power-scale Adelaide 5 W laser and develop deliverable hardware.

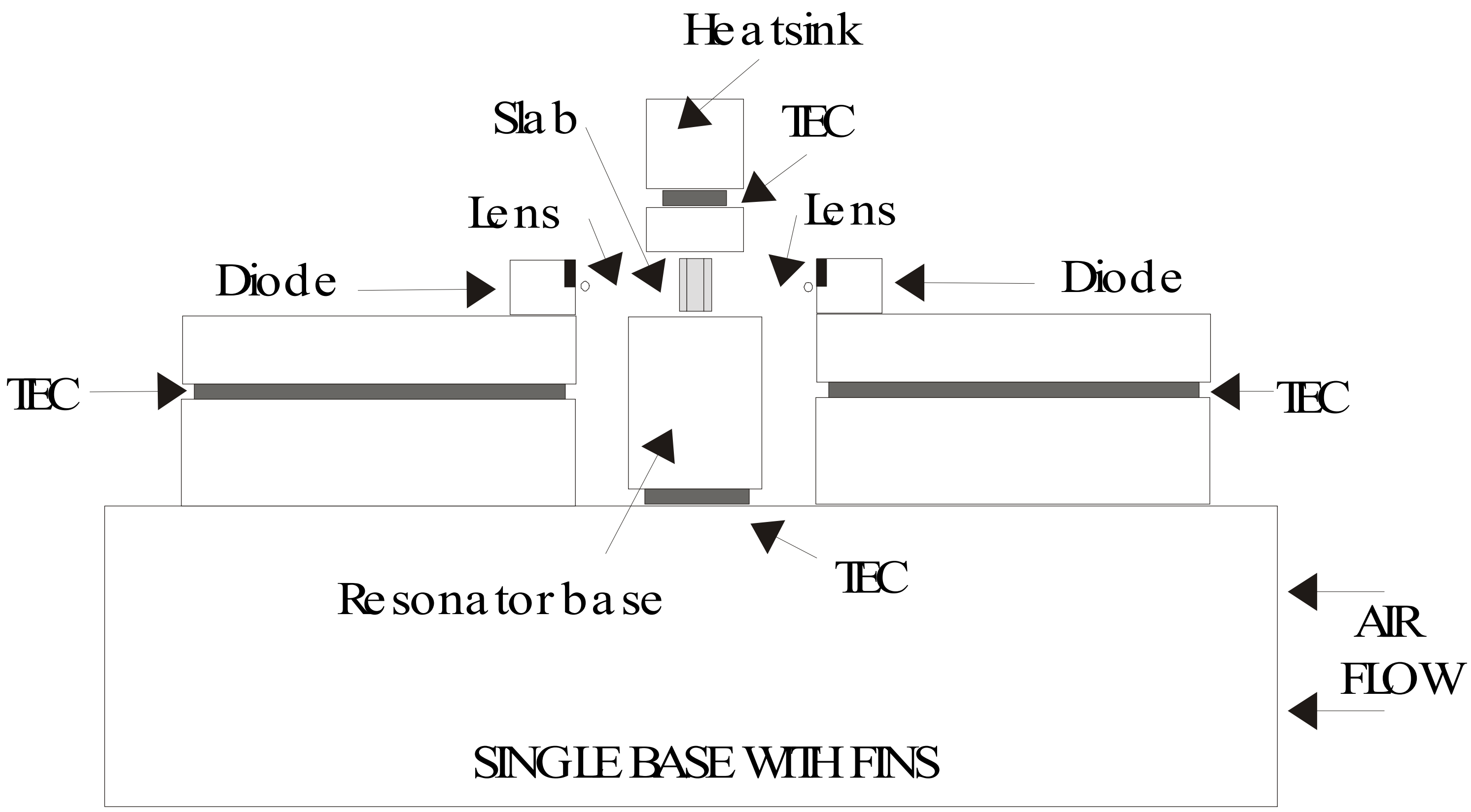
50 W laser
Use current injection-locked, side-pumped side-cooled unstable resonator laser.

100 W laser
Further development of current laser to 100W, or
Incorporate new diode-pumped zigzag slab architecture in unstable resonator.

10W laser resonator

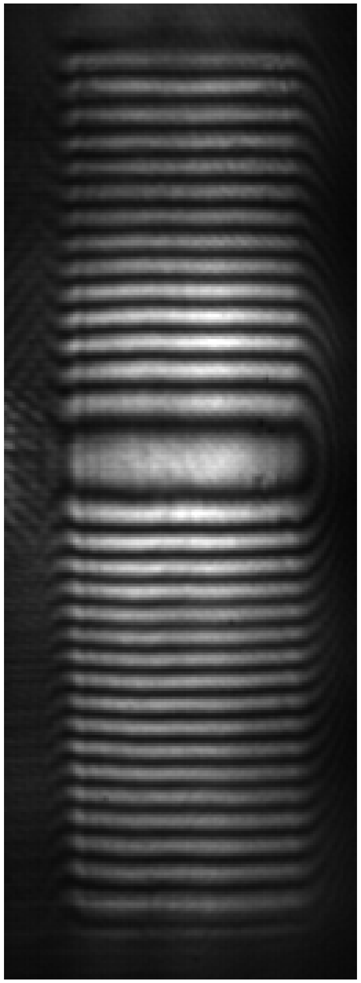


10 W prototype laser head



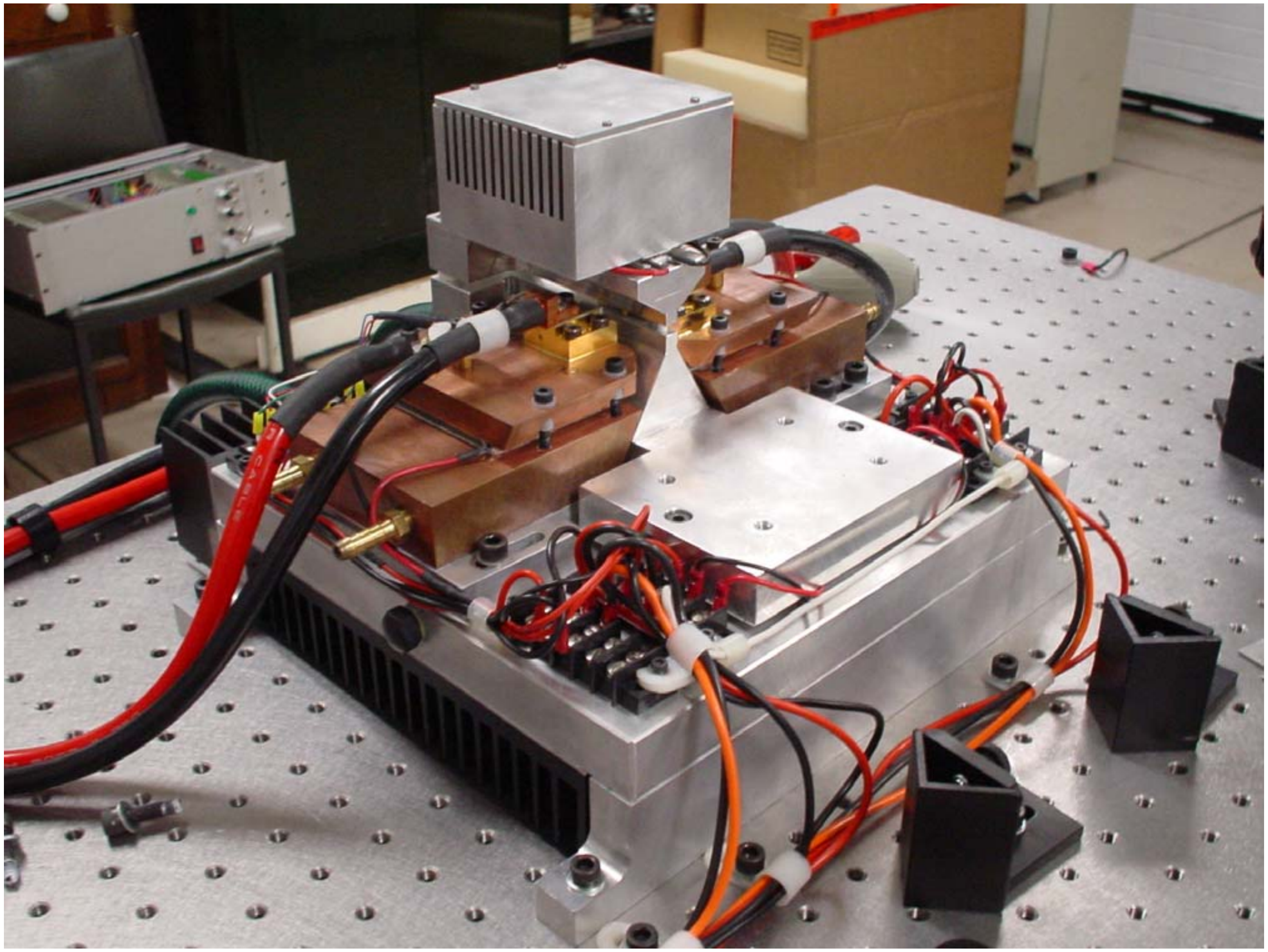
Refractive index profile in 10W gain medium

- measured using Mach-Zehnder interferometer
- pumped at 40W and lasing
- no lensing in horizontal direction
- vertical component of index gradient symmetric about pumped region
- vertical index is quadratic (simple lens) in pumped region



THE UNIVERSITY OF ADELAIDE AUSTRALIA

10W laser prototype



THE UNIVERSITY
OF ADELAIDE
AUSTRALIA

10W laser status

Prototype

TEM_{00} traveling-wave laser demonstrated

Optimum output coupler: R ≈ 90% → 9 W from 40 W pump (80 W available)

Next: confirm injection-locking using Pound-Drever-Hall and tilt-locking stabilization.

Brass-board

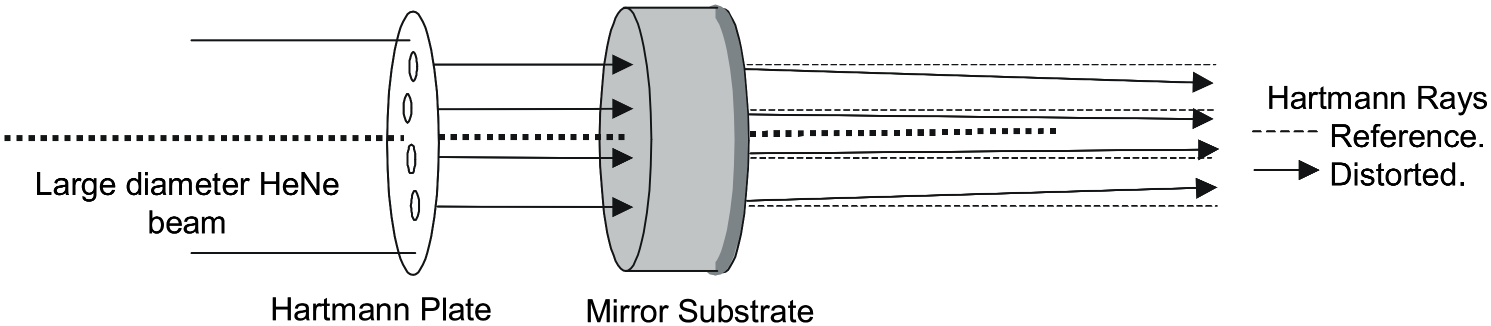
Improved design:

- pump from single side using commercial fast-axis-collimated 80W diode
- incorporate pump reflector
- use more efficient TECs for diode temperature control
- monolithic air-cooled base
- improved thermal control of slab

Fabrication of air-cooled base and resonator base complete.

Assembly begin April 2003 (when TECs and diodes are delivered)

Hartmann wavefront sensor



- Distortion deflects rays from reference positions.
- Determine positions using CCD camera
- Transverse aberration of each ray is used to reconstruct the wavefront distortion.

Advantages

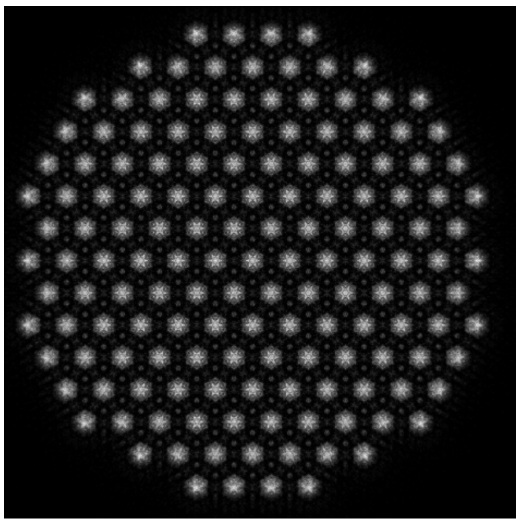
- Alignment much less critical than an interferometer.
- Can be configured as off-axis sensor in working interferometer.
- More sensitive than Shack-Hartmann (more precise centroid location).
- Our implementation gives absolute accuracy.

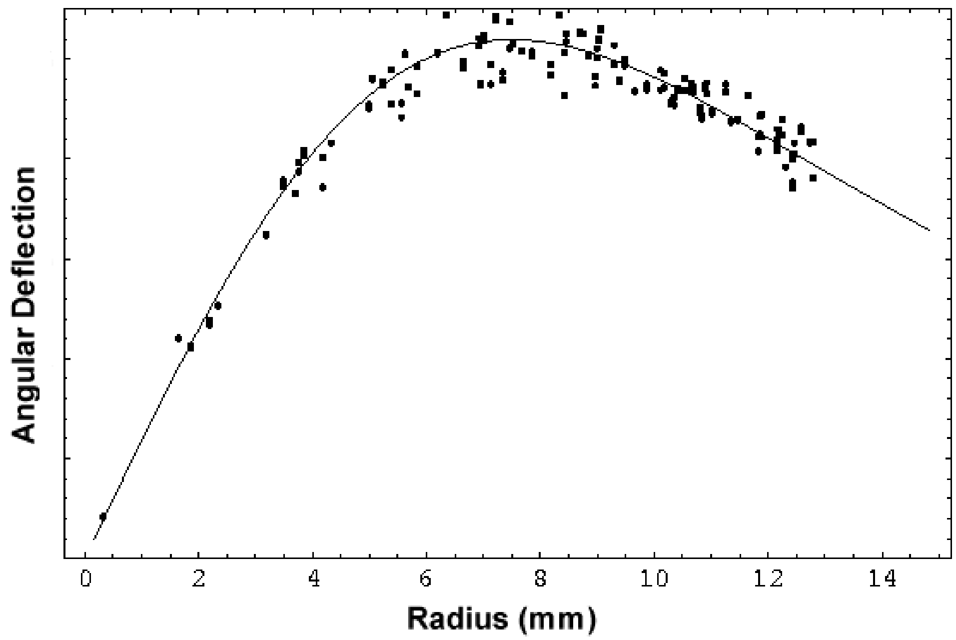
Issue

- Analysis is more complicated when sensor is rotated off the optical axis.

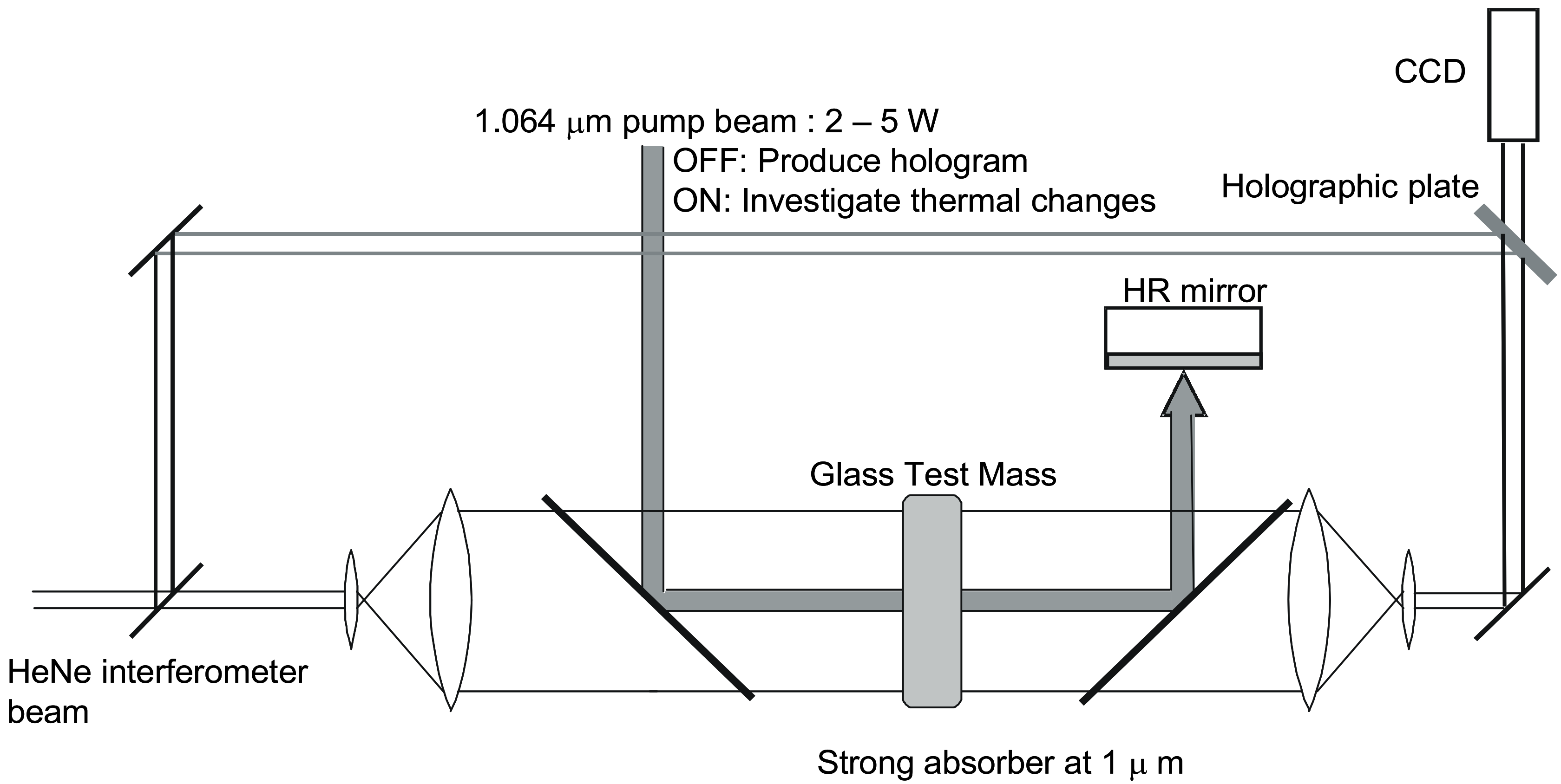
ZEMAX modeling of Hartmann sensor - preliminary

Introduced wavefront distortion predicted by Hello-Vinet into numerical model that used ZEMAX Physical Optics Propagation computer package.





Measure the thermally-induced aberration using stored-beam holography

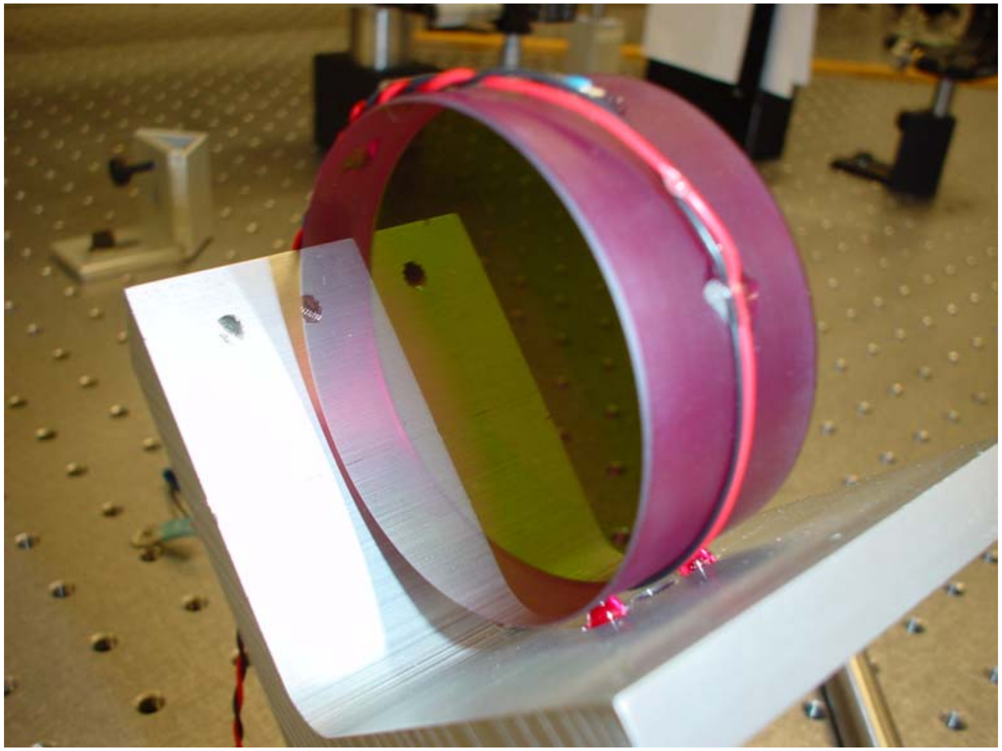


THE UNIVERSITY OF ADELAIDE AUSTRALIA

Glass test mass

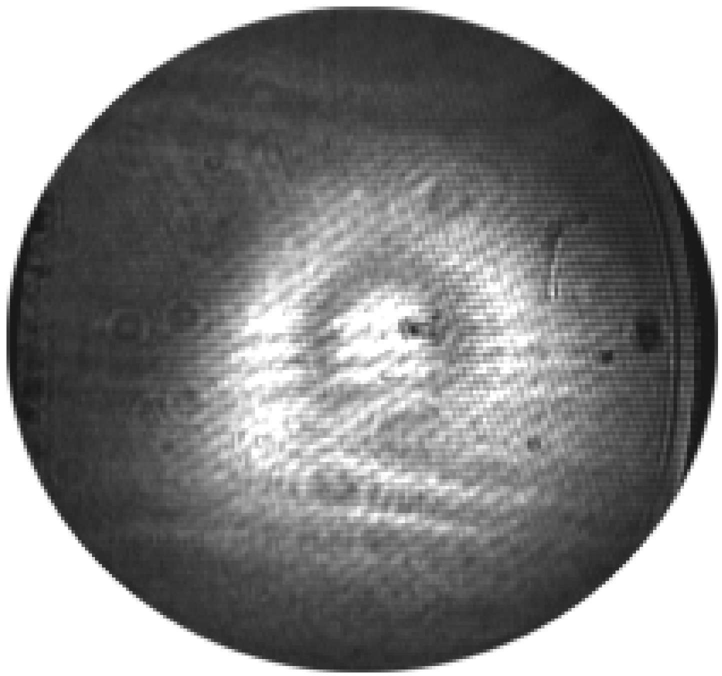
BG20 Filter glass from Schott

Absorption: 0.36% per mm



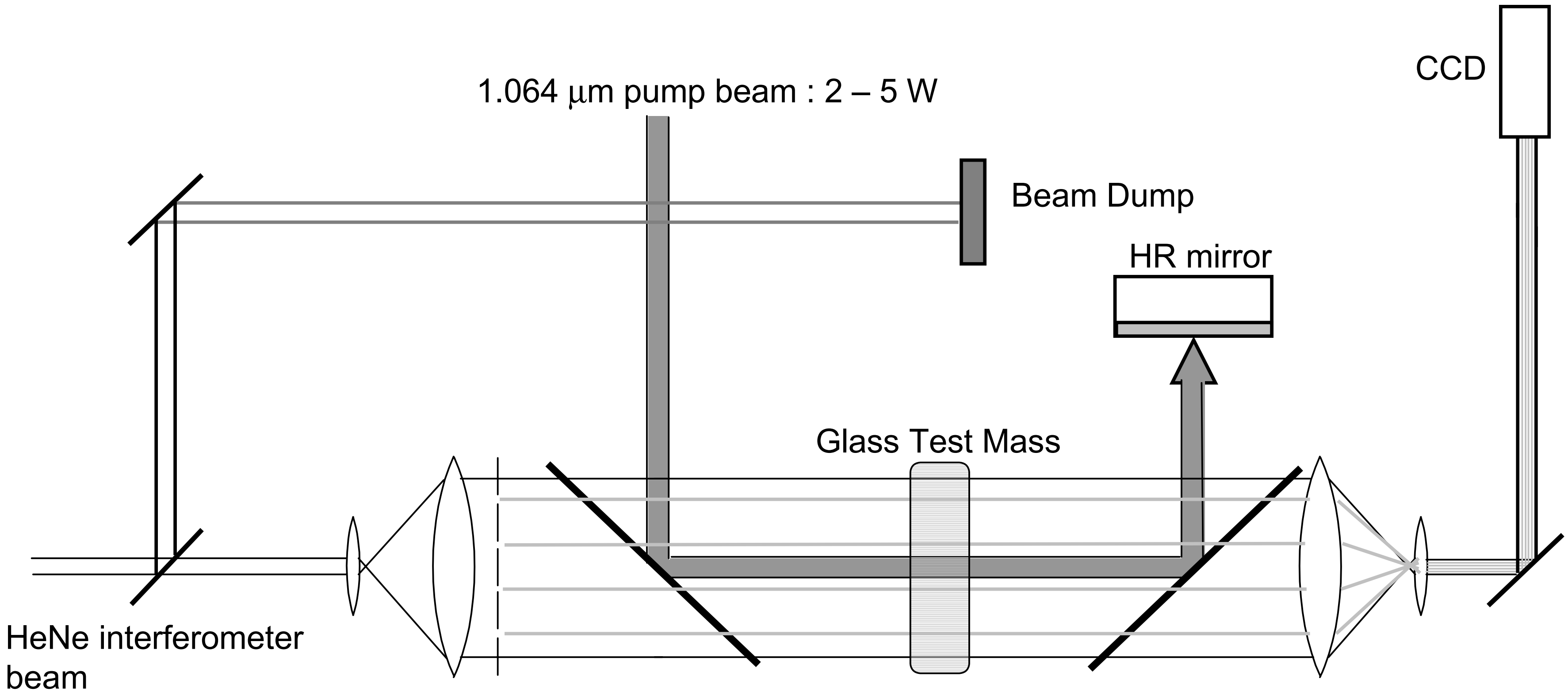
Initial results

Absorbed power ≈ 0.6 W
Spot diameter = 3 mm



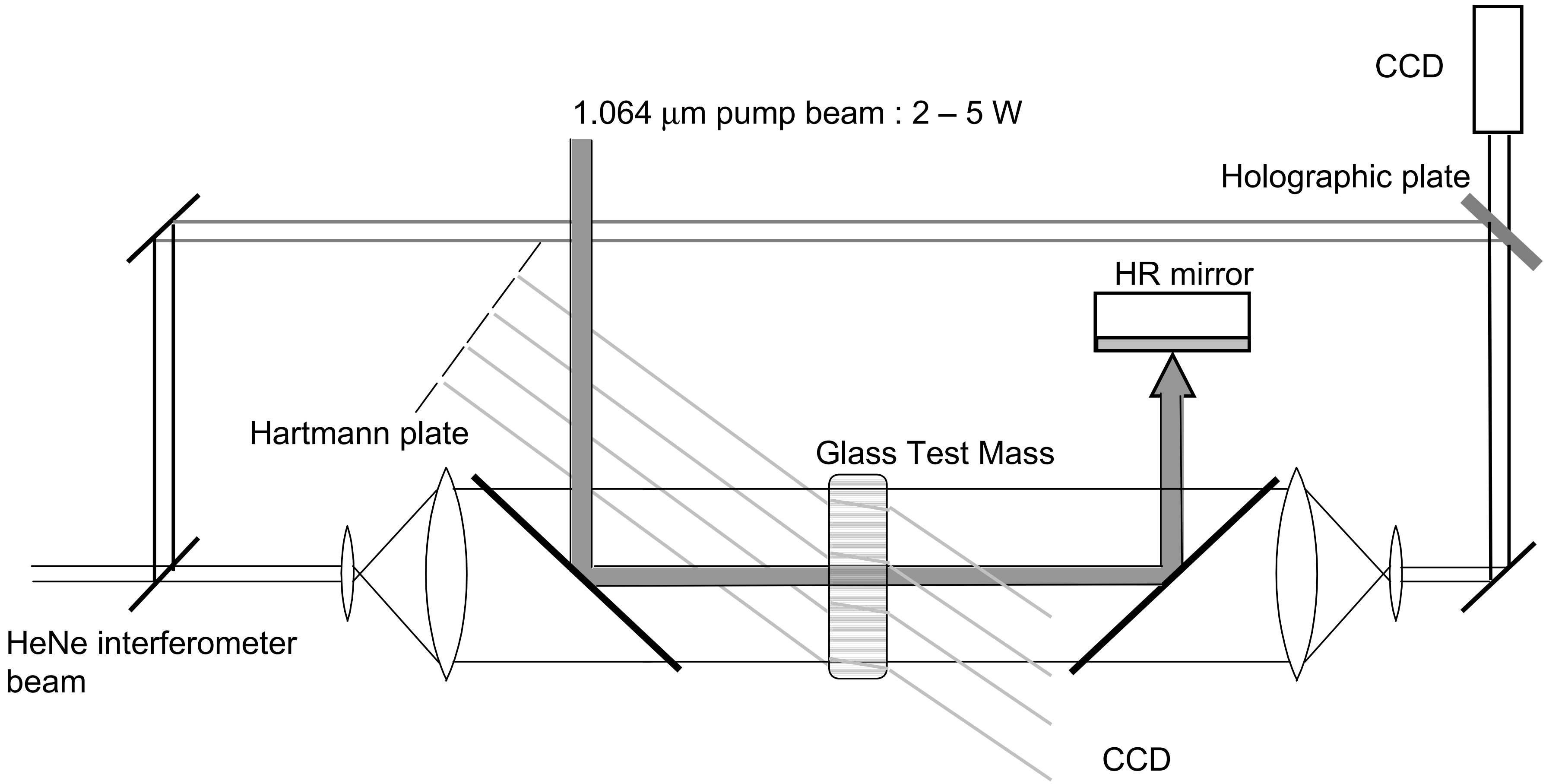
THE UNIVERSITY OF ADELAIDE AUSTRALIA

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



THE UNIVERSITY OF ADELAIDE AUSTRALIA

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



Schedule

Gingin Vacuum envelope	04/03
Isolation, local control, clean environment	06/03
Suspension systems delivered	06/03
80m cavity locked to NPRO	07/03
10W laser delivered to Gingin	**09/03**
80m cavity locked to 10W laser	**10/03**
HPTF Test 1 completed	**12/03**
HPTF Test 2 Installation begin	**01/04**
100W laser installed	**03/04**
HPTF Test 2 completed	**06/04**
Test 3 installation begin	**07/04**
Test 3 completed	**02/05**

Adelaide involvement beyond end of 2003 subject to renewal of grant.

Future Plans
Advanced High Power Optics

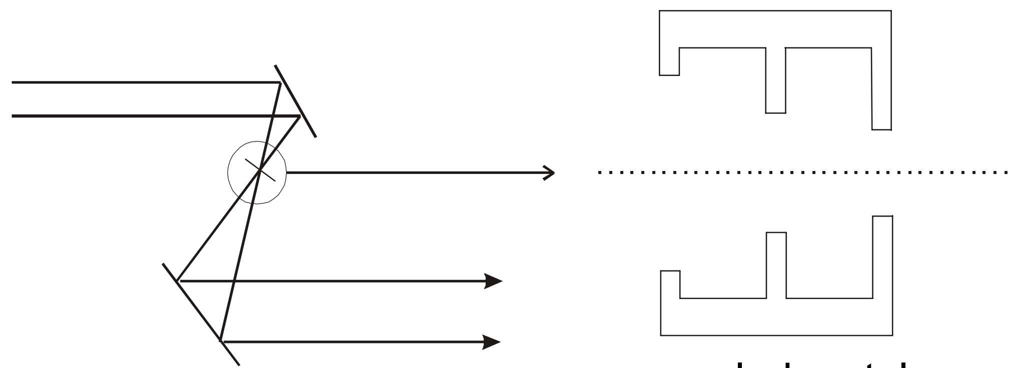
Proposed for 2004 - 2009:

Objectives:

- Continuation of high power laser development
- Continuing participation in Gingin HPTF experiments
- Develop and demonstrate optical components suitable and required for high power interferometry:
  - high power spatial filters
  - high power mode-cleaner
  - all-reflective optical elements (eg. Diffractive beamsplitter)

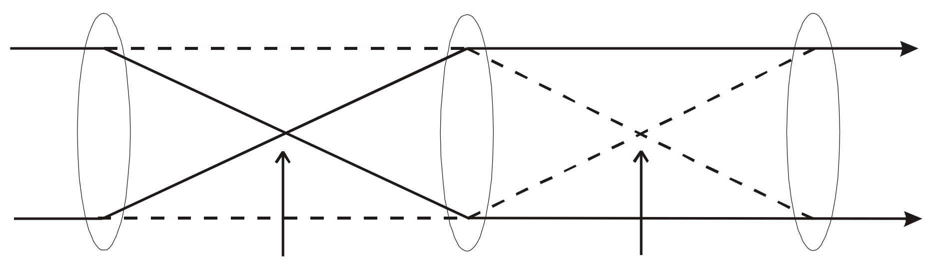
50/100 W Laser Development for HPTF

If 100 W beam is close to TEM_{00} then can use point focus spatial filter:



cooled metal
'pin hole'

If 100 W beam is not good enough then will use line focus spatial filter:



cylindrical mirror | line focus | spherical mirror | line focus | cylindrical mirror

THE UNIVERSITY
OF ADELAIDE
AUSTRALIA