10W Injection-Locked CW Nd:YAG laser

David Hosken, Damien Mudge, Peter Veitch, Jesper Munch

Department of Physics
The University of Adelaide
Adelaide SA 5005
Australia

LSC – LLO March 2004

LIGO-G040069-00-Z

Talk Outline

- Overall motivation
- ACIGA HPTF
- Laser design
- Laser performance
- Conclusions

Overall Motivation

- Gravitational wave interferometers require high power CW lasers that produce a single frequency TEM_{00} mode

- Our strategy: injection-locked chain

- injection-locking of 5W prototype previously demonstrated

Specific project objectives:

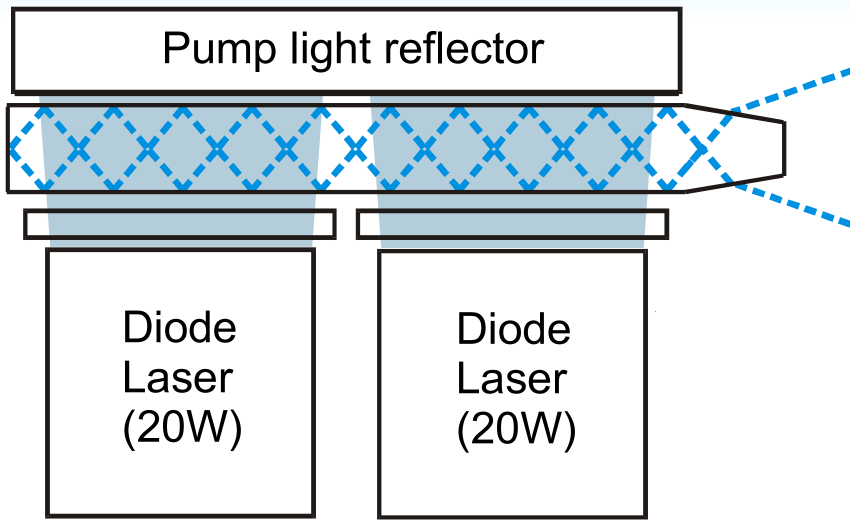
- Field deployable 10W TEM_{00} CW Nd:YAG travelling-wave slave laser
- Characterise injection-lock
- Meet or exceed the frequency and intensity noise requirements of ACIGA / TAMA 300

ACIGA HPTF

- The lasers we are developing will be delivered to the Australian Consortium for Interferometric Gravitational Astronomy (ACIGA) high power test facility (HPTF) at Gingin, Western Australia.
- We will also provide a laser upgrade for the TAMA300 gravitational wave interferometer in Japan.

The Australian International Gravitational Observatory (AIGO)

Gain Medium for 10W Slave Laser

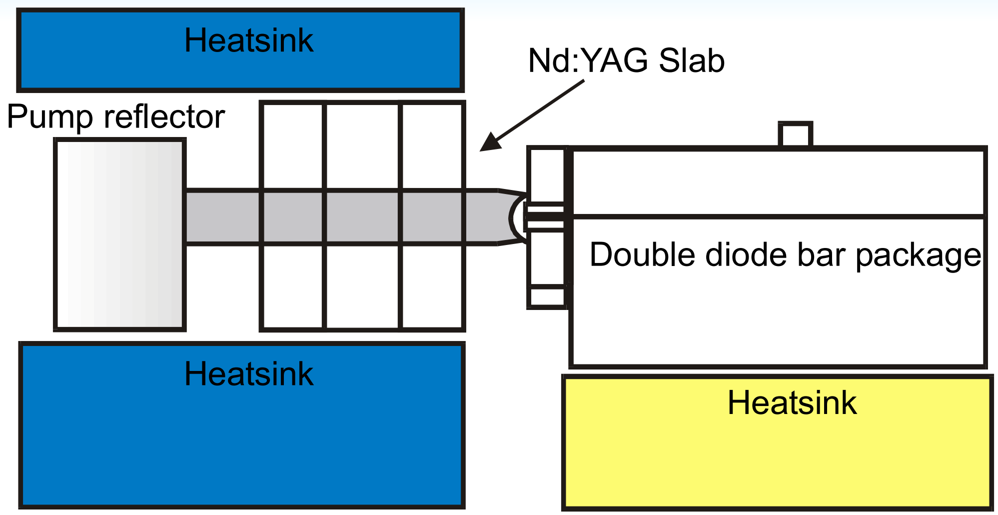


(Diode power derated for increased lifetime)

- Coplanar folded zigzag slab (CPFS) *
- Side pumped using fast-axis collimated diode bars

*J. Richards and A. McInnes, *Opt. Lett.* **20**, (1995), 371.

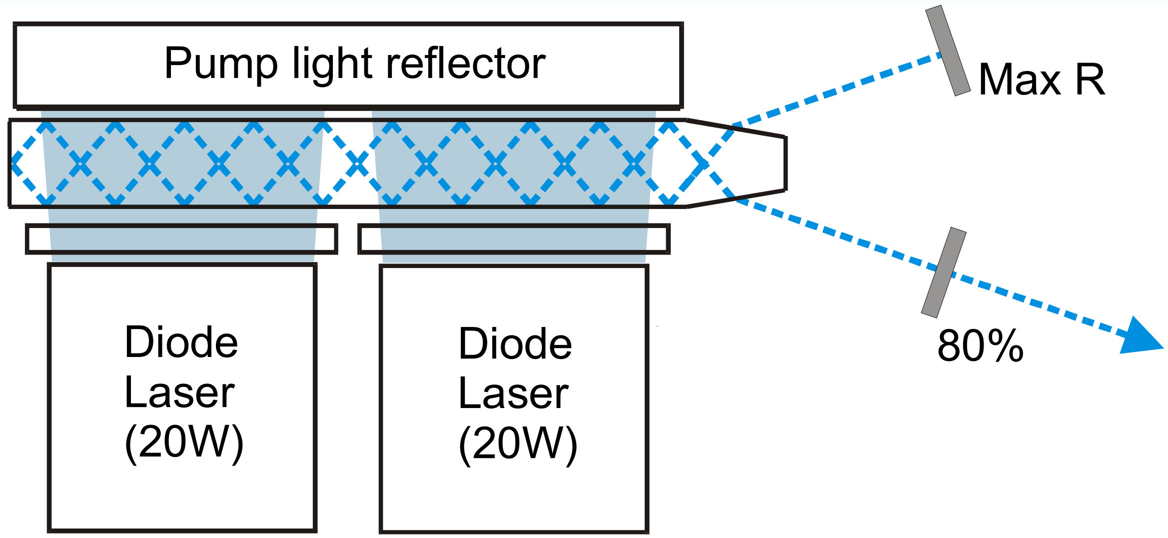
Gain Medium for 10W Slave Laser



- Top and bottom cooled
- Mounted on a single air-cooled base

→ Compact laser with increased portability and reliability

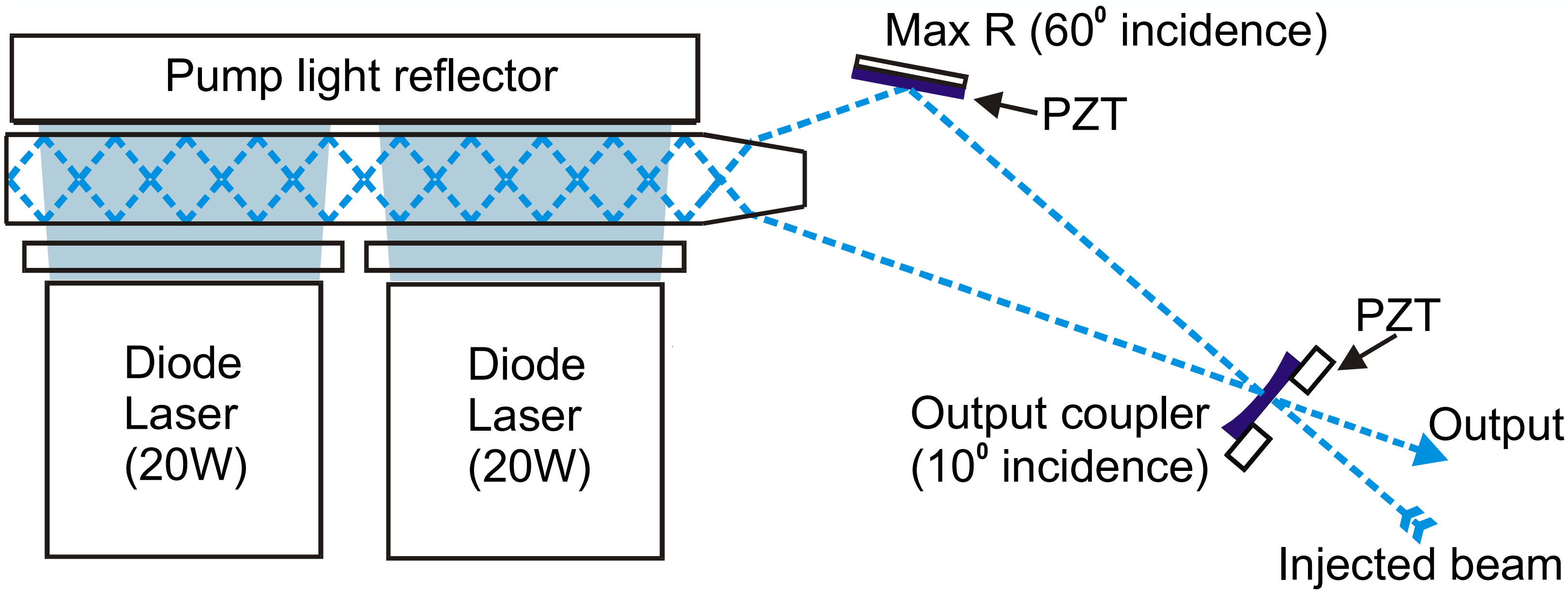
Standing-Wave Results



With ~20mm mirror to slab arm lengths we achieved:

- Multimode power = 15.9W (40W pump power)
- Multimode slope efficiency = 45%

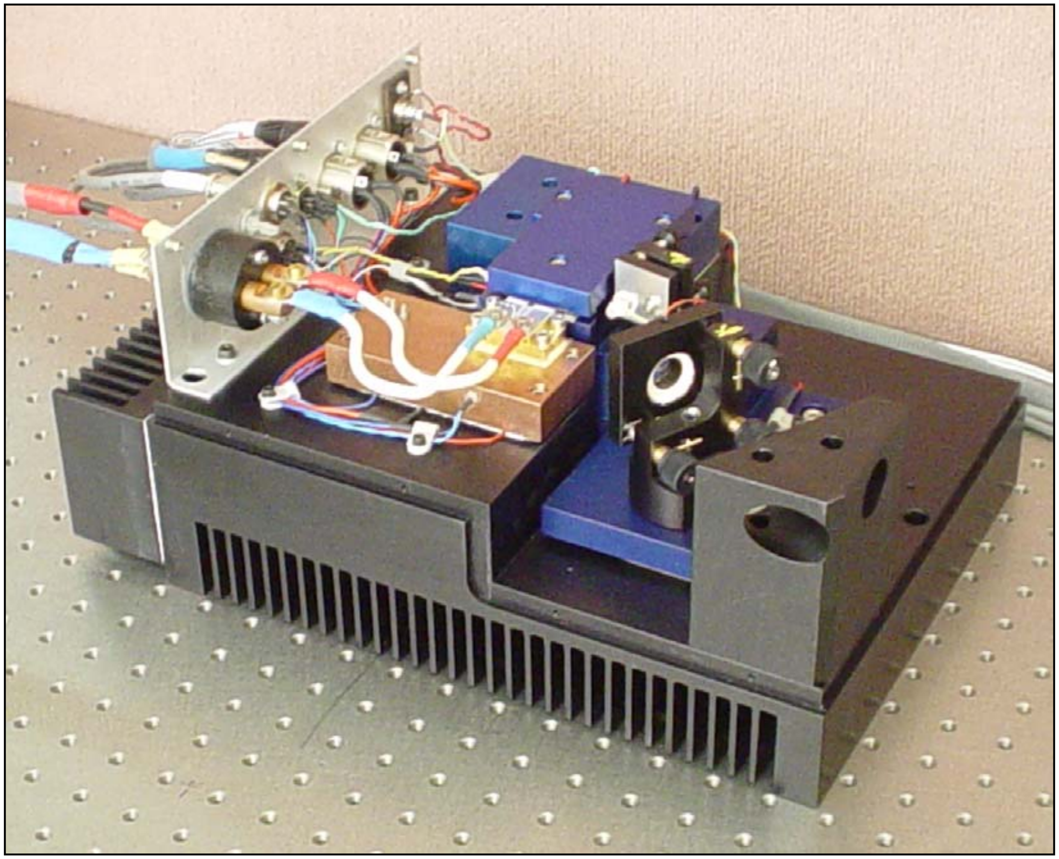
Travelling-Wave Resonator



Injection locking servo control system:

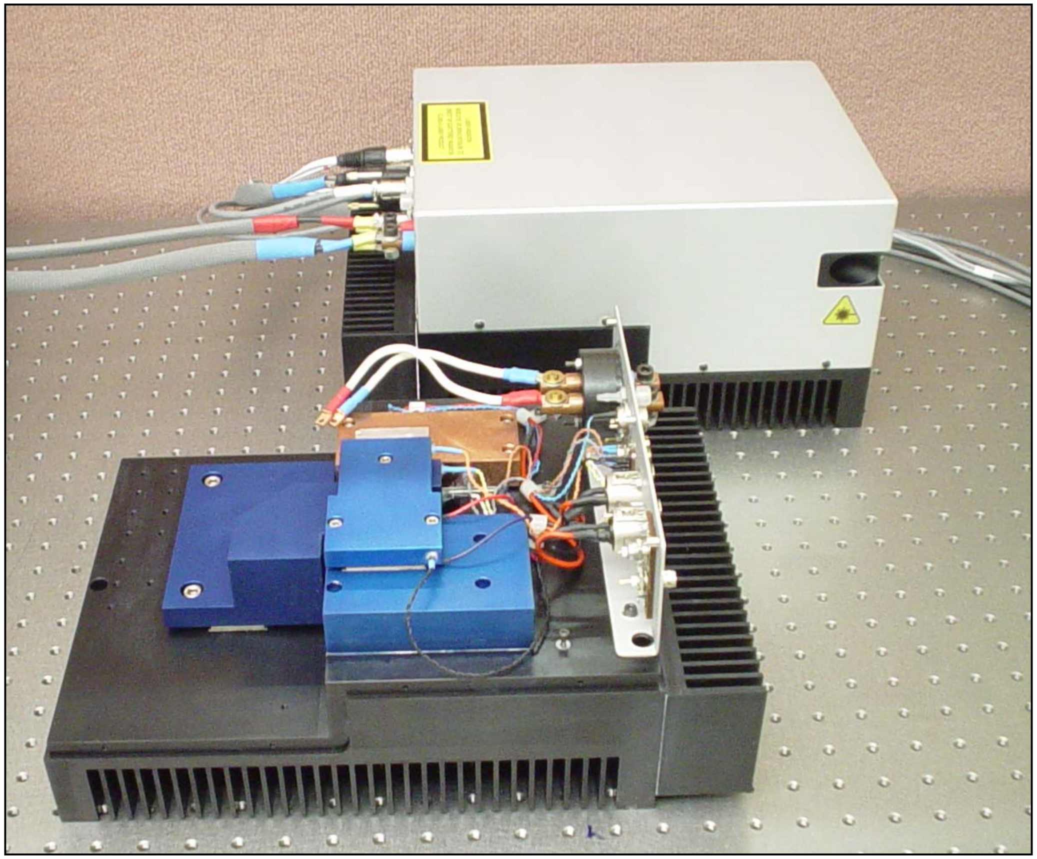
Low bandwidth, high dynamic range PZT plus high bandwidth, low dynamic range PZT together provide sufficient bandwidth and dynamic range.

10W Slave Laser



THE UNIVERSITY OF ADELAIDE AUSTRALIA

ACIGA HPTF and TAMA Lasers



Control and Confinement of Mode

- Astigmatic thermal lensing in the pumped slab: $f_{vertical}$ ~ 6-8cm
  $f_{horizontal}$ ~ 2-3m
- Vertical (cooling) plane
  - mode confinement provided primarily by strong thermal lensing
  - mode control achieved by matching the laser mode to the pumped region
- Horizontal plane
  - mode confinement by residual curvature of the slab sides, very weak thermal lens and mirror curvature
  - higher order mode rejection by apertures formed by Brewster entrance/exit windows

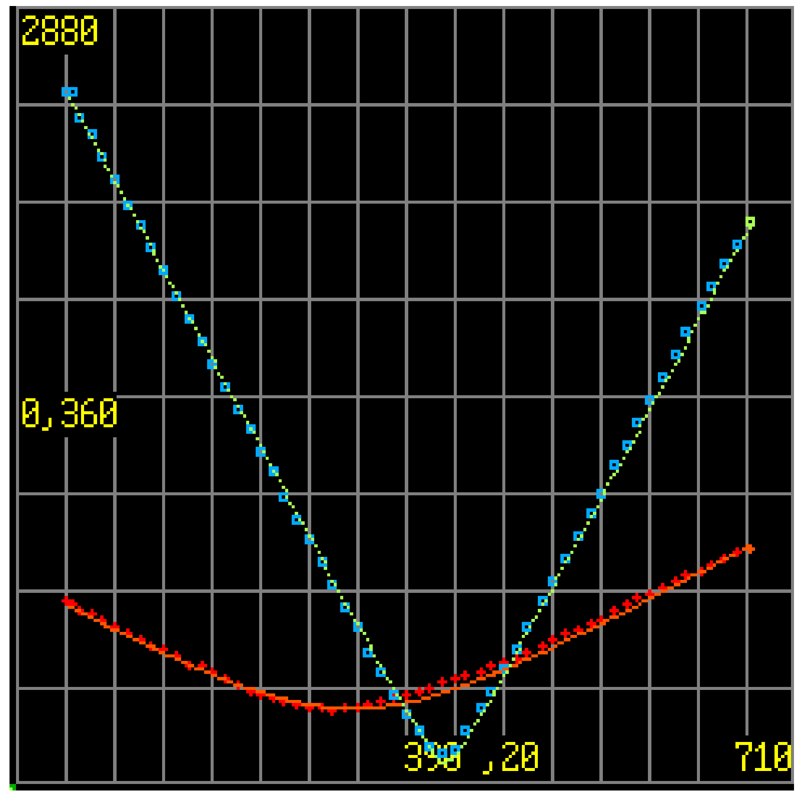
Careful adjustment of cavity length and pump power achieves an excellent fundamental mode, in both horizontal and vertical planes.

Travelling-Wave Results

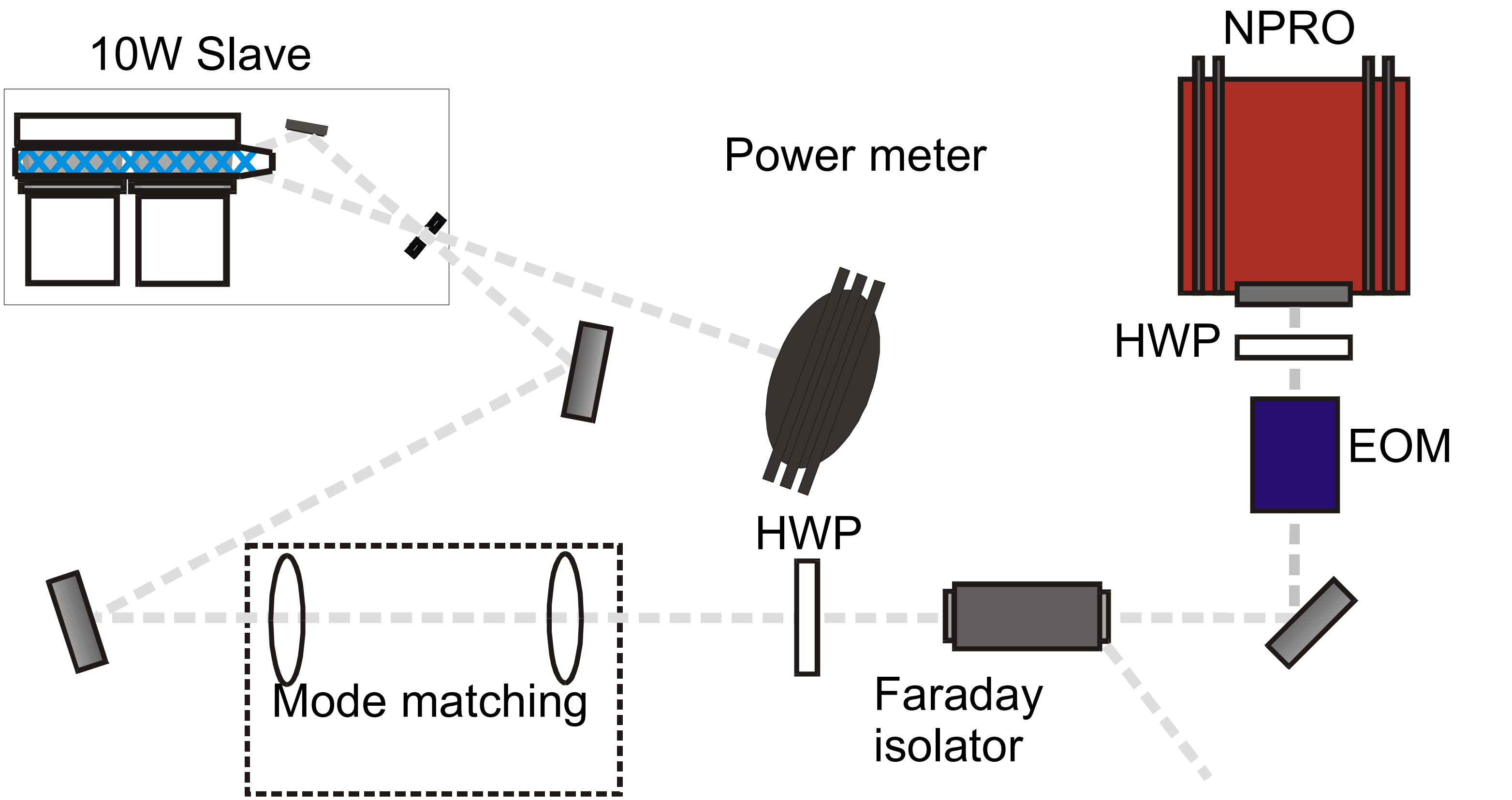
Using 90% reflective, 5.00m concave output coupler

- **$M^2_{horizontal}$ < 1.1**
- **$M^2_{vertical}$ < 1.1**
- **Output power = 9.2 W (31W pump power)**

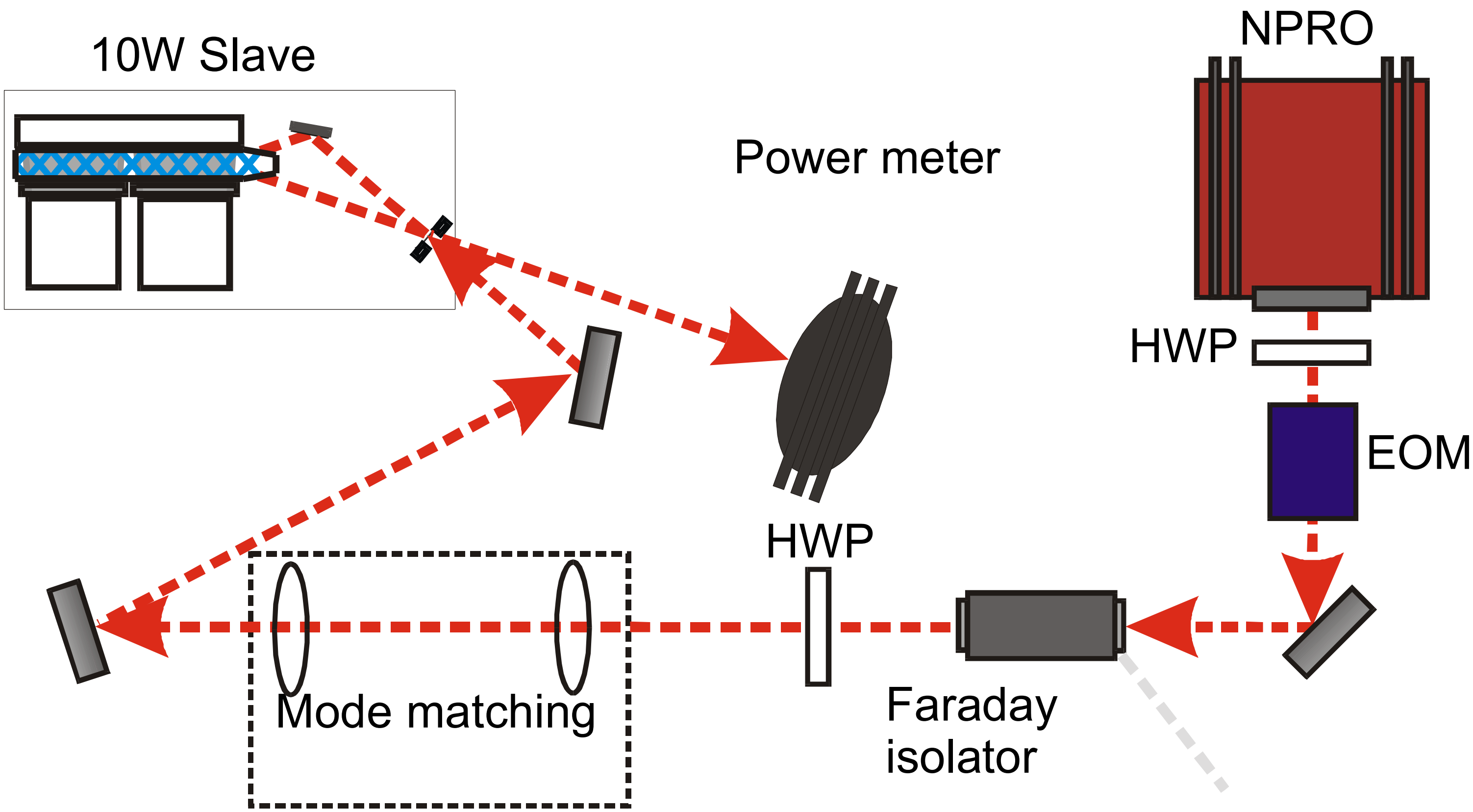
Measured using Spiricon M^2 Beam Analyser



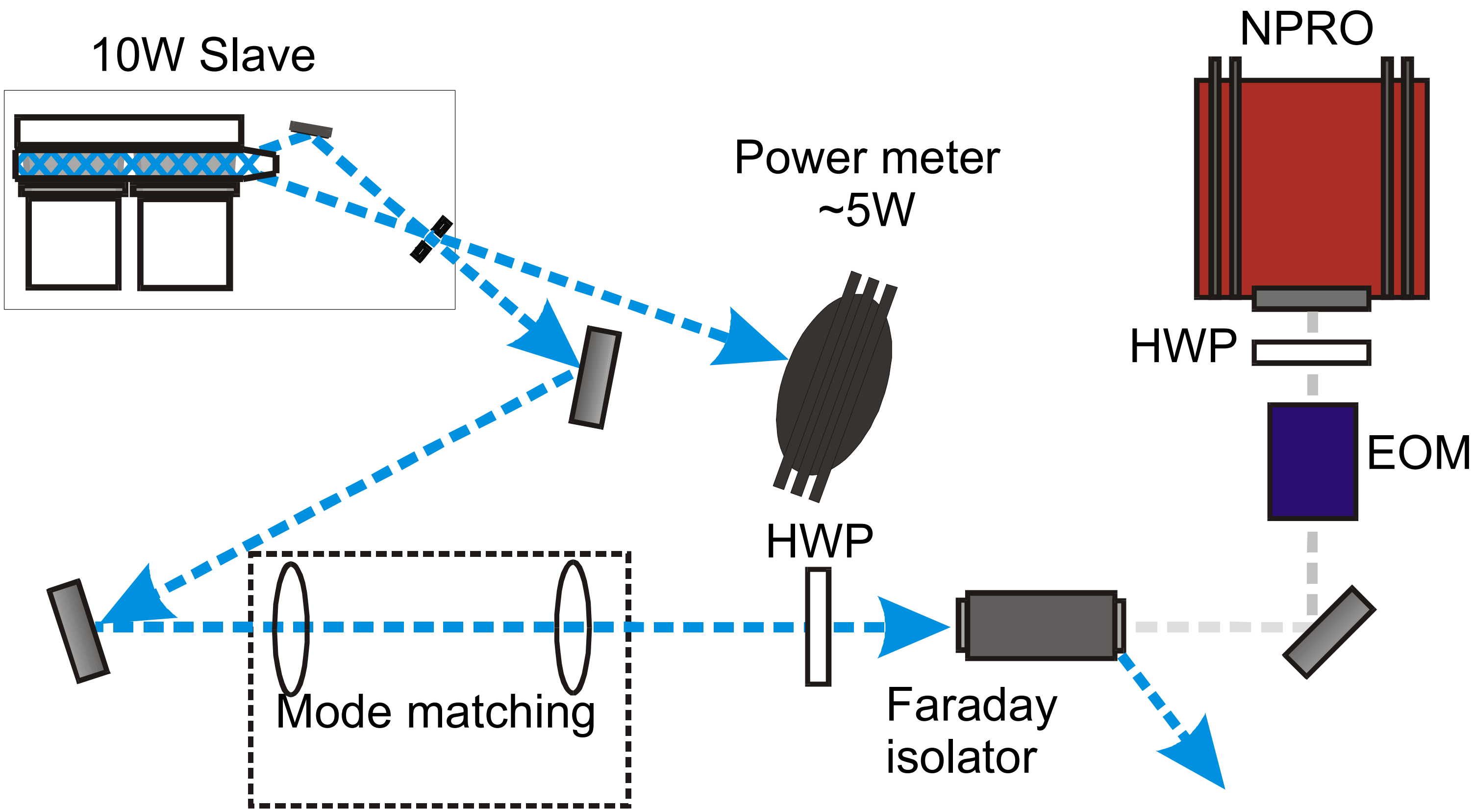
Injection-Locking Setup



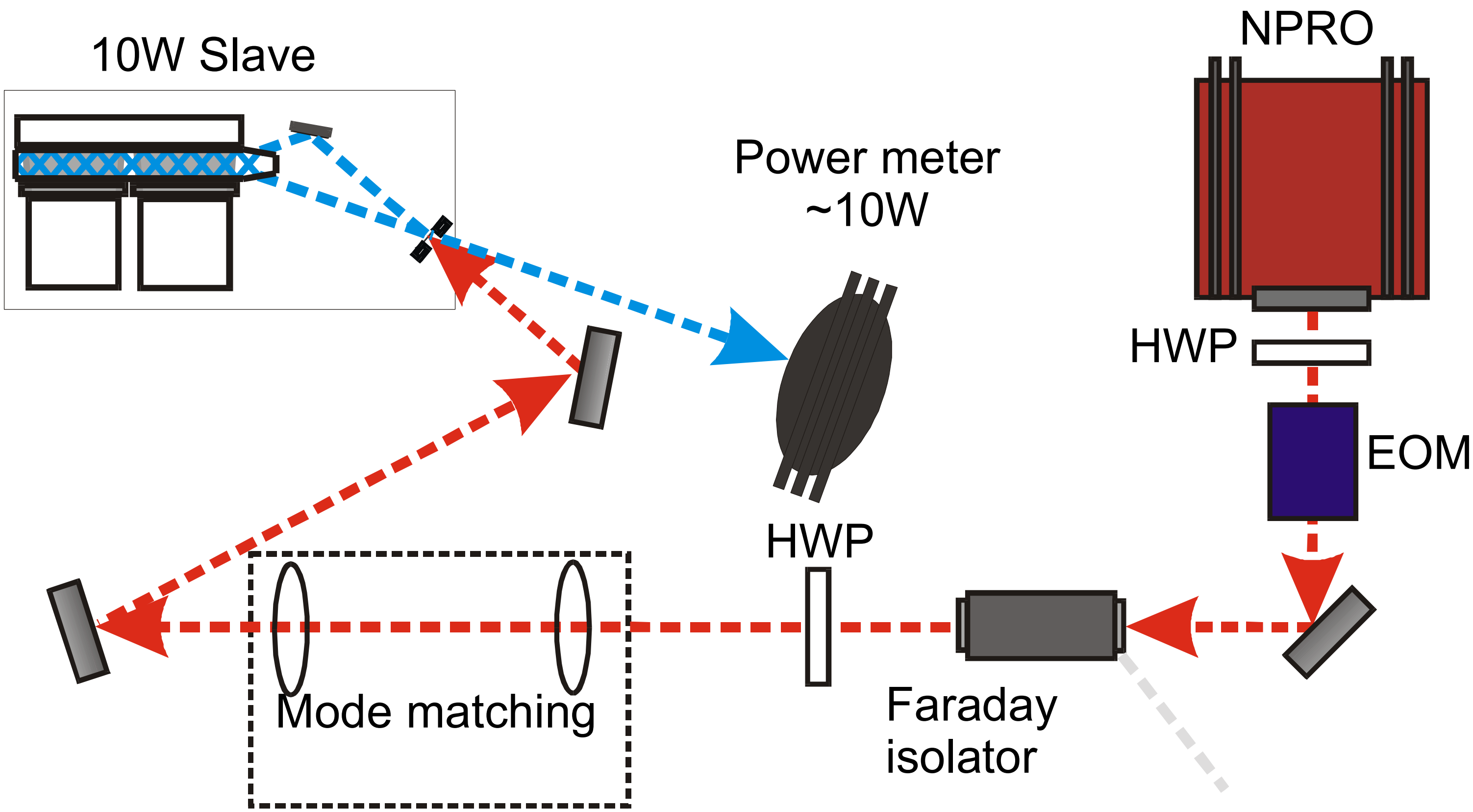
Injection-Locking Setup



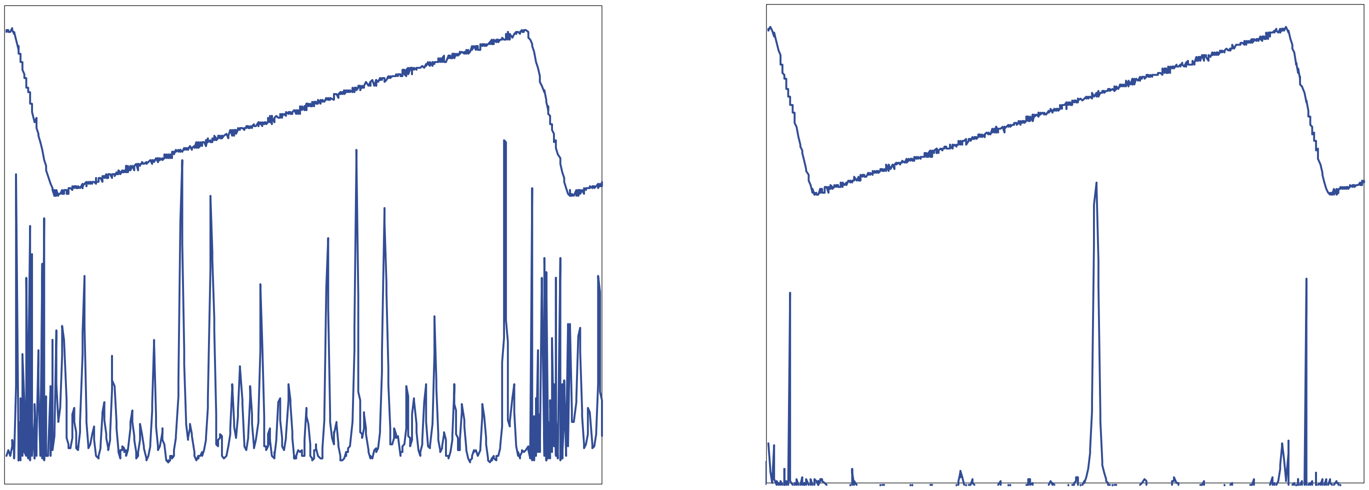
Injection-Locking Setup



Injection-Locking Setup



Passive injection-locking



Multi- longitudinal mode operation of free-running slave laser (left), and single frequency operation (right) when locked using a stable master laser.

- Currently developing and testing a PDH servo control circuit, and have achieved prolonged suppression of reverse-wave with closed servo loop

THE UNIVERSITY OF ADELAIDE AUSTRALIA

(Traces measured using a scanning Fabry-Perot cavity (10GHz FSR))

Conclusions

Progress to date:
- Efficient robust compact design
- Robust thermal control system
- $M^2_{x,y} < 1.1$ with 9.2W output in travelling-wave
- Short term injection-locking achieved

Future plans:
- Increase output power to over 10W
- Long-term injection-locking
- Characterisation of noise

Delivery of injection-locked laser to AIGO in May 2004.