Laser Developement for Advanced LIGO

Benno Willke

NSF review

Caltech, Jan 2001

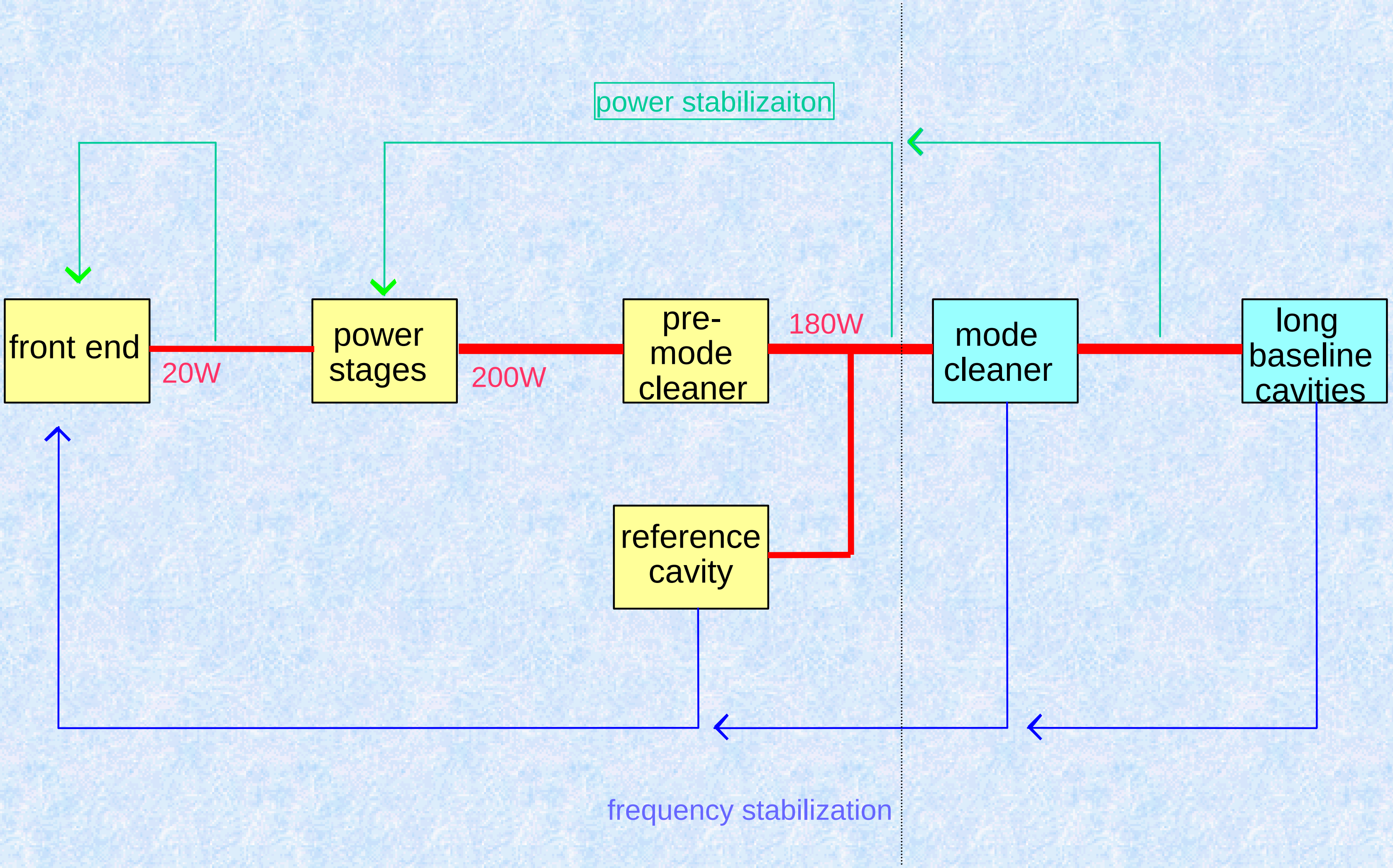
LIGOII PSL – requirements

- 180W in gausian TEM_{00} mode
- less than 1W in non- TEM_{00} modes

Fourier Frequency (Hz)	Power Noise Spectral Density ($1/Hz^{1/2}$)
10	10^{-6}
100	10^{-7}
1k	10^{-7}
10k	10^{-7}
25MHz	technical noise <10% shot noise of 1W

Fourier Frequency (Hz)	Frequency Noise Spectral Density ($Hz/Hz^{1/2}$)
10	10
100	1
1k	10^{-1}
10k	10^{-2}

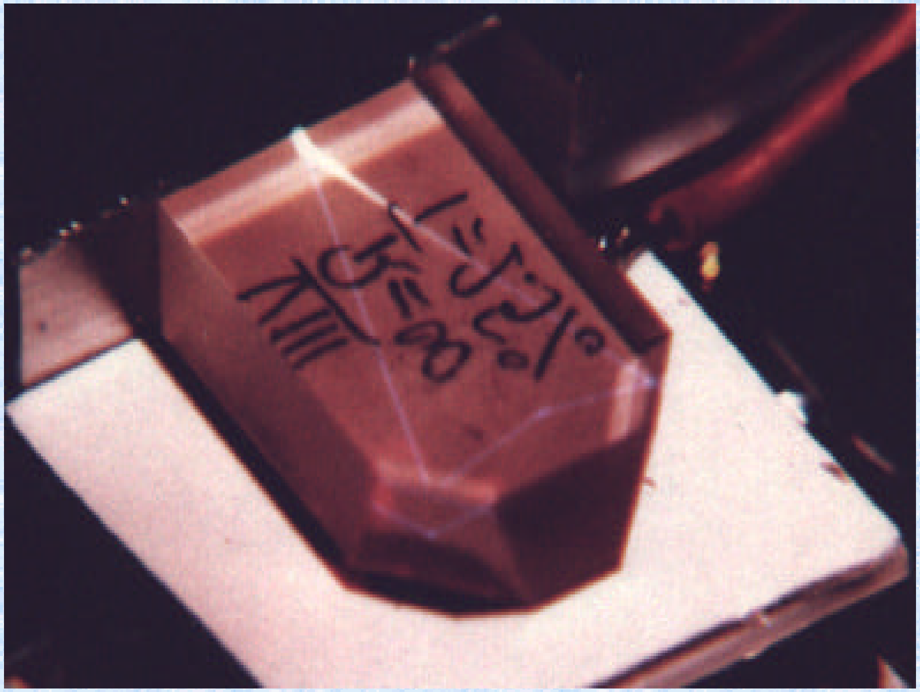
LIGOII PSL – subsystem layout



LIGOII PSL – project stages

- develop concepts
- design and build laboratory version
- design and build final version
- PSL fabrication
- PSL installation

Nd:YAG Master-Laser

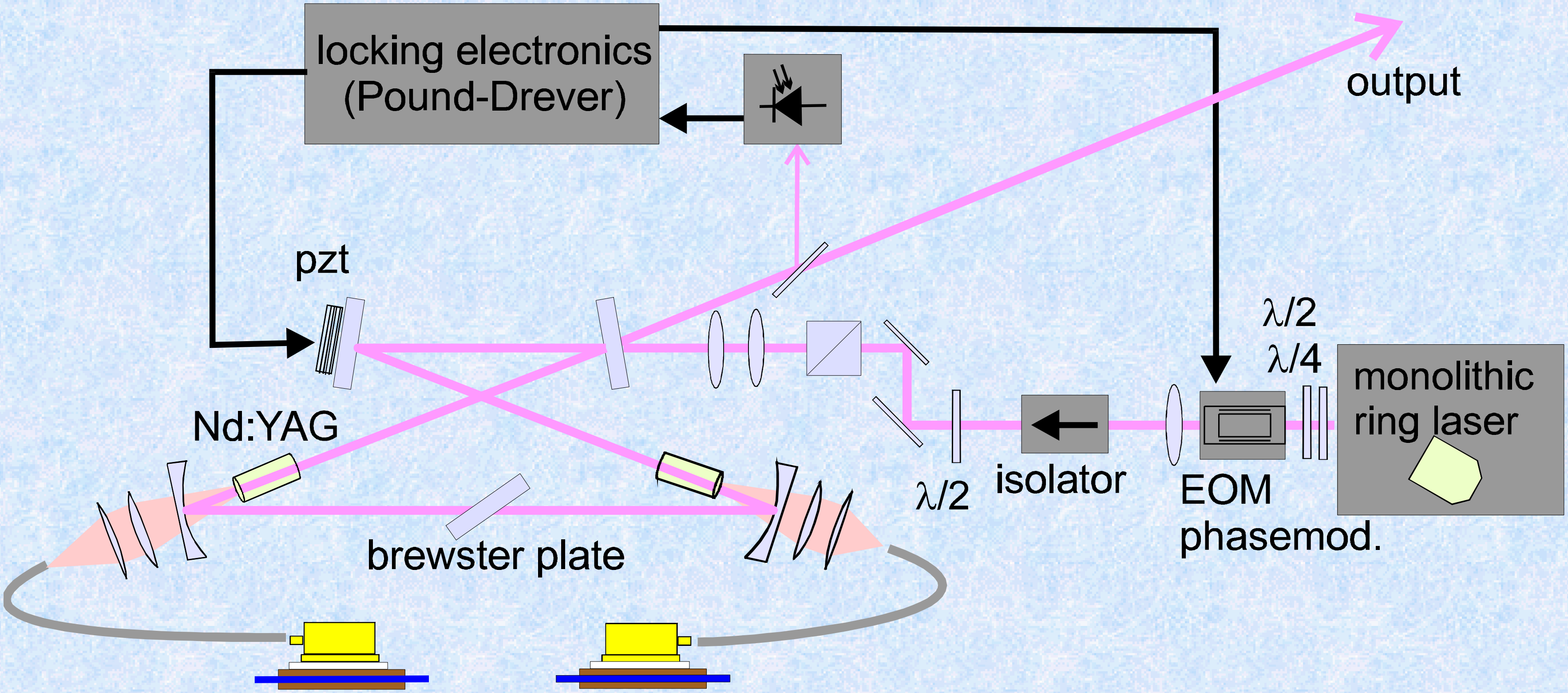


NPRO (non-planar ring oscillator) by Innolight*

- output power: 800mW
- frequency noise:
  [10kHz/f] Hz/sqrt(Hz)
- power noise:
  10^{-6} /sqrt(Hz)

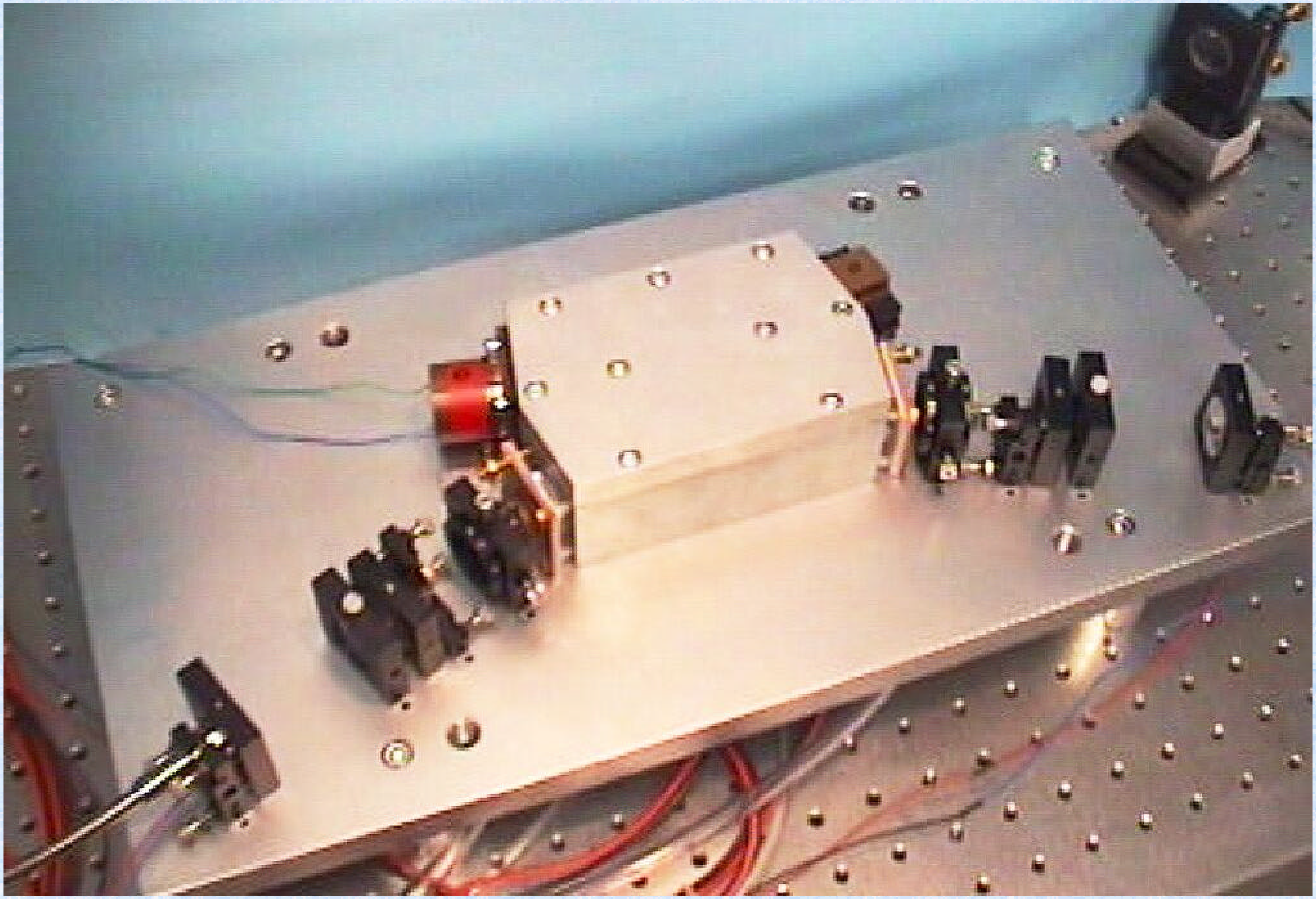
* US dristibution: Resonant optics Corp., San Martin CA

Laser for GEO600: Injection Locked Ring Laser



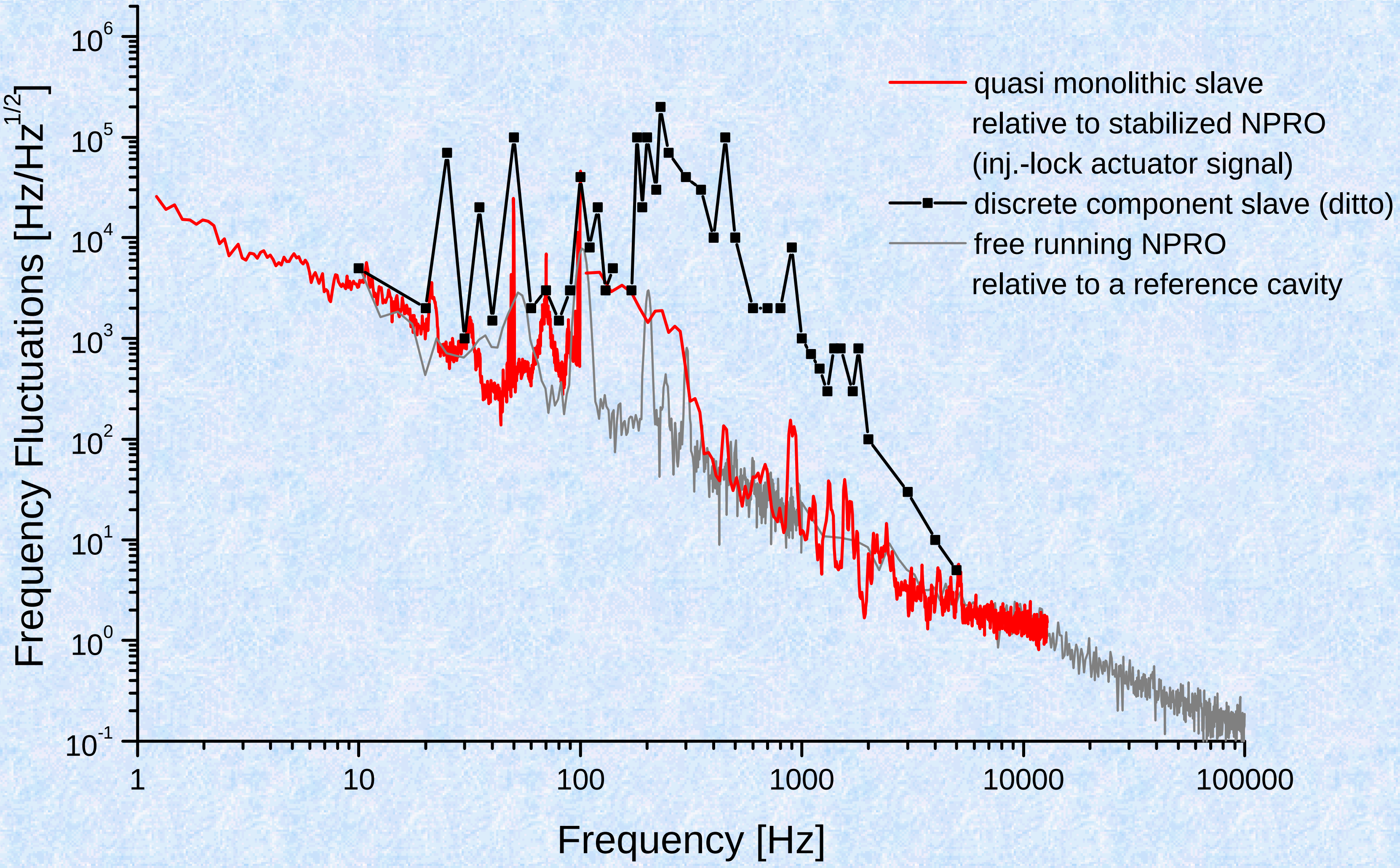
temperatur stabilized fibre coupled laser diodes

GEO 600 Slave Laser

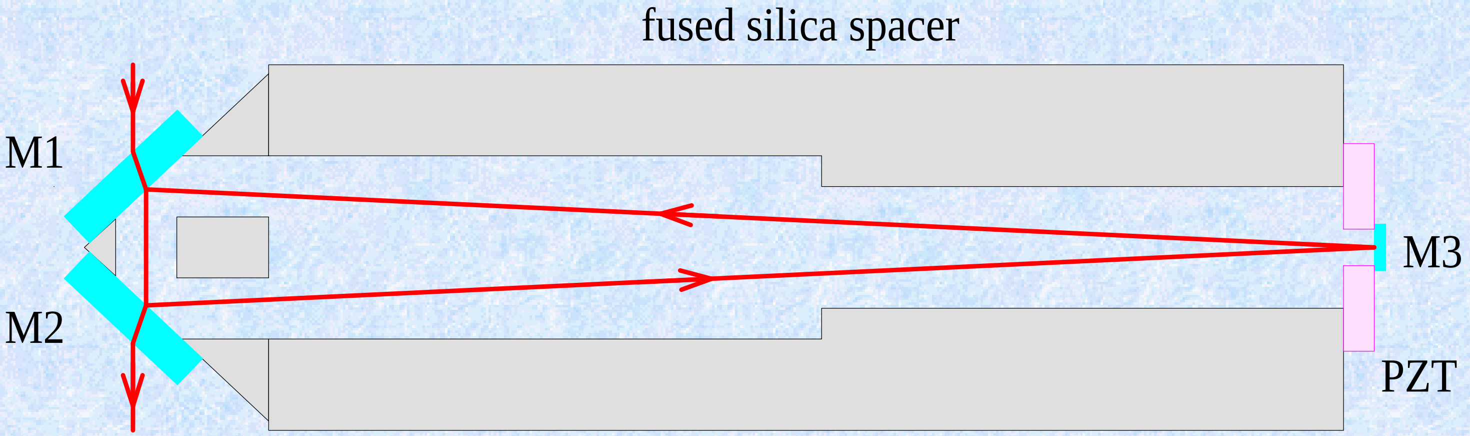


GEO 600 Slave Laser Prototype II

Frequency Stability



pre-modecleaner



- 713 MHz free spectral range
- linewidth: 162 kHz in s-pol. , 3.2 MHz in p-pol.
- circulating power 0.135MW/cm^2 (for p-pol.), 2.64MW/cm^2 (for s-pol.)
- linewidth required to filter RIN(@25MHz) of 180W laser: 3.7MHz

develop concepts

- increase power of front-end

Power Scaling of End Pumped Nd:YAG

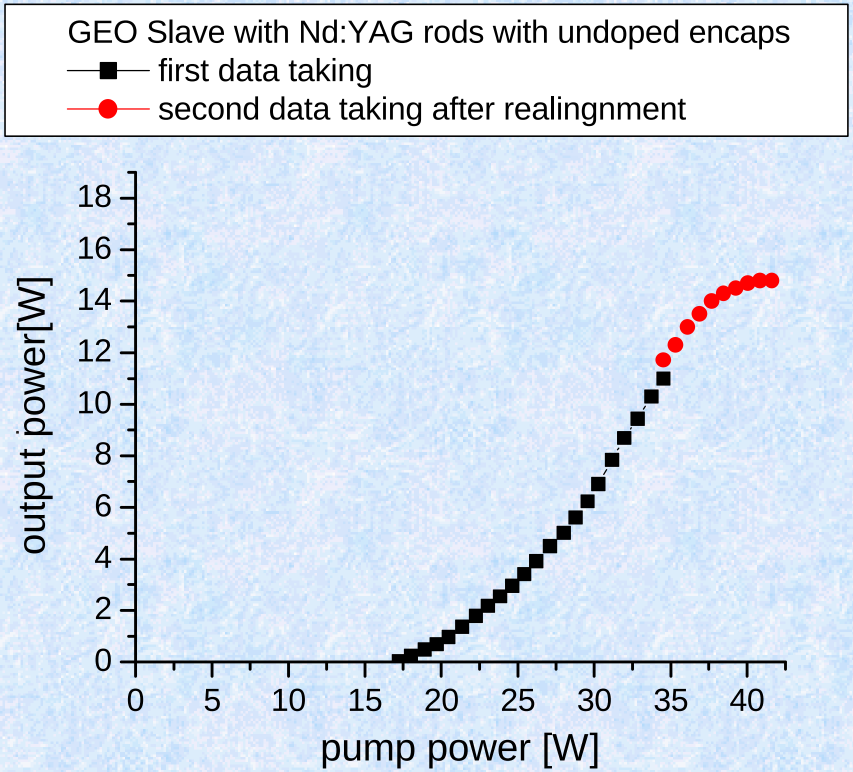
A
standard rods
good coating
13.5 W @ 2x17 W pump power.

B
standard rods
bad coating
11.5 W @ 2x17 W pump power

C
rods with undoped endcaps
same coating as in B
15 W @ 2x 20 W pump power

D
expectations for
rods with undoped endcaps
good coating
probably 17 W at 2 x 20 W pump

E
redesign of cavity and pumpoptics
might yield 20 W



Power Scaling of End Pumped Nd:YVO_4

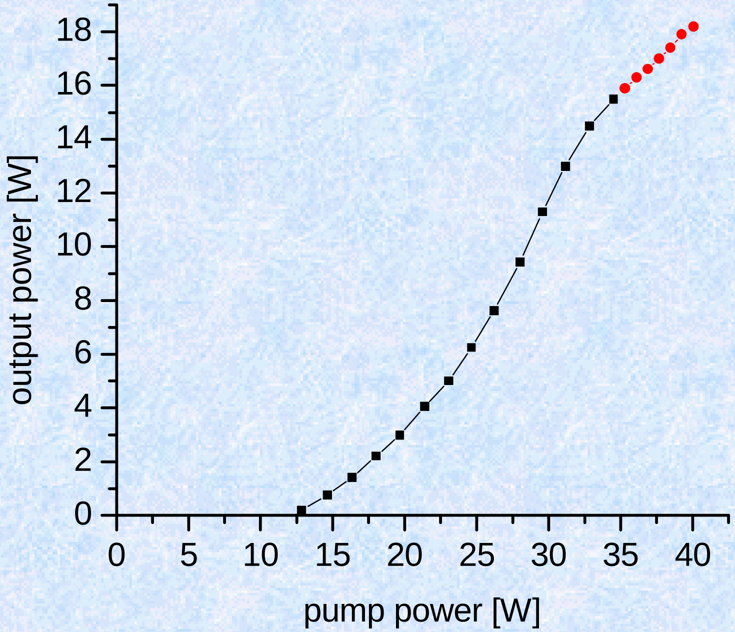
Advantages of Nd:YVO_4 1)

- amplifies 1064 nm emission of Nd:YAG
 (basic requirement)
- birerefingence $n_a = 1.96$ / $n_c = 2.17$
→ no depolarization
- emission $s_{||} = 25 \mathrm{x} 10^{-19}$ cm^{-2}
$s_{+} = 7 \mathrm{x} 10^{-19}$ cm^{-2}
→ polarized emission
- large product of $s_{||} t_{sp}$ ($t_{sp} \cong 90$ µs)
→ loss insensitive high gain lasers
- 8 nm broad absorption @ 808 nm
→ low requirements on pump diodes

Disadvantage of Nd:YVO_4 1)

- low pump intensity damage threshold
58 W / mm^2 @ 0.5 % doping
29 W / mm^2 @ 1.0 % doping
increased by 50 % by undoped endcaps

GEO slave with standard Nd:YVO_4 "rods"
brewsterplates removed

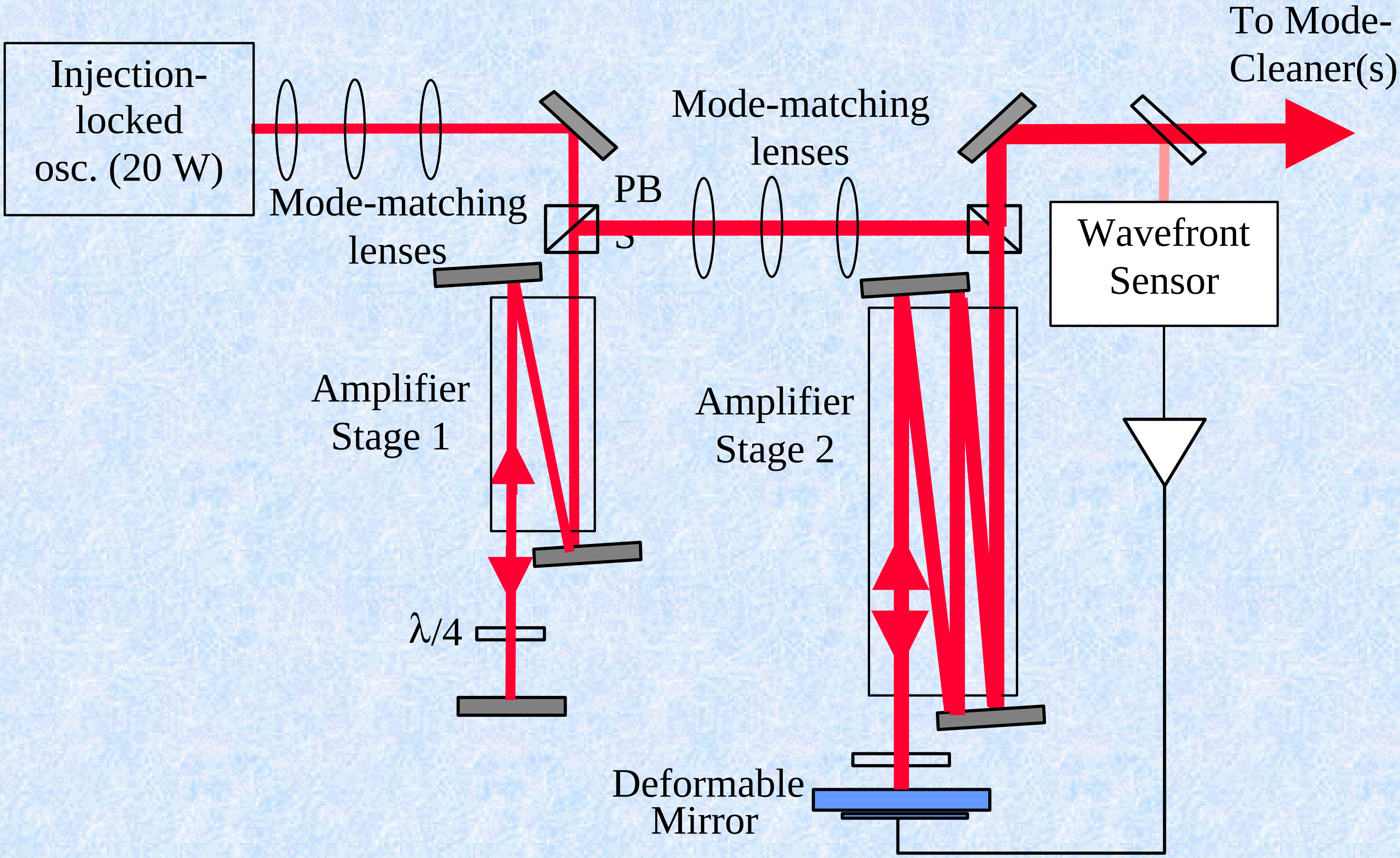


1) Data from Y.-F. Chen, IEEE J. Q. E. **35**(2), 234 (1999) / Tsunekane et. al. Elt. Lett. 32(1), 41 (1996) / VLOC, Casix, Castech web pages

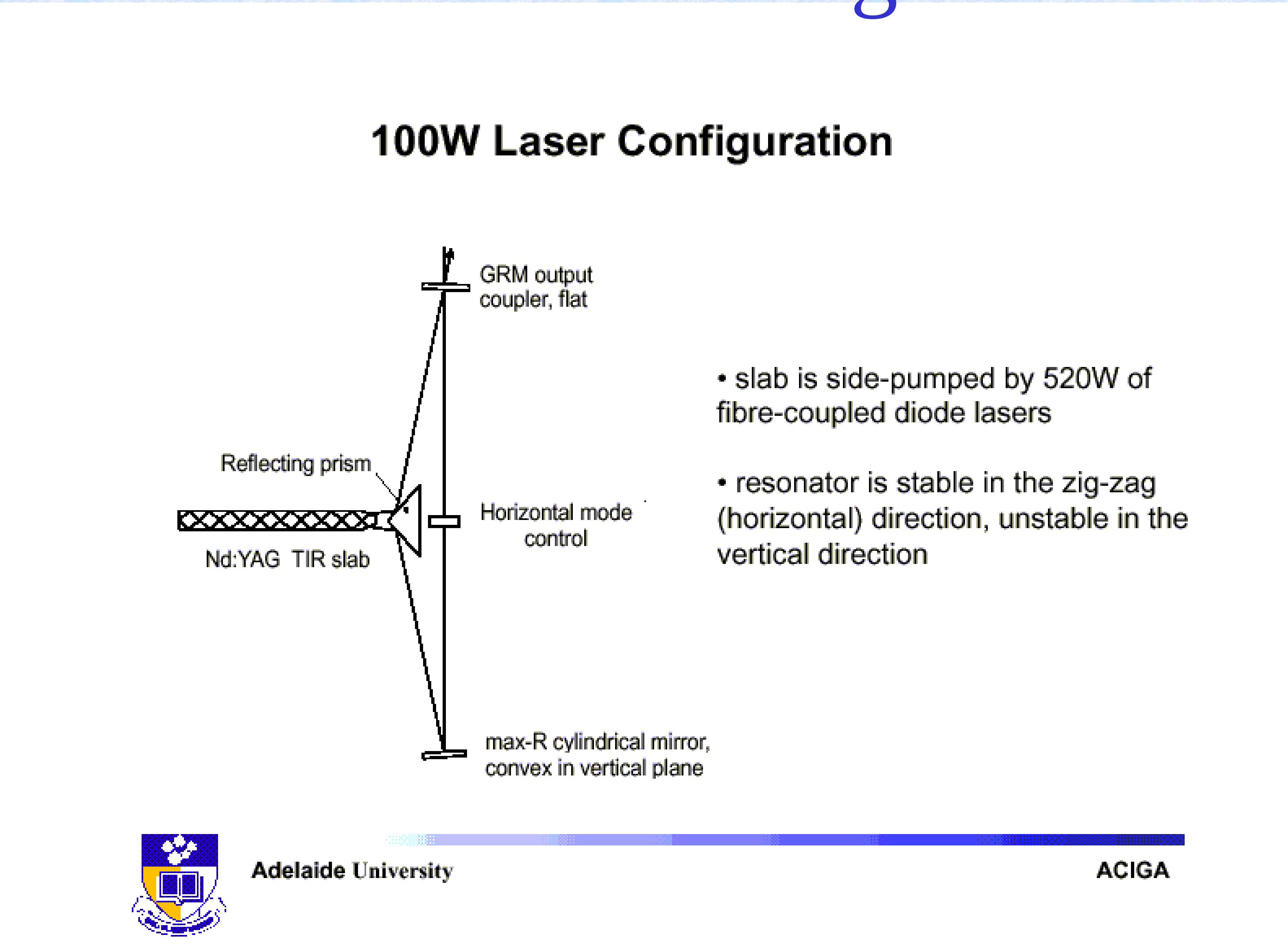
develop concepts

- increase power of front-end
- evaluate high-power-stage concepts
  - MOPA slab (Stanford)
  - stable-unstable slab oscillator (Adelaide)
  - rod systems (Hannover)

Stanford MOPA design



Adelaide 100W configuration



100W Laser Configuration

- slab is side-pumped by 520W of fibre-coupled diode lasers
- resonator is stable in the zig-zag (horizontal) direction, unstable in the vertical direction

Adelaide University

ACIGA

develop concepts

- increase power of front-end
- evaluate high-power-stage concepts
  - MOPA slab (Stanford)
  - stable-unstable slab oscillator (Adelaide)
  - rod systems (Hannover)
- test current lock frequency stabilization
- front-end power stabilization

LIGOII Laser – project plan

• concept phase (100W)	Jan01 - Apr02
• lab-version phase (200W)	Apr02 – Feb04
• longterm test (Hannover/LASTI)	Feb04 – Feb 05
• final version phase	Feb04 – Jul05
• installation PSL1	Jul05 – Feb06
• fabr. & inst. PSL2&3	Feb06 –Oct06

LIGOII laser-team

- 4 FTE Laser Zentrum Hannover
  - Fallnich, Zawischa, Martina
- 1 FTE Stanford - Rutherford
- 1 FTE Adelaide - Veitch
- 3 FTE University Hannover/Max-Planck-Group
  - Willke, Kirchner, Weidner
- 1 FTE Glasgow
  - Ward, Robertson
- 1 FTE LIGO
  - King, Abbott
- workshop support Hannover / CDS

critical steps in 2001

- staff-up at LZH
- transfer knowledge about LIGO standards to Hannover
  - A. Weidner will spend time at Caltech
  - VME based frequency control servo will be installed in Hannover
- evaluate high-power-stage options
  - work at Stanford and Adelaide
  - rod program in Hannover
  - Hannover people will visit Adelaide and Stanford
  - LSC will come up with test program