Laser Developement for Advanced LIGO

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LSC meeting

LIGO-Livingston Site, Mar 2001

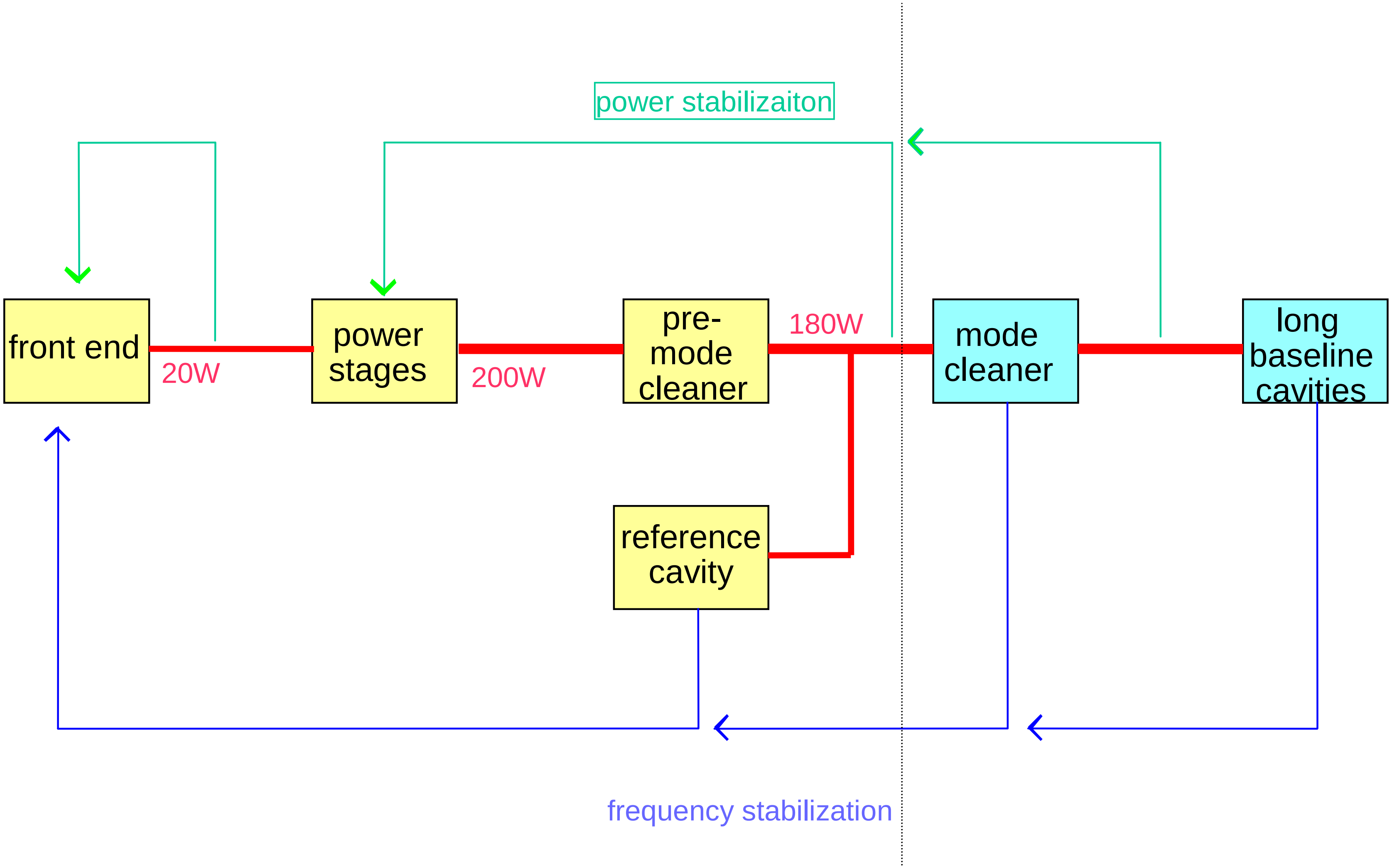
LIGOII PSL – requirements

- 180W in gausian TEM_{00} mode
- less than 10W 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



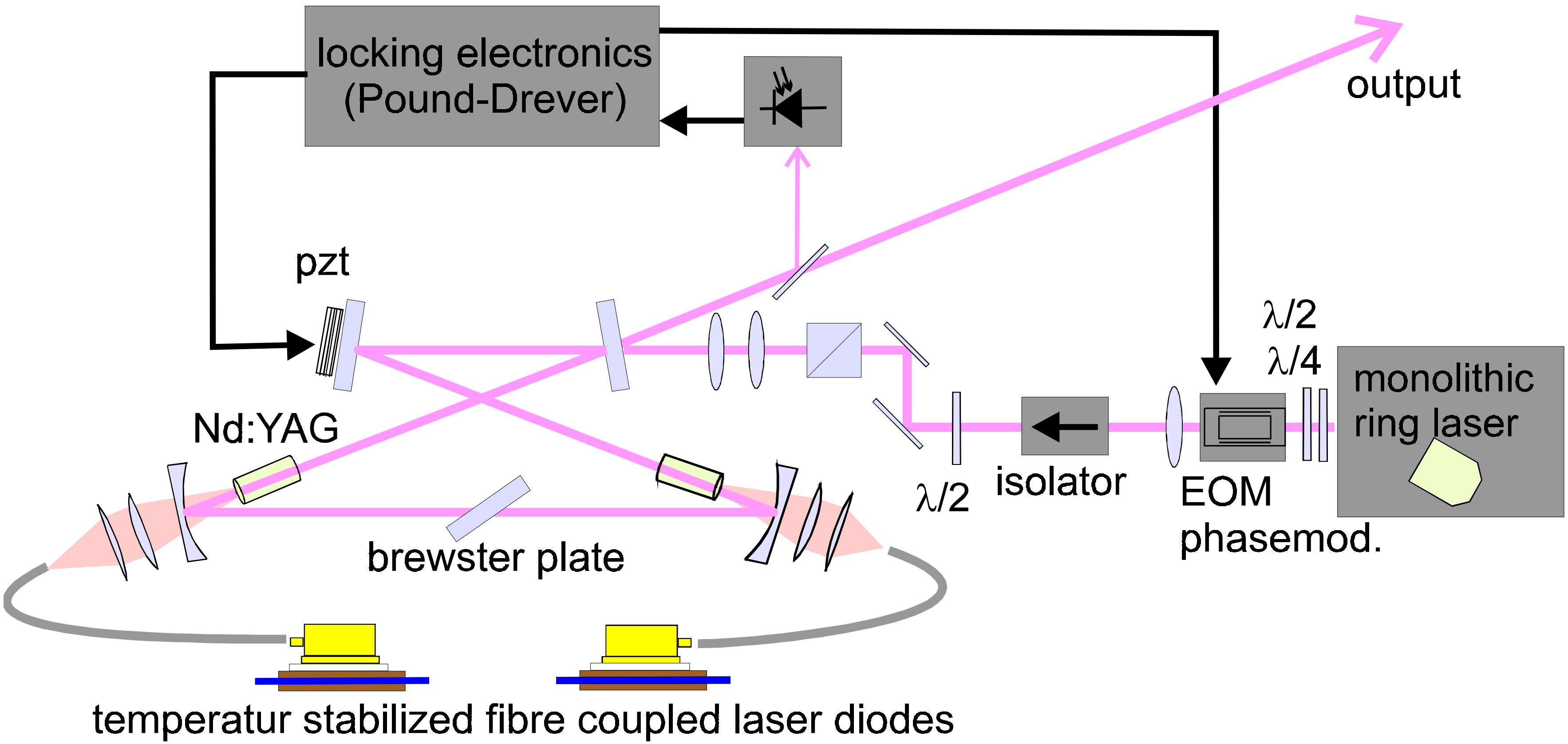
LIGOII PSL – project stages

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

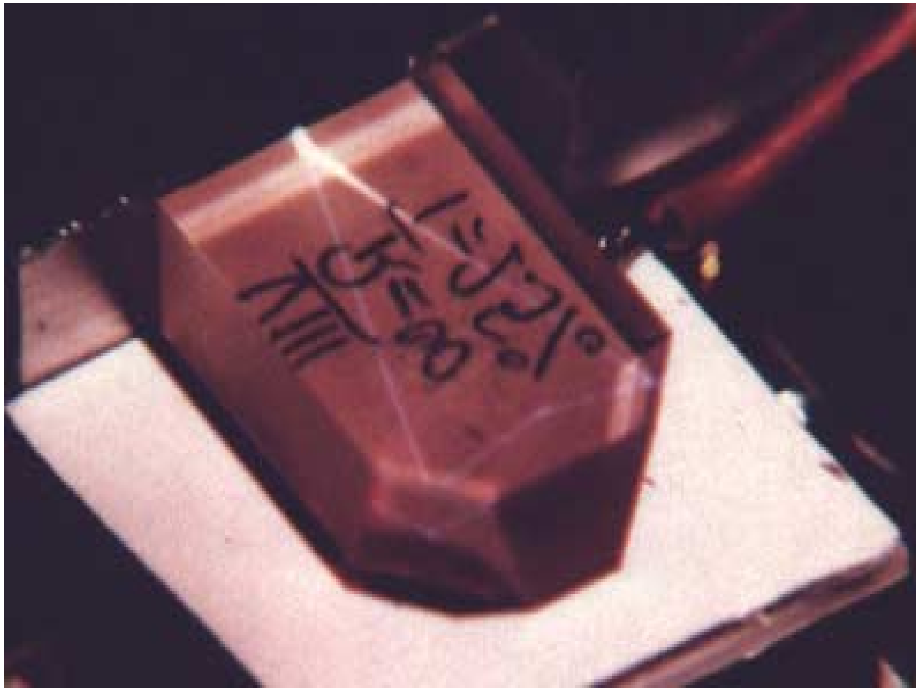
develop concepts

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

Laser for GEO600: Injection Locked Ring Laser



Nd:YAG Master-Laser

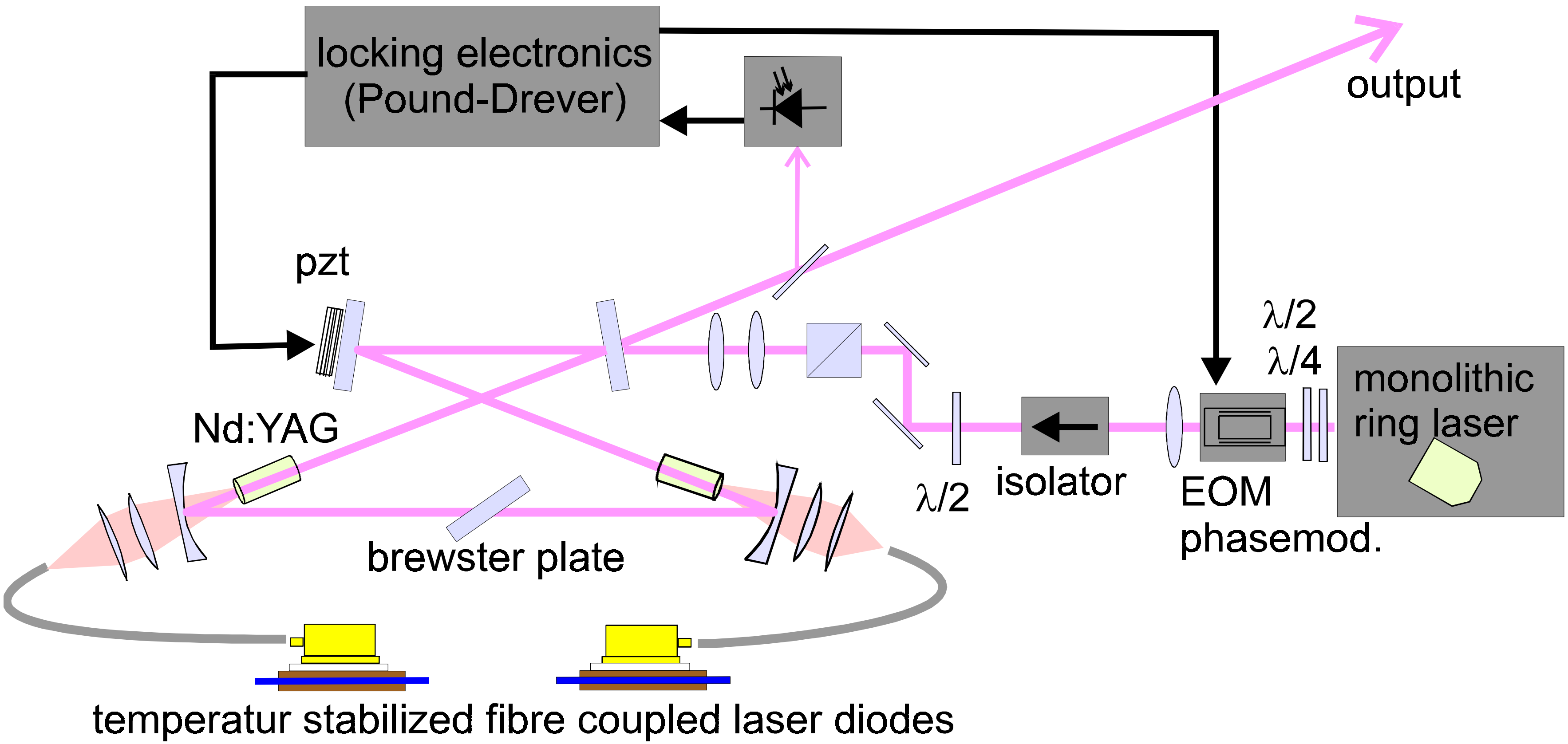


NPRO (non-planar ring oscillator) by Innolight*

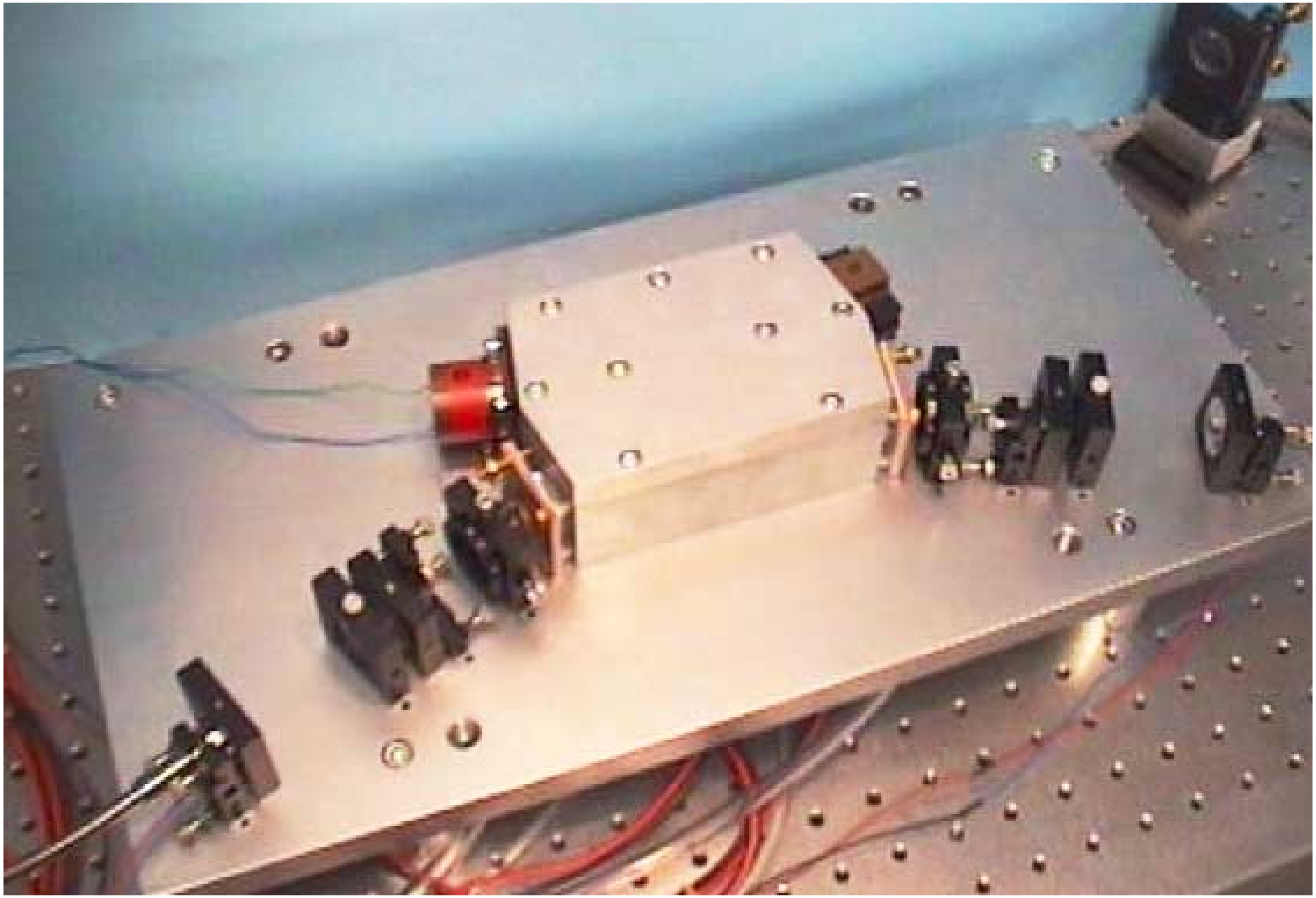
- output power: 800mW
- frequency noise:
  [10kHz/f] Hz/sqrt(Hz)
- power noise:
  10^{-6} /sqrt(Hz)

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

Laser for GEO600: Injection Locked Ring Laser

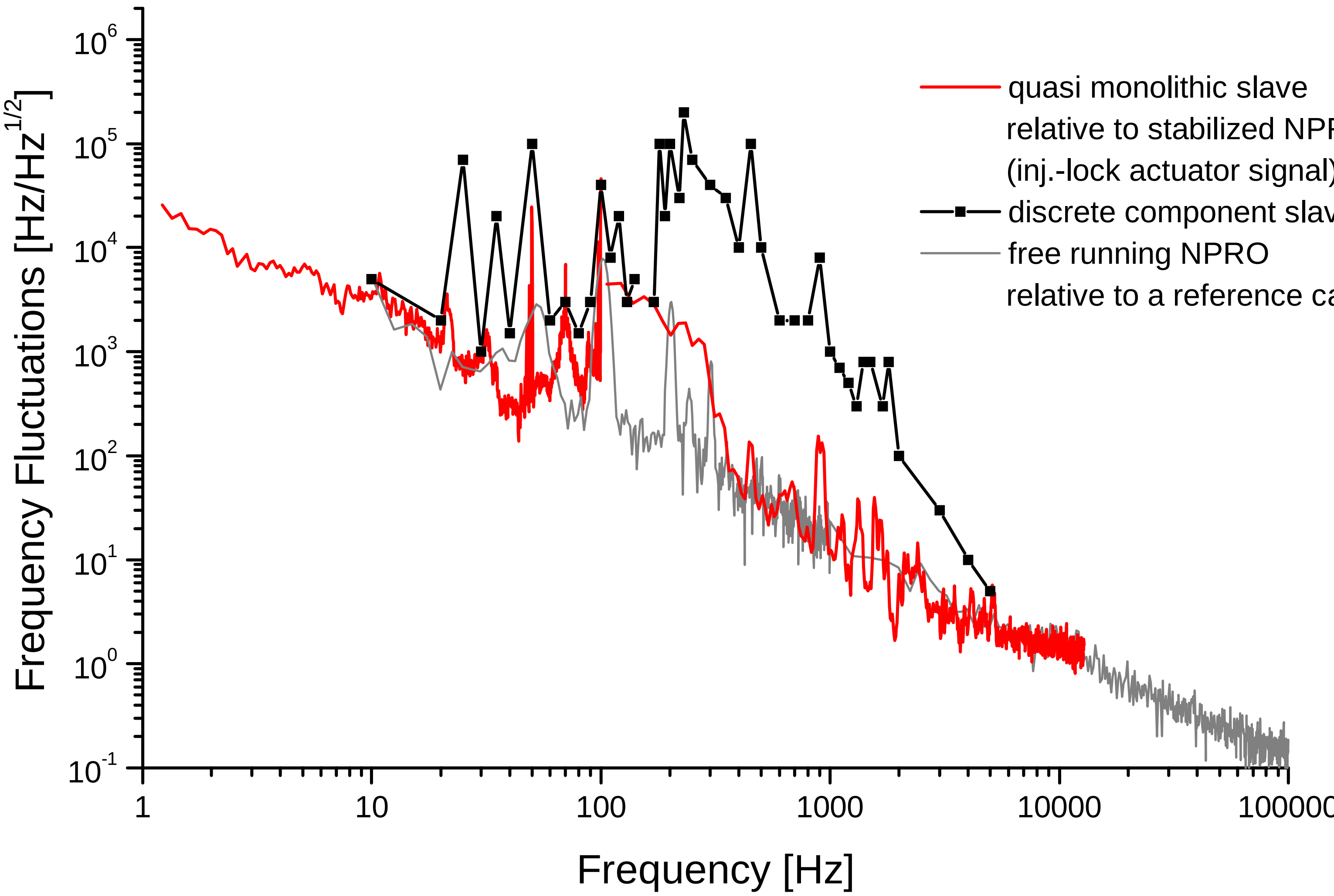


GEO 600 Slave Laser



GEO 600 Slave Laser Prototype II

Frequency Stability



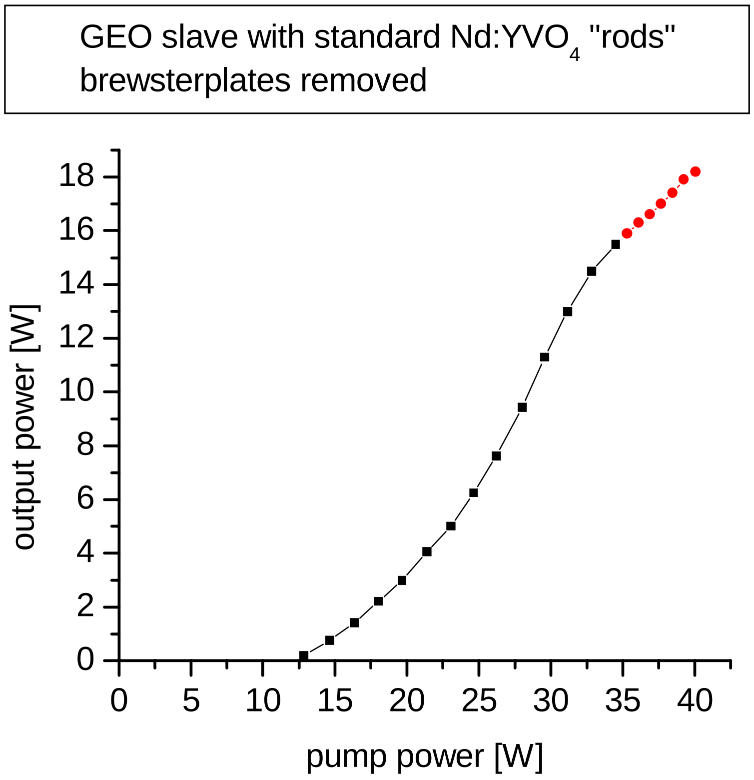
Power Scaling of End Pumped Nd:YVO_4

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 $\sigma_{||} = 25 \times 10^{-19}\ cm^{-2}$
  $\sigma_{+} = 7 \times 10^{-19}\ cm^{-2}$
  → polarized emission
- large product of $\sigma_{||}\,\tau_{sp}$ ($\tau_{sp} \cong 90\ \mu s$) → loss insensitive high gain lasers
- 8 nm broad absorption @ 808 nm → low requirements on pump diodes

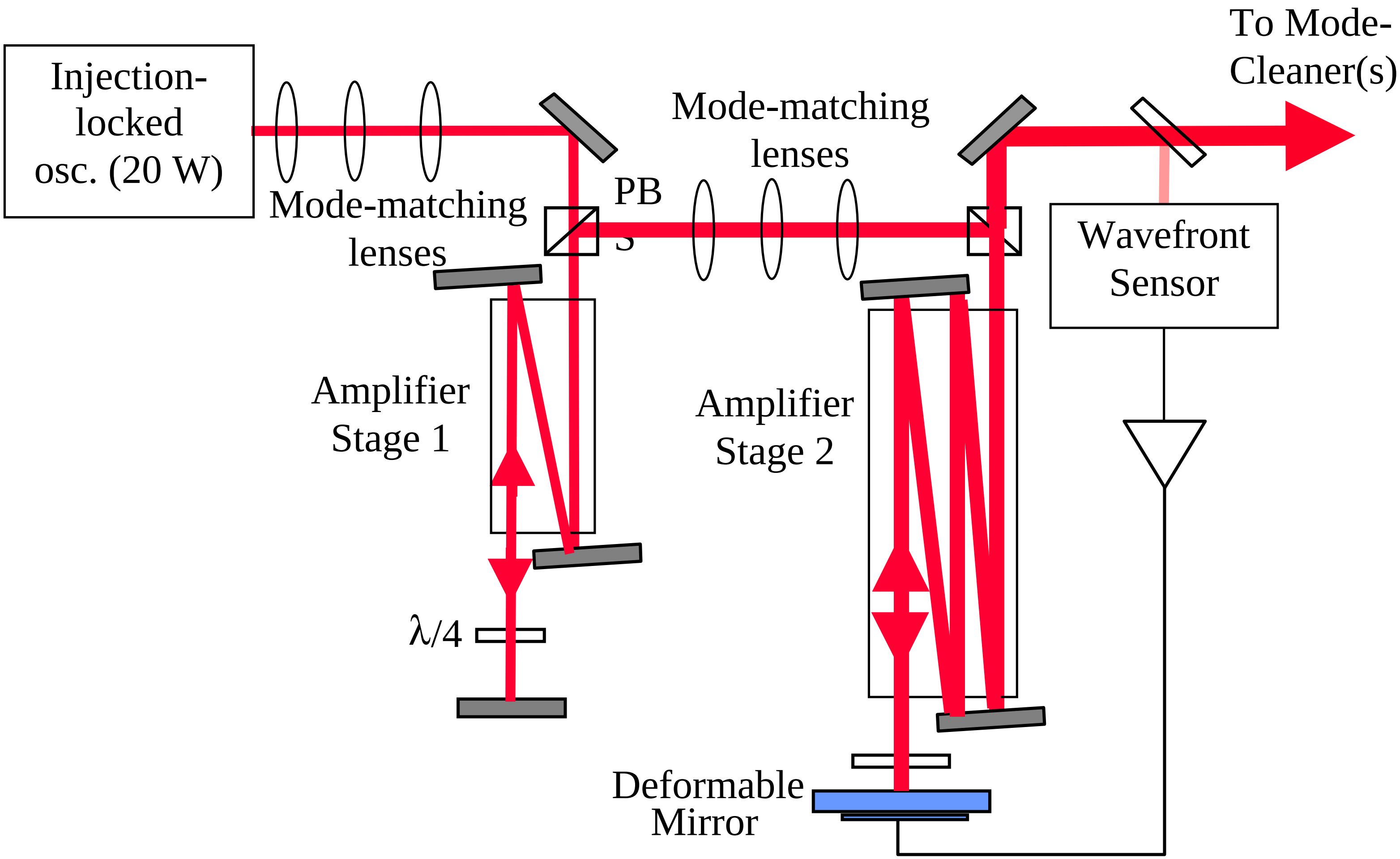
Disadvantage of Nd:YVO_4 [1)]

- 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



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

Stanford MOPA design

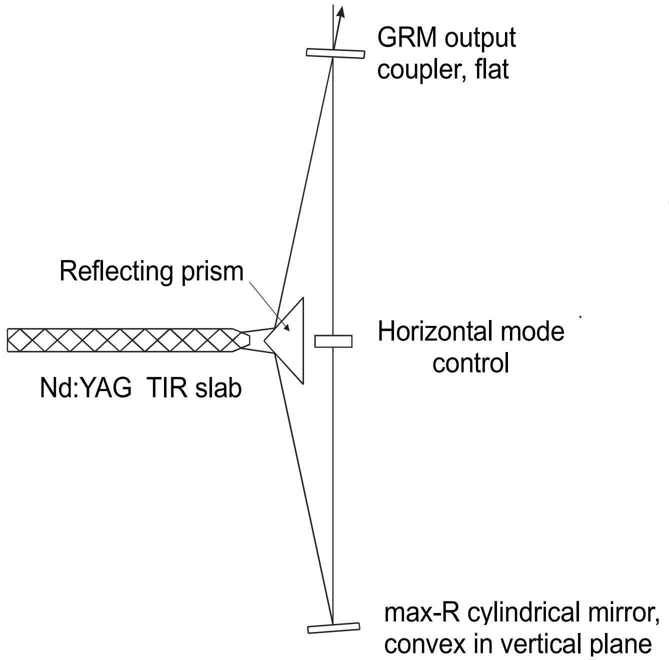


results Stanford Jan01

- 12W injection locked laser was shipped to Stanford and showed stable operations
- 27W stable operation of first ampl. stage
- some fluid (oil ?) developed on the entrance surface of second ampl. slab and degraded its performance for powers above 35W

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

design and build lab-version

- design reliable laser heads for power stages
- include suitable actuators in laser design
- integrate stabilized front-end, high-power-stages and pre-modecleaner
- design power stabilization (in-loop test)

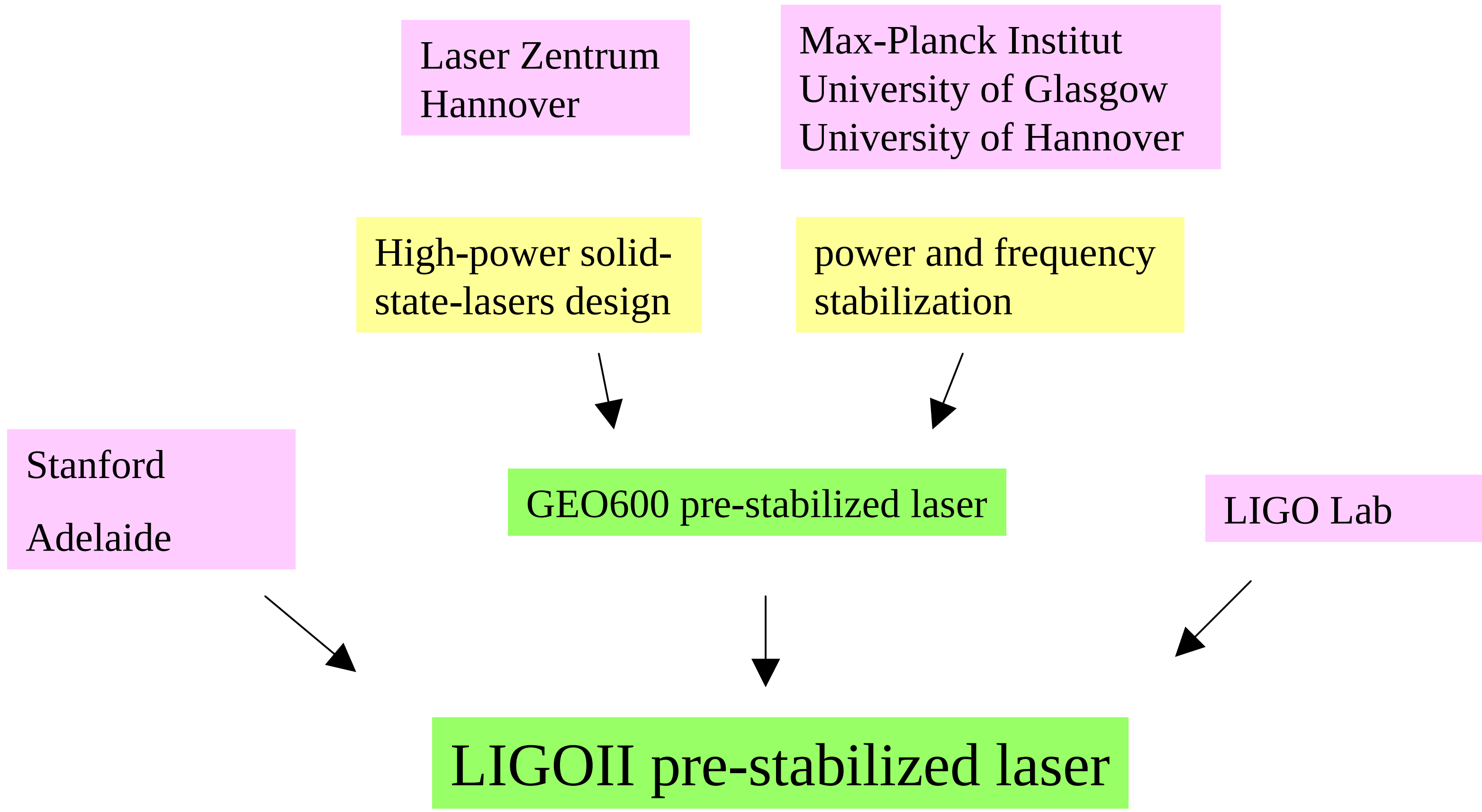
design and build final version

- optimize design according to lessons learned with lab-version and including system aspects like reliability, safety, robustness, automation and system interfaces (DAQ, power, cooling, ...)
- keep flexibility to react on long-term behavior of lab-version

PSL fabrication & installation

- quality check
- system integration (if components are fabricated at different locations)
- reproducibility
- user training

the LIGOII laser-team



LIGOII laser-team

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

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