Universität Hannover

Lasers for Advanced Interferometers

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Aspen Meeting

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G040041-00-Z

Requirements - Topology

- Sagnac:
  - broadband source to reduce scattered light noise
  - power control
- recycled Michelson:
  - coherence control
  - power control
  - spatial control

Prestabilized Laser System (PSL)

- squeezed light IFOs
  - power control
- different wavelength

Design Requirements

- stability / reliability
- soft failure mode
- easy to maintain / rare maintenance interval
- good efficiency
- good stationarity / low glitch rate
- high bandwidth / large range actuators

Laser Design

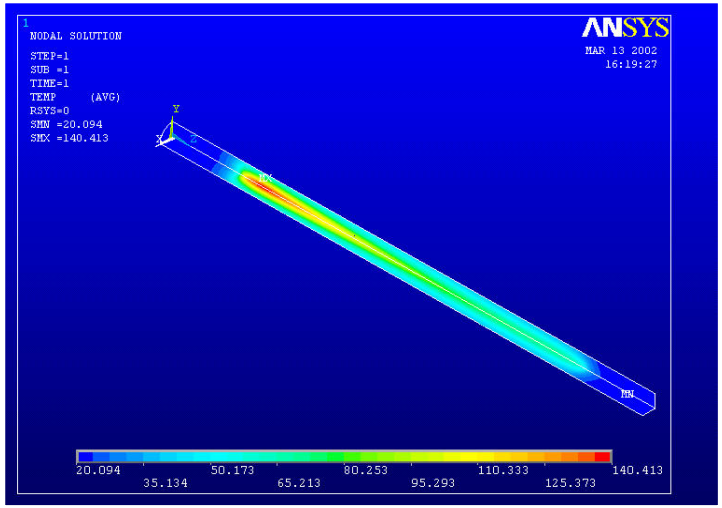
- common concept:
  - laser diode pumped solid state lasers
  - transfer frequency stability of low power master laser to high power stage
    - Maser Laser Power Amplifier (MOPA)
    - injection locked oscillator
- different power stage concepts:
  - rods
  - zig-zag slabs
  - fibers
  - thin disc lasers / active mirror laser

Nd:YAG Master-Laser

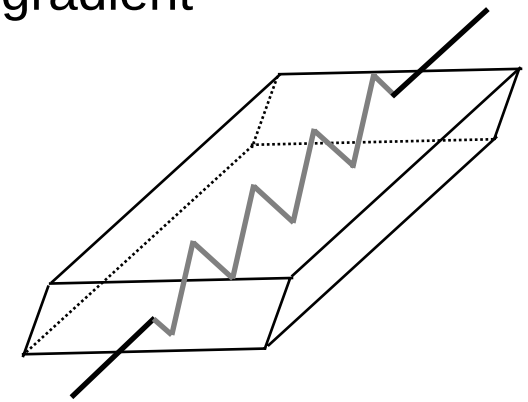
NPRO (non-planar ring oscillator)

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

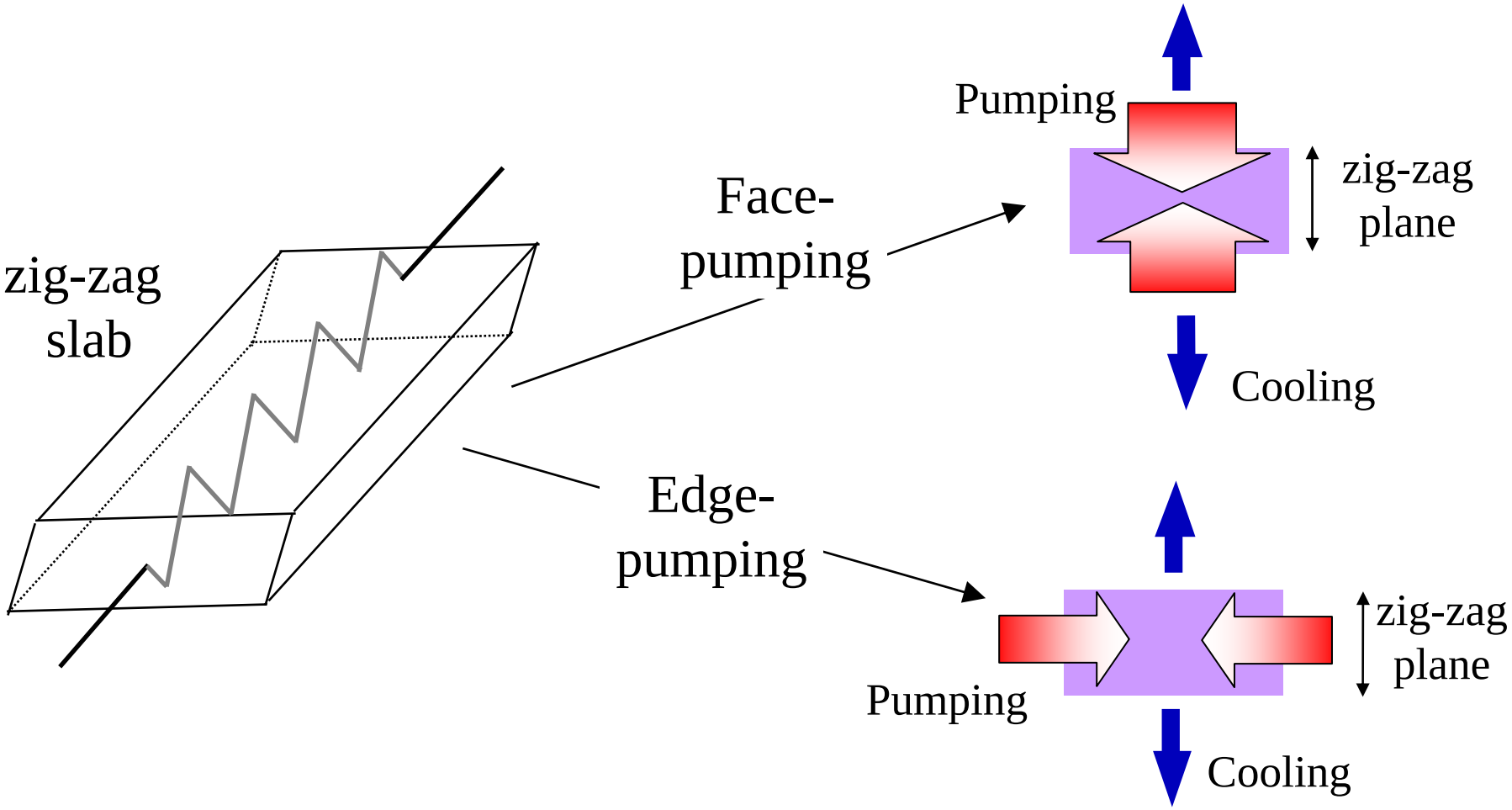
High Power Stage



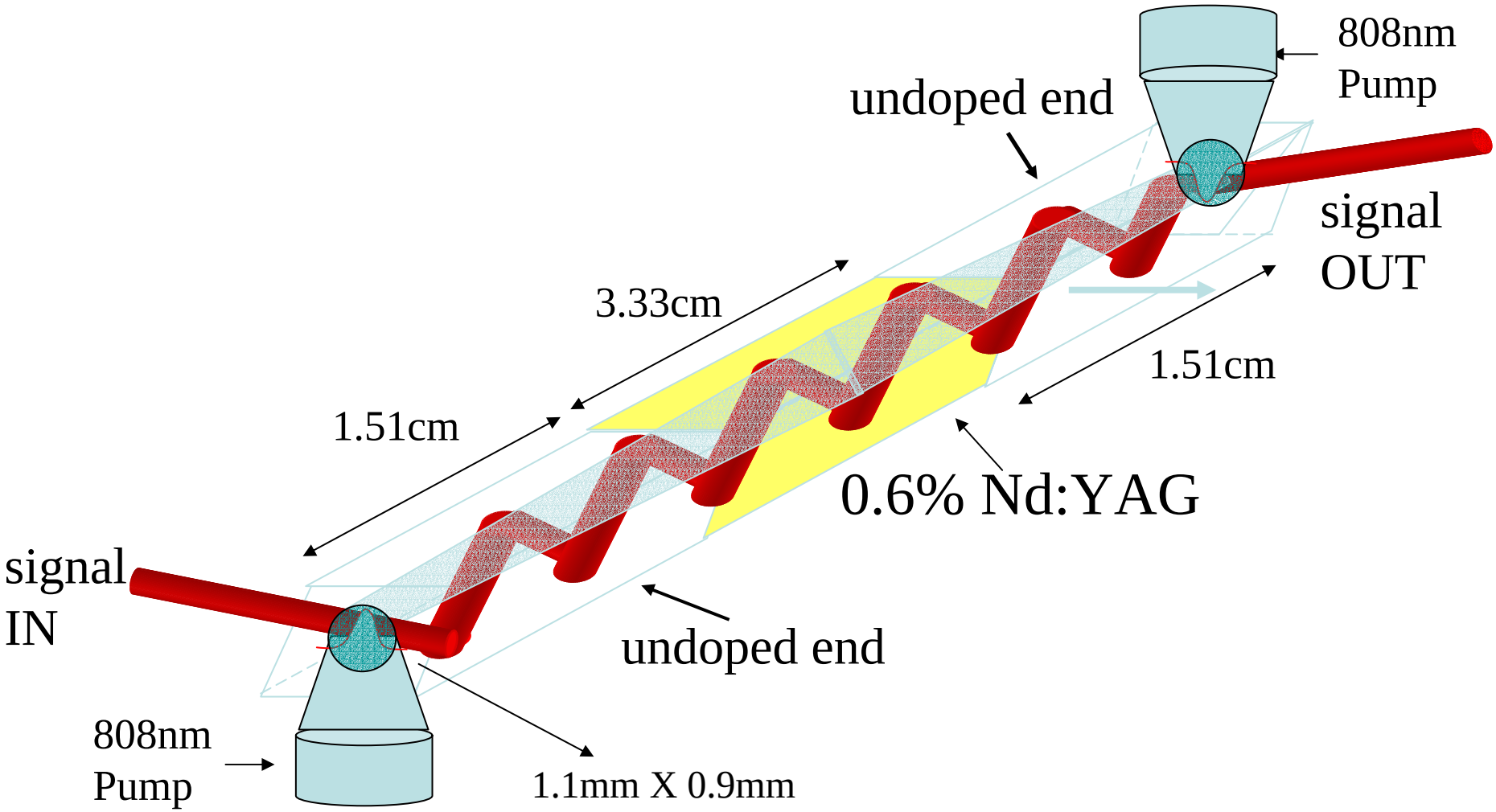
- main problem: thermal design
  - stress fracture
  - thermal lensing – spatial profile
  - birefringence with tangential and radial principle axis
- solutions
  - reduce deposited heat – Yb:YAG, high efficiency
  - propagate beam perpendicular to temperature gradient – zig-zag, thin disc lasers
  - increase interaction length – fiber lasers
  - compensate birefringence



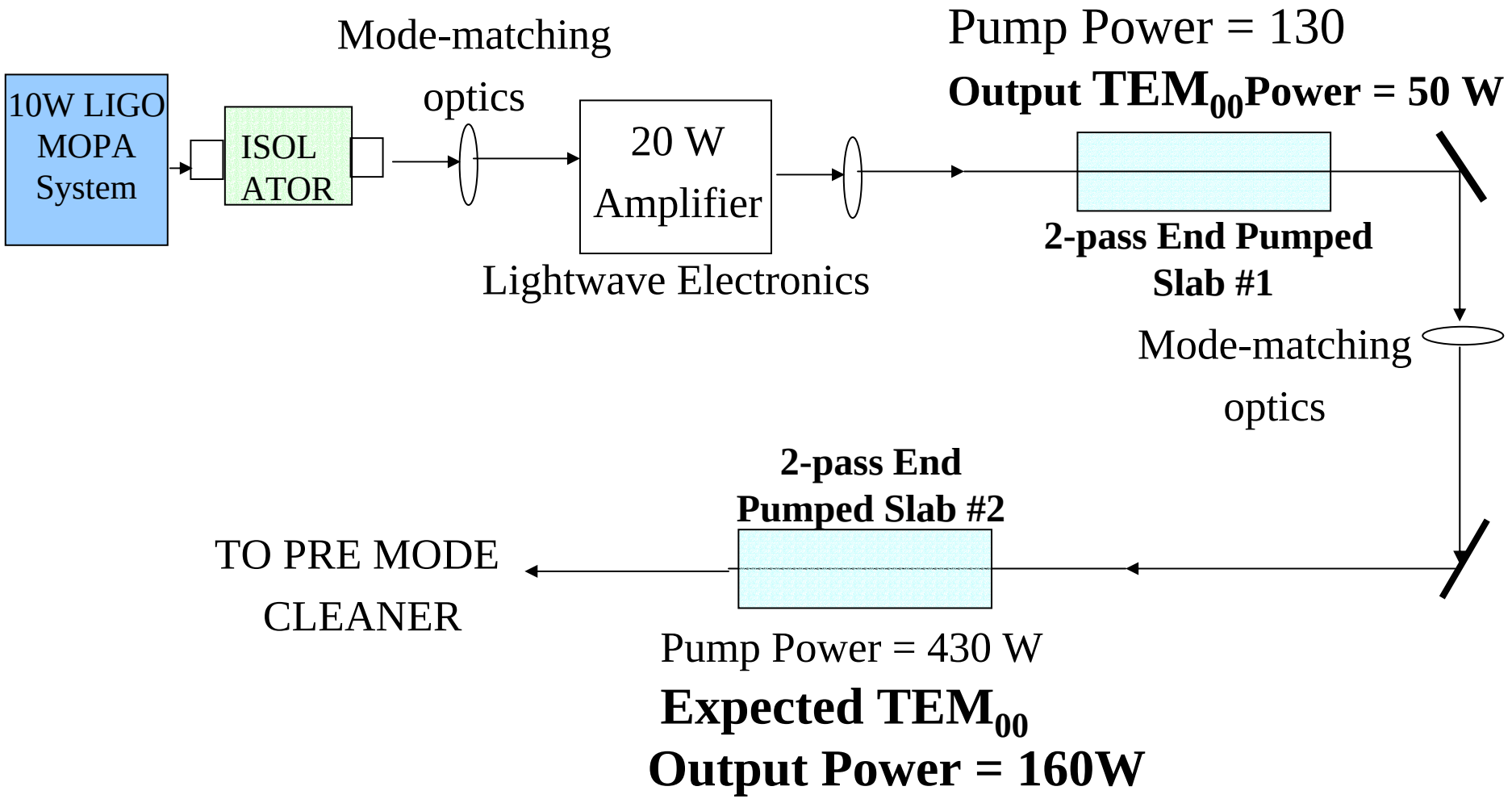
Face-pumping - Edge-pumping



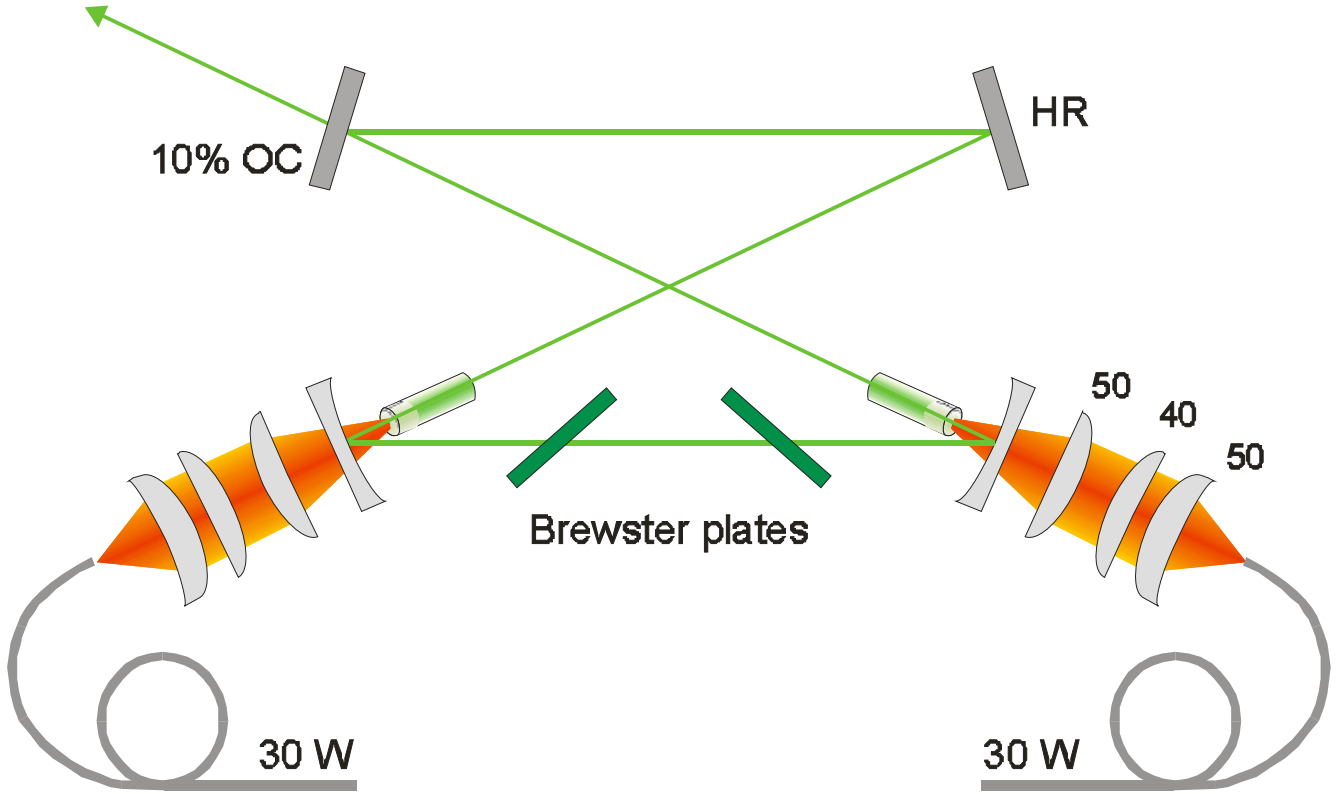
End pumped slab geometry



Stanford High Power Concept



End Pumped Rods

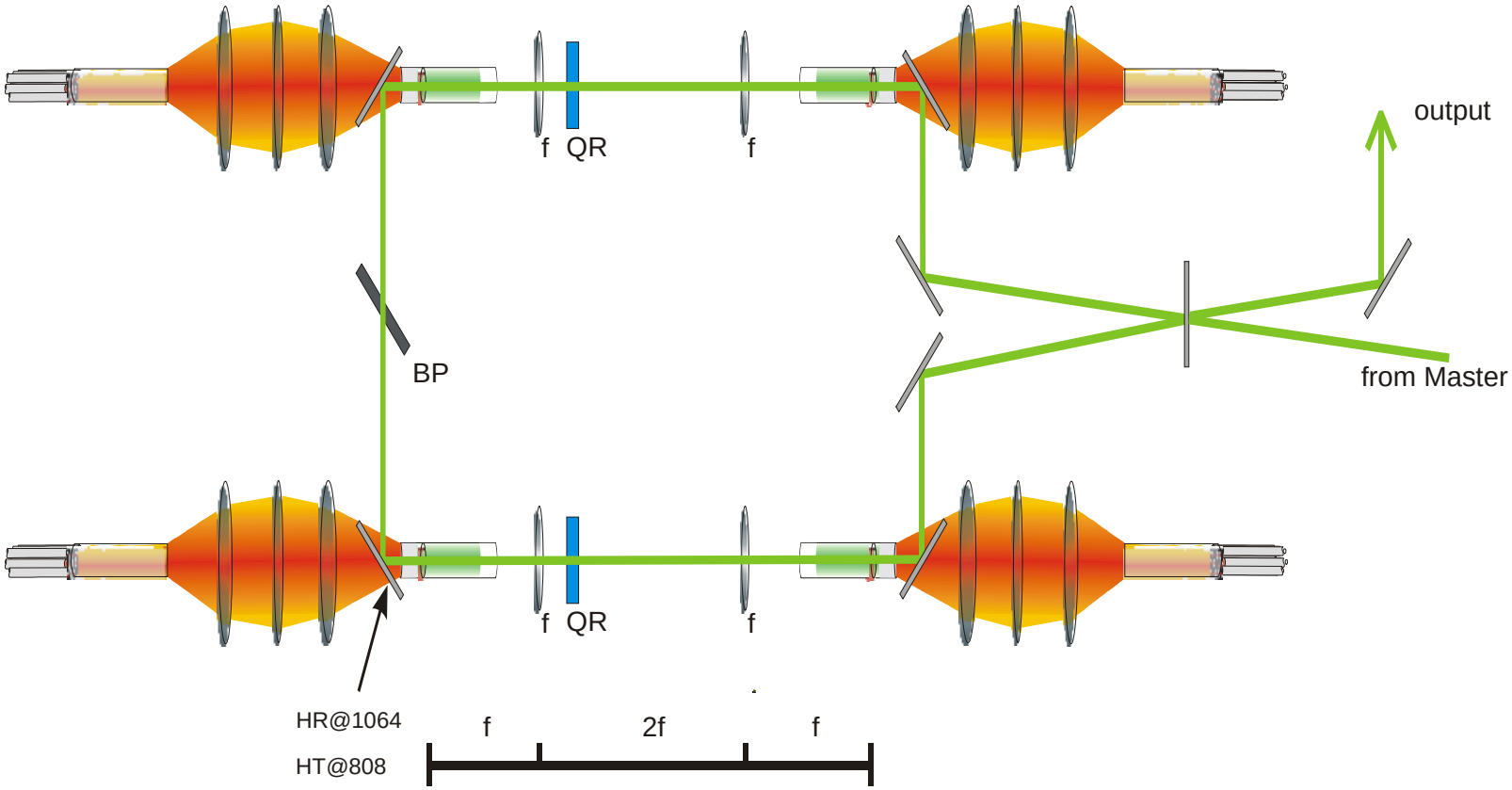


Nd:YAG - GEO600 Laser (14W)

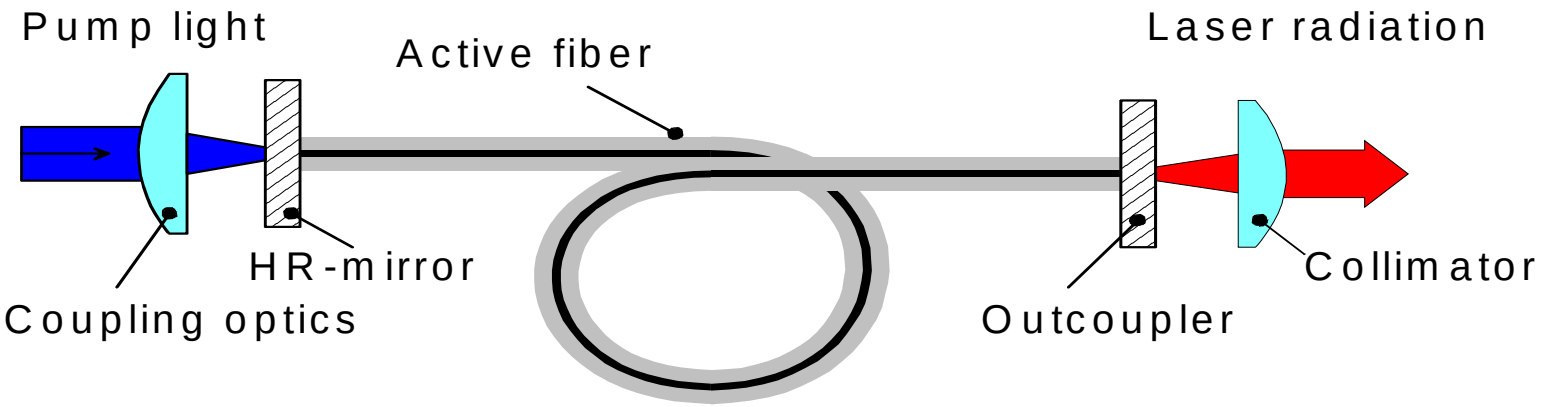
Nd:YVO_4 - Virgo Laser (20W)

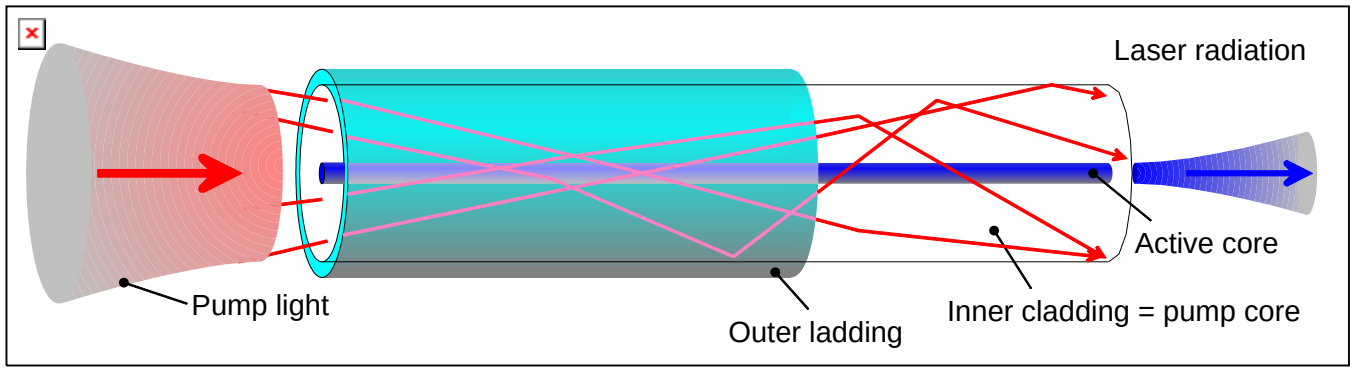
Laser Zentrum Hannover

LZH High Power Concept



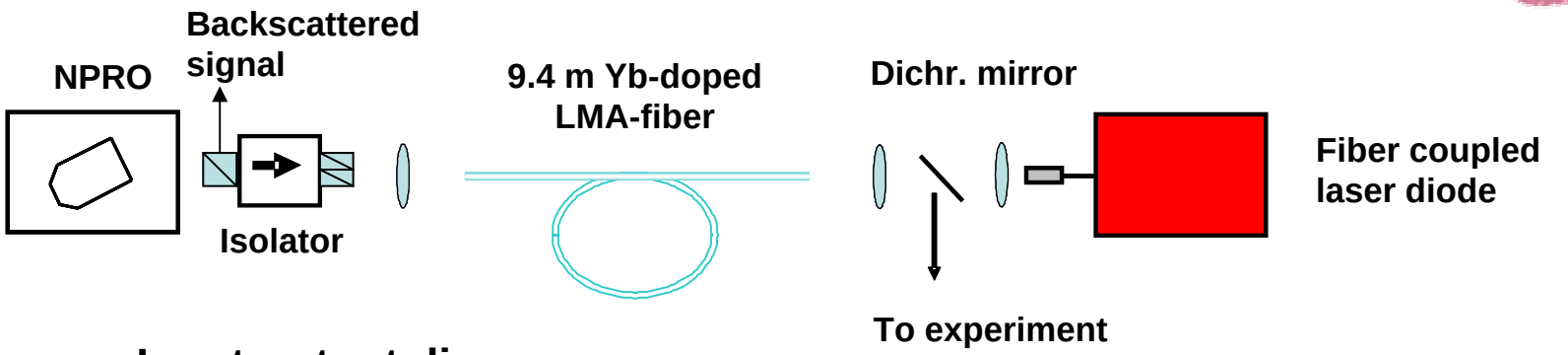
Fiber Lasers



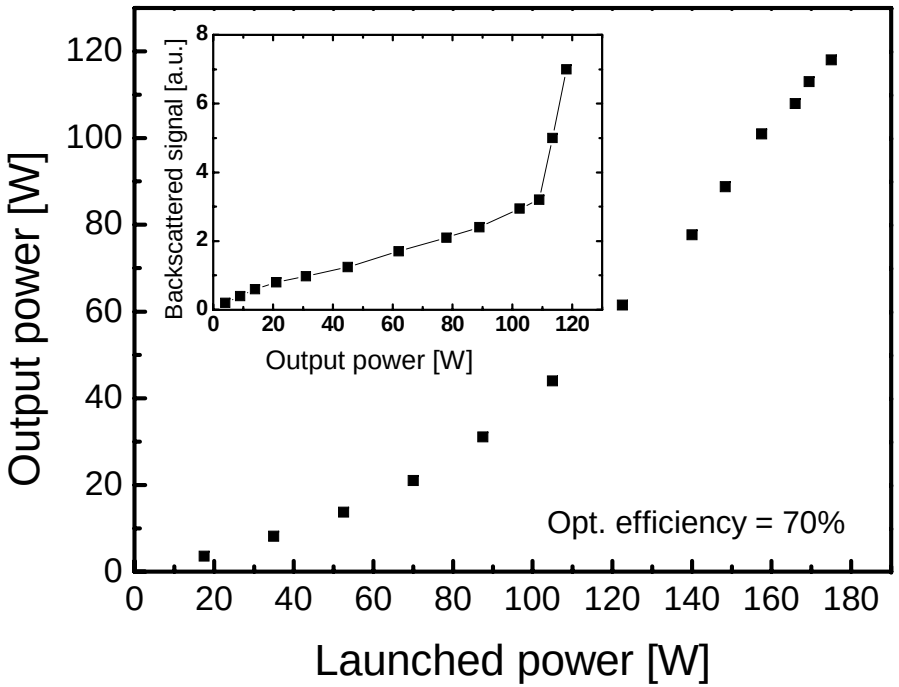


courtesy H. Zellmer

Fiber Laser Result of Jena Group



Input-output diagram



Yb-doped LMA-Fiber

Core:	∅ = 28.5 µm, NA = 0.06
MFD	23 µm
Doping.	700 ppm (mol) Yb_2O_3
Pumpc.:	∅ = 400 µm, NA = 0.38, D-Form
Seed:	800 mW

- Diffraction limited (M^2 = 1.1)
- Polarization 82% (10:1)

Modeling/Overview

pump light distribution

- ray tracing
- analytical approximation
- experimental data

heat generation

Finite Element Method for calculating

- temperature distribution
- mechanical stress
- deformation

cooling

gain

wave propagation through inhomogenous medium

- finite differencing
- split step fourier approach

k-vector

calculation of optical properties

- thermal lens
- stress-induced birefringence

Advanced LIGO Laser – Requirements

Power / Beamprofile:

- 165W in gausian TEM_{00} mode
- less than 5W in non- TEM_{00} modes

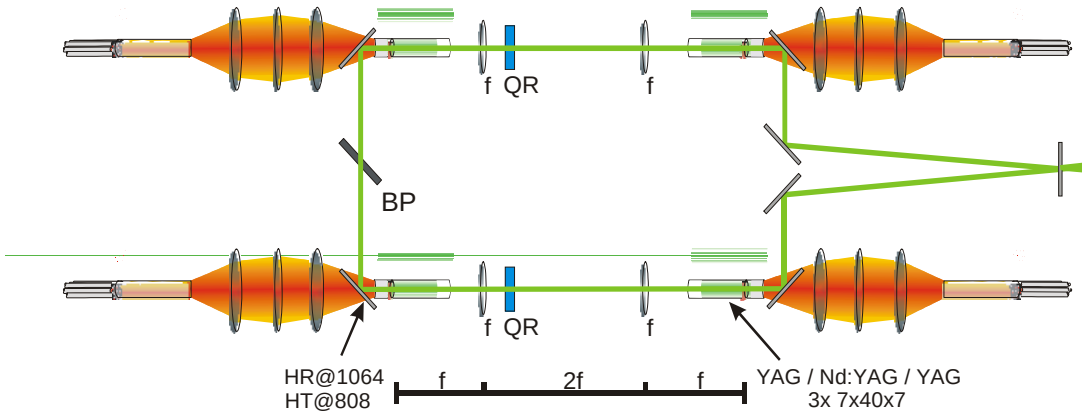
Drift:

- 1% power drift over 24hr.
- 2% pointing drift

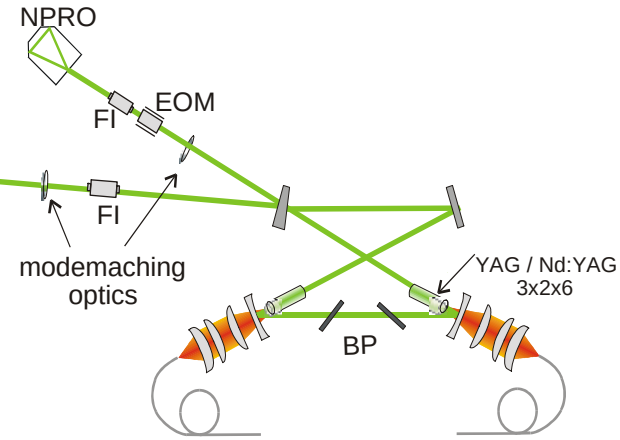
Control:

- tidal frequency acuator +/- 50 MHz, time constant < 30min
- power actuator 10kHz BW, +/-1% range
- frequency actuatot BW:<20^{o} lag at 100kHz, range: DC-1Hz: 1MHz, 1Hz-100kHz: 10kHz

Injection Locked Oscillators - Hannover



High Power Slave



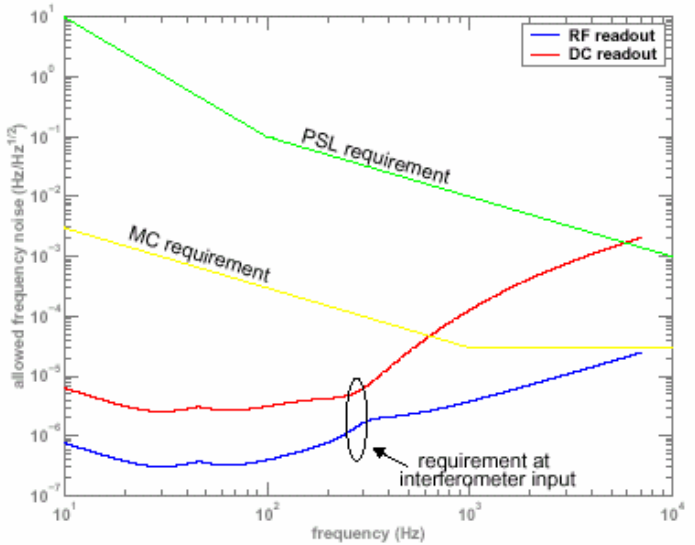
20 W Master

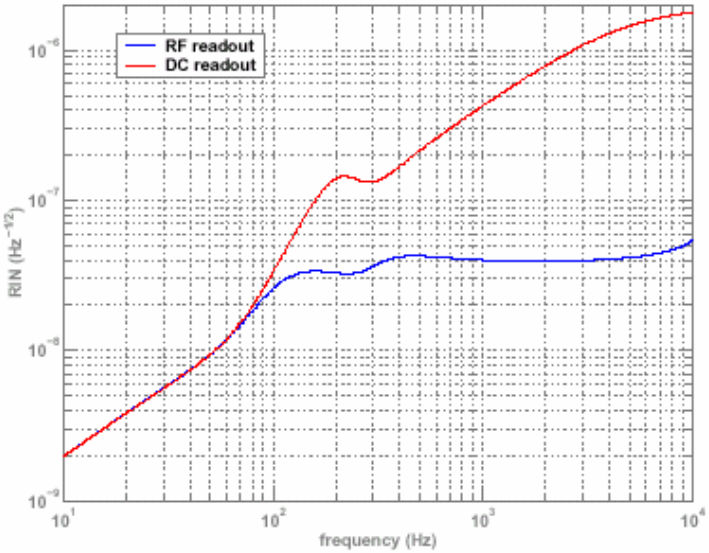
key elements:

- undoped bonded end-caps
- birefringence compensation
- pumplight homogenization

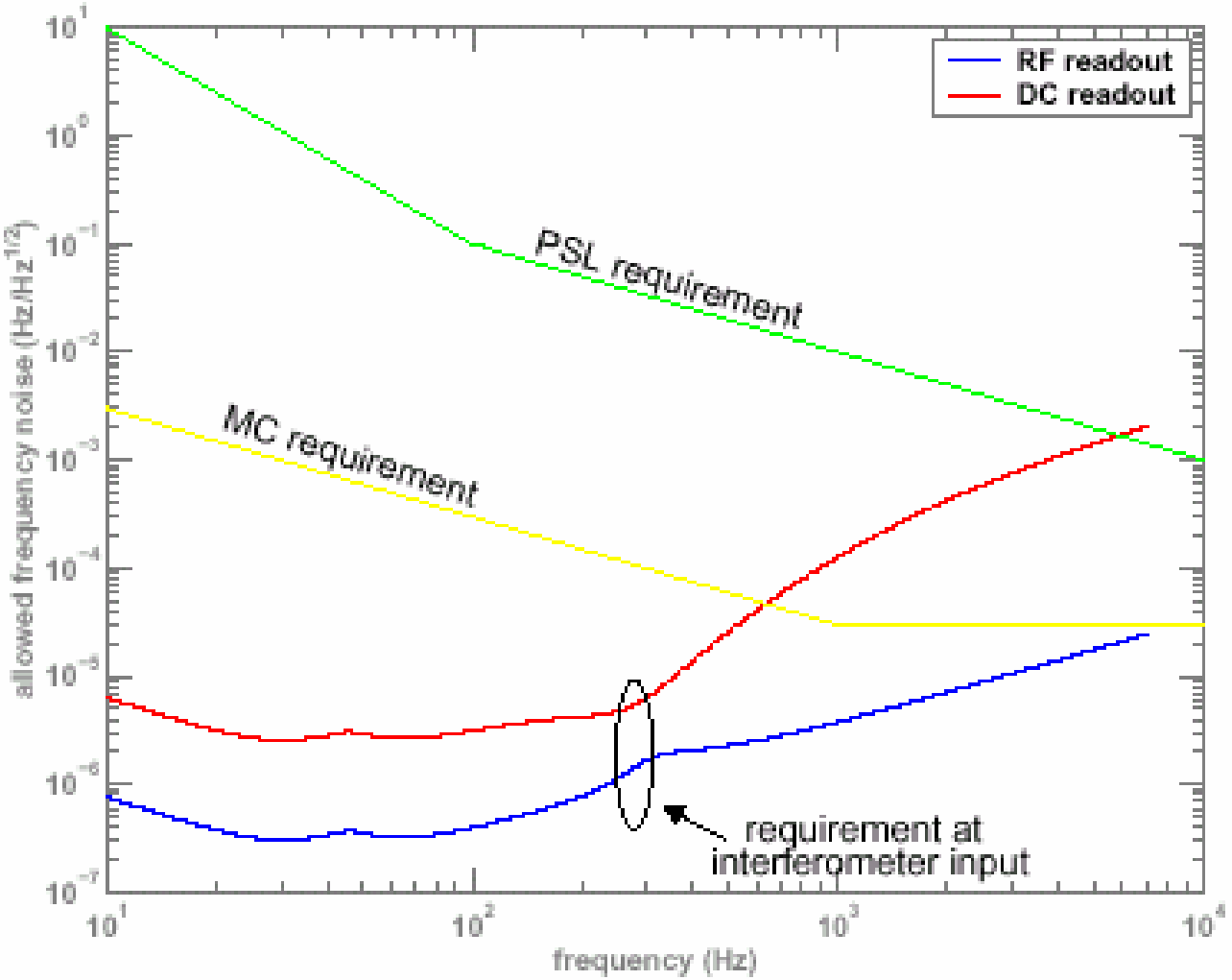
Prestabilized Laser PSL

- frequency stability:
  - stabilize master laser to rigid or suspended-mirror cavity
- power stability:
  - feed-back to pump source of high power stage
  - passive filtering at rf
- spatial profile
  - passiver modecleaning
  - active mode compesation

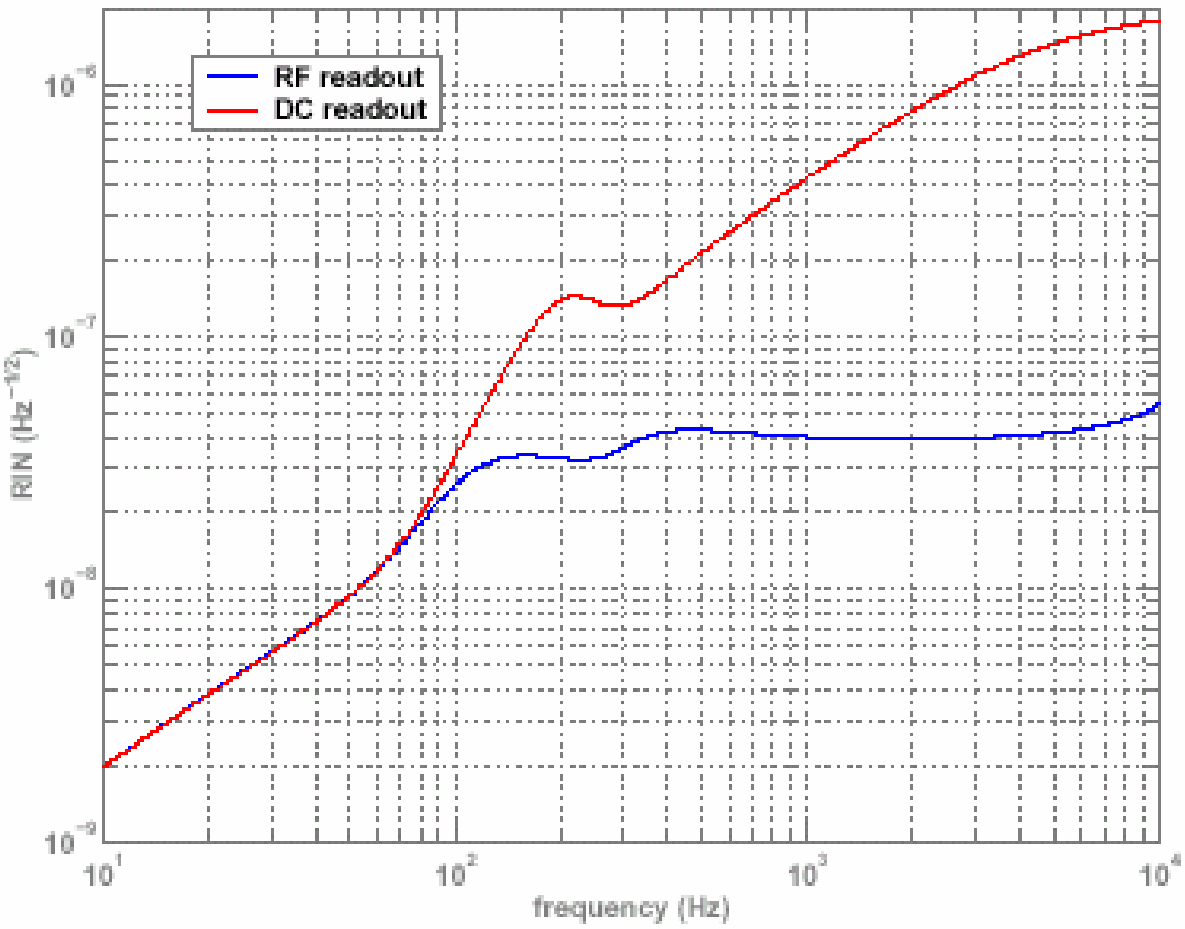




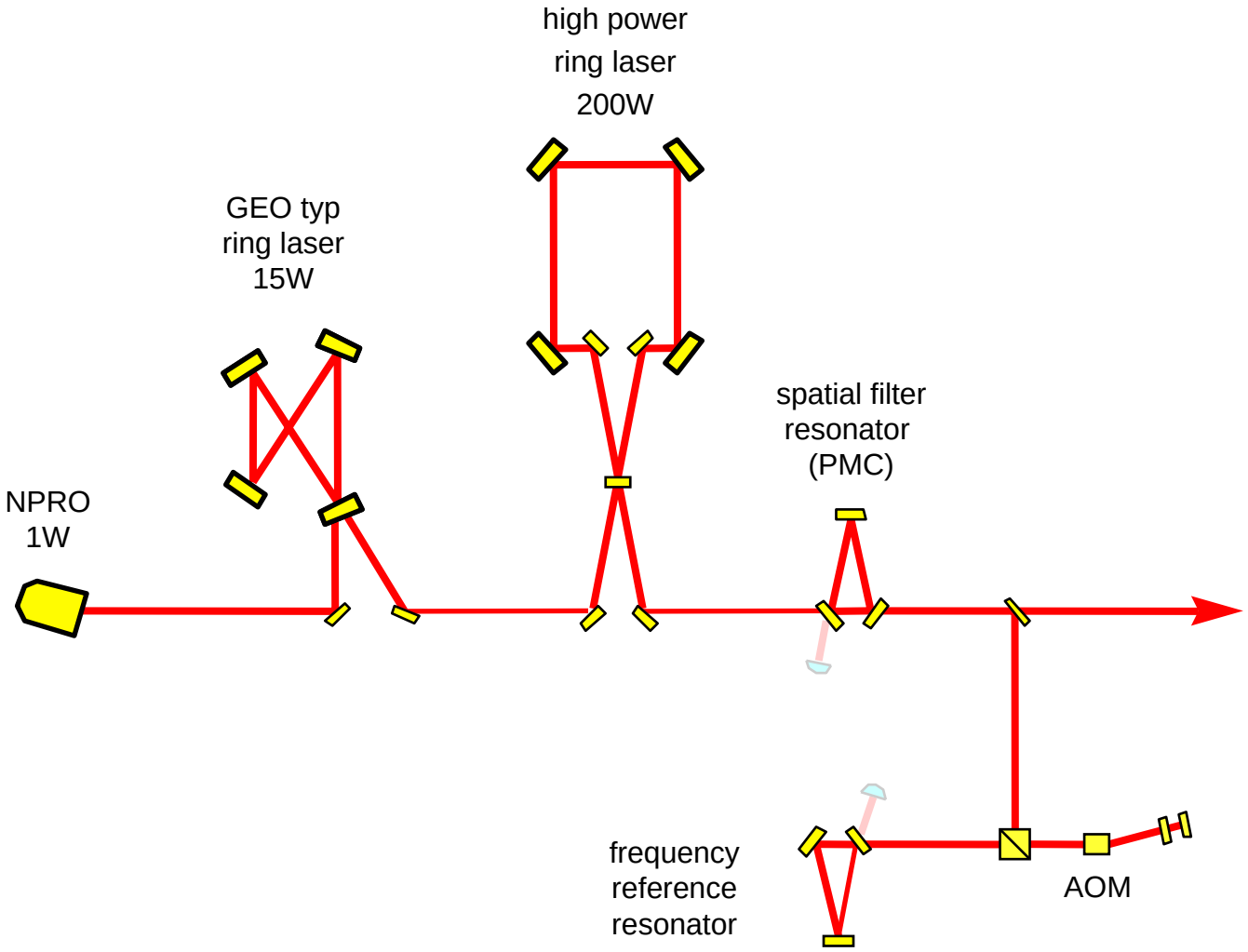
frequency noise requirement



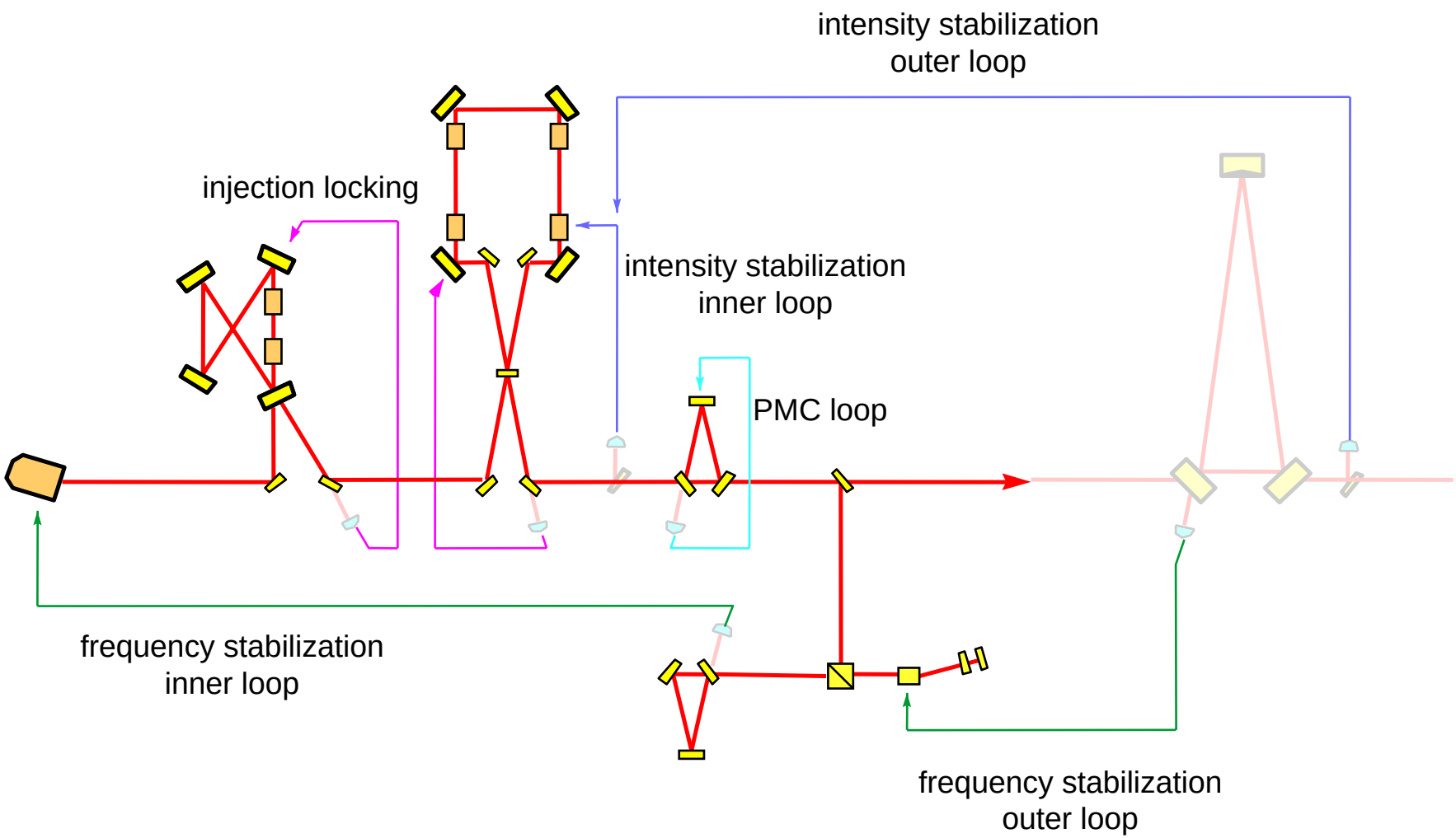
intensity noise requirement



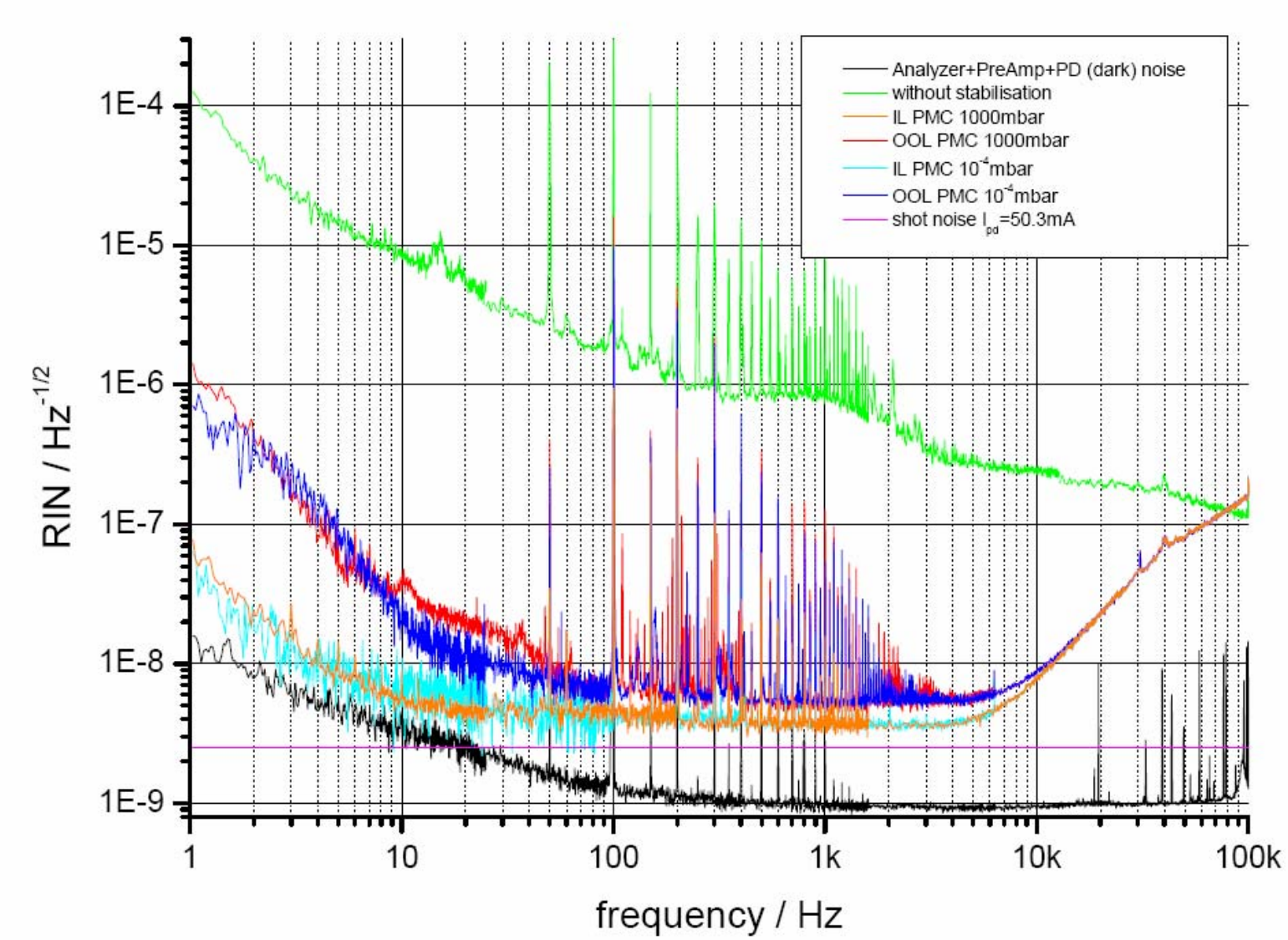
Adv LIGO - PSL optical layout



PSL – stabilization scheme

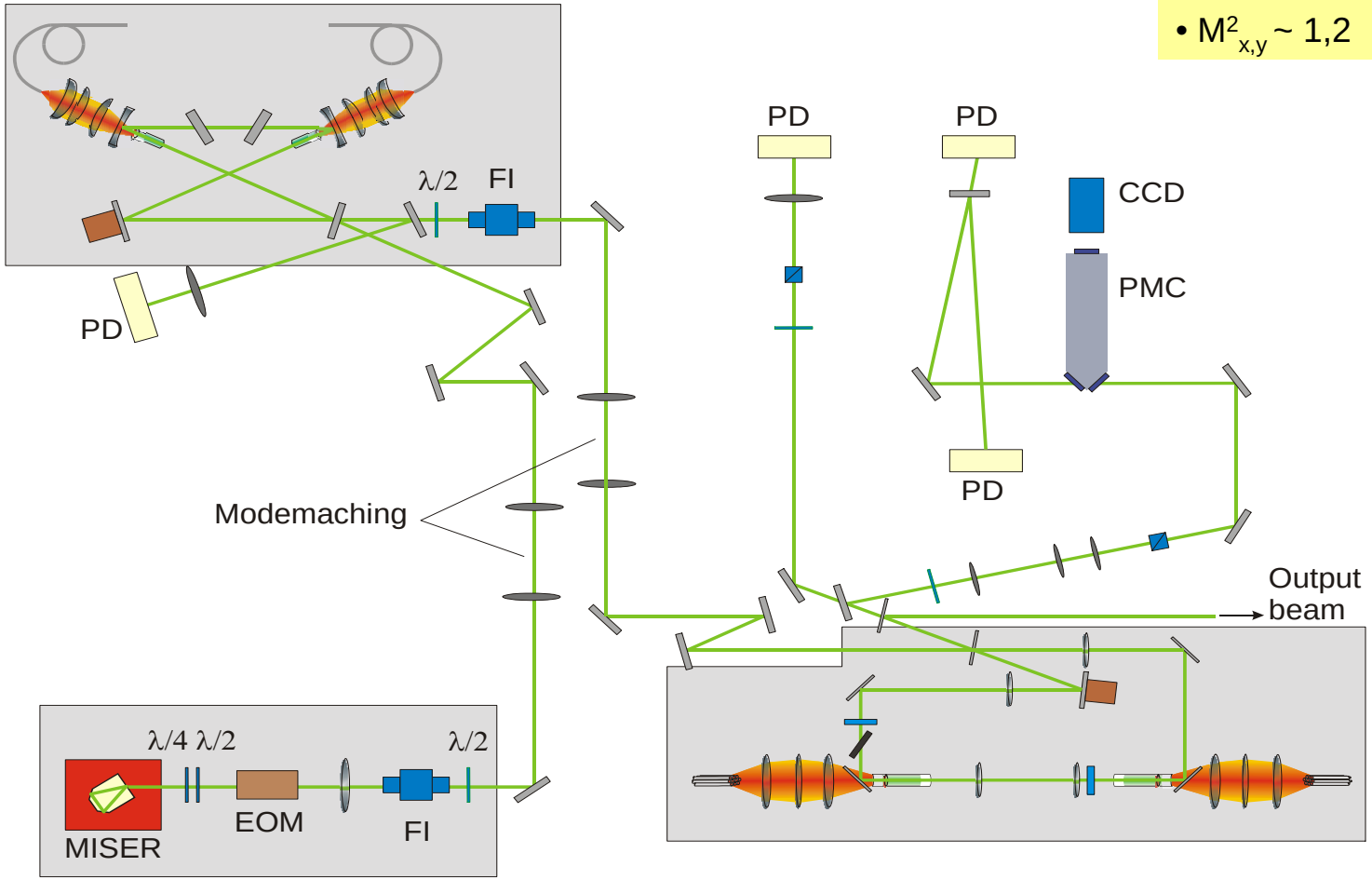


Power Noise Reduction

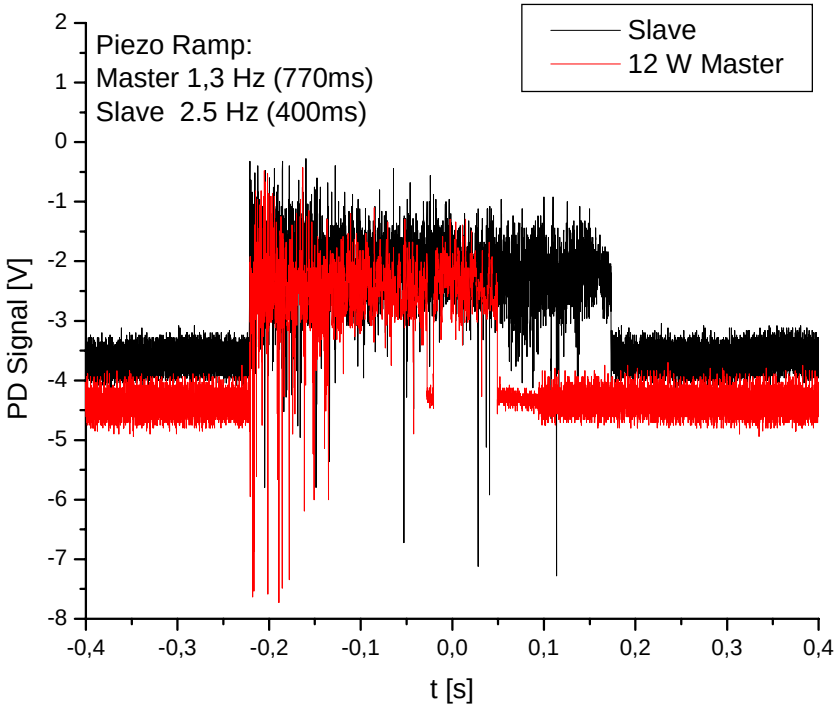


High Power Slave

- 87 W output power
- linear polarized
- single transverse mode
- $M^2_{x,y}$ ~ 1,2



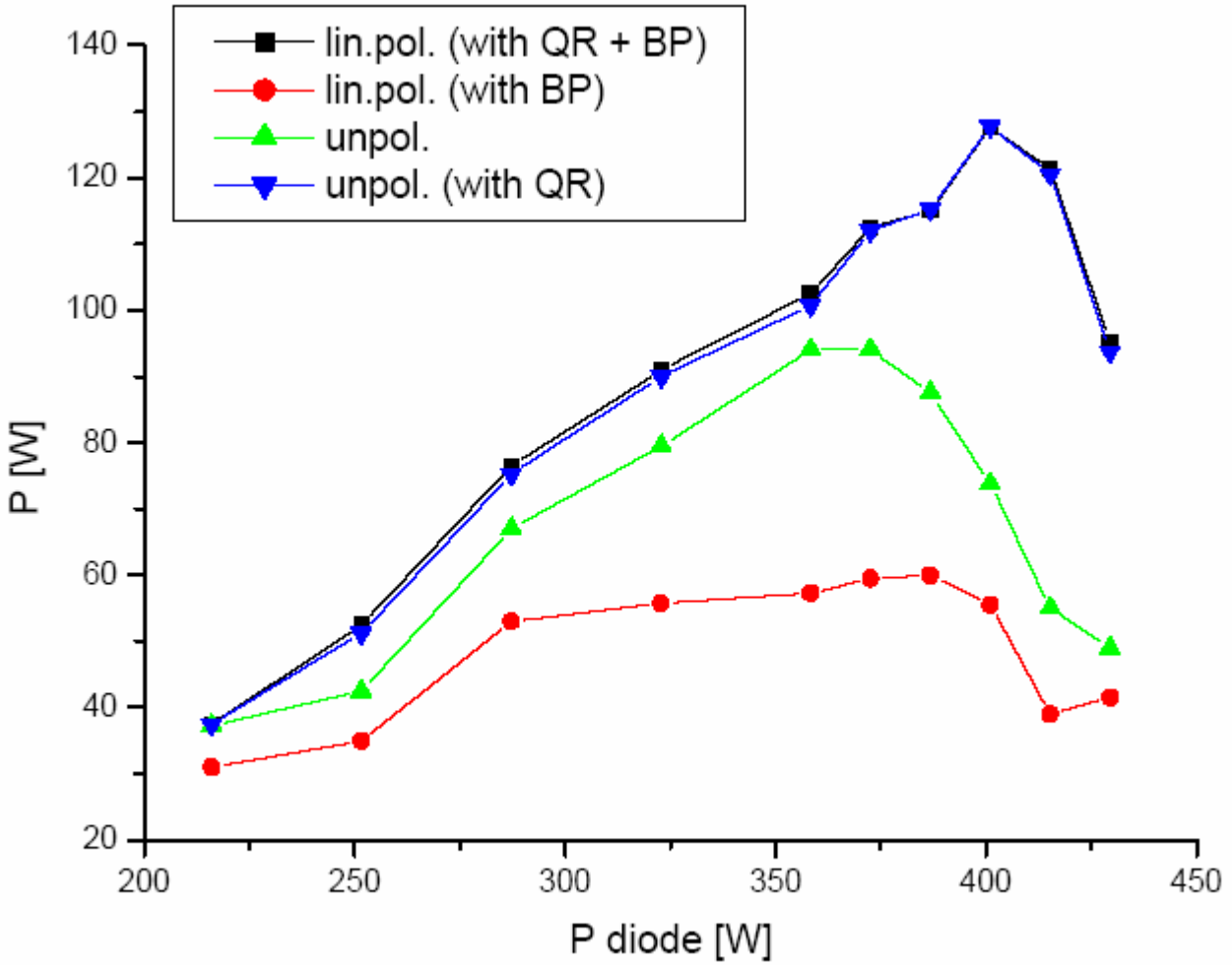
Relock Time



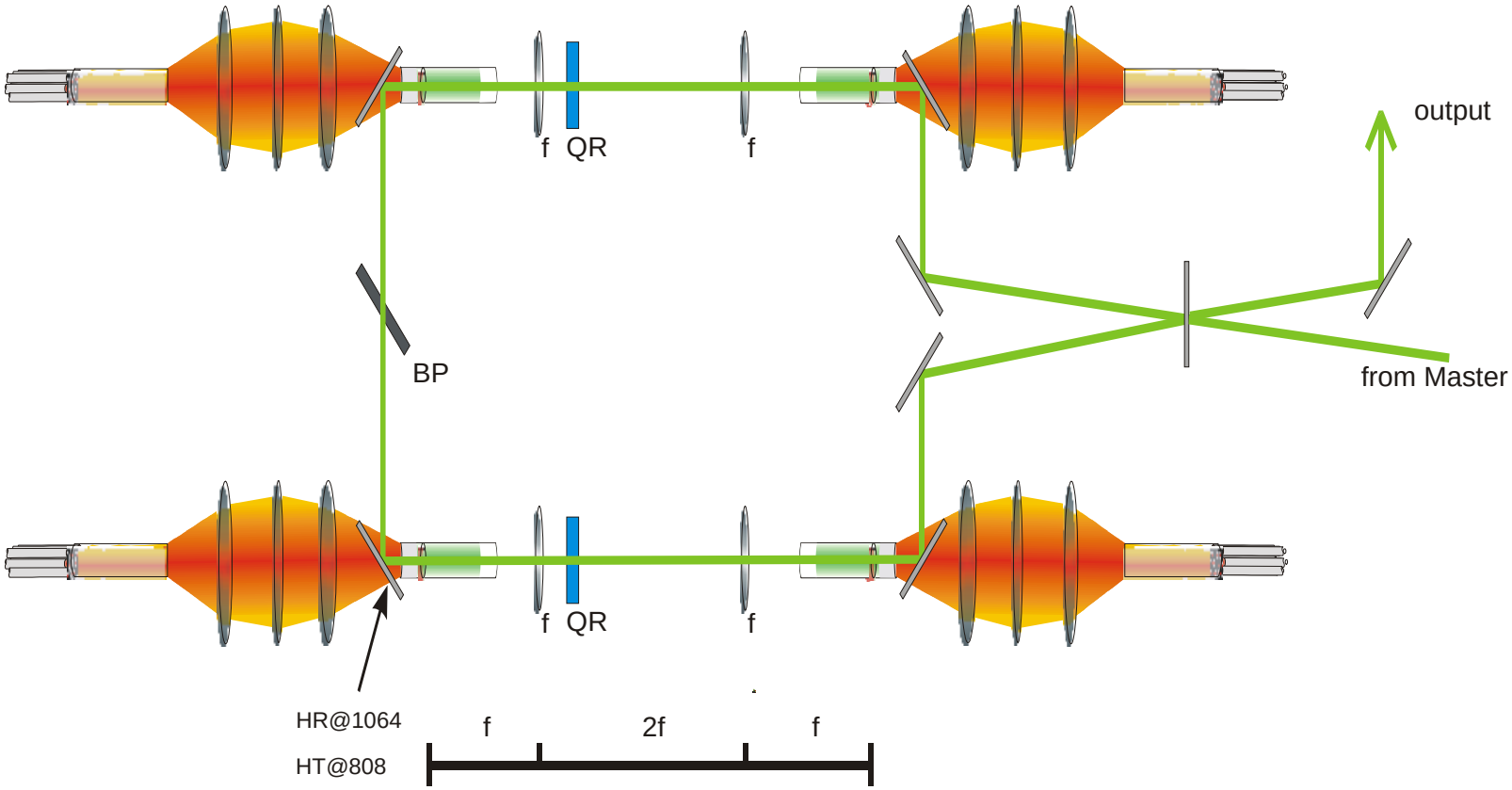
relock time < 500 ms

faster relock possible depending on piezo ramp

Birefringence Compensation



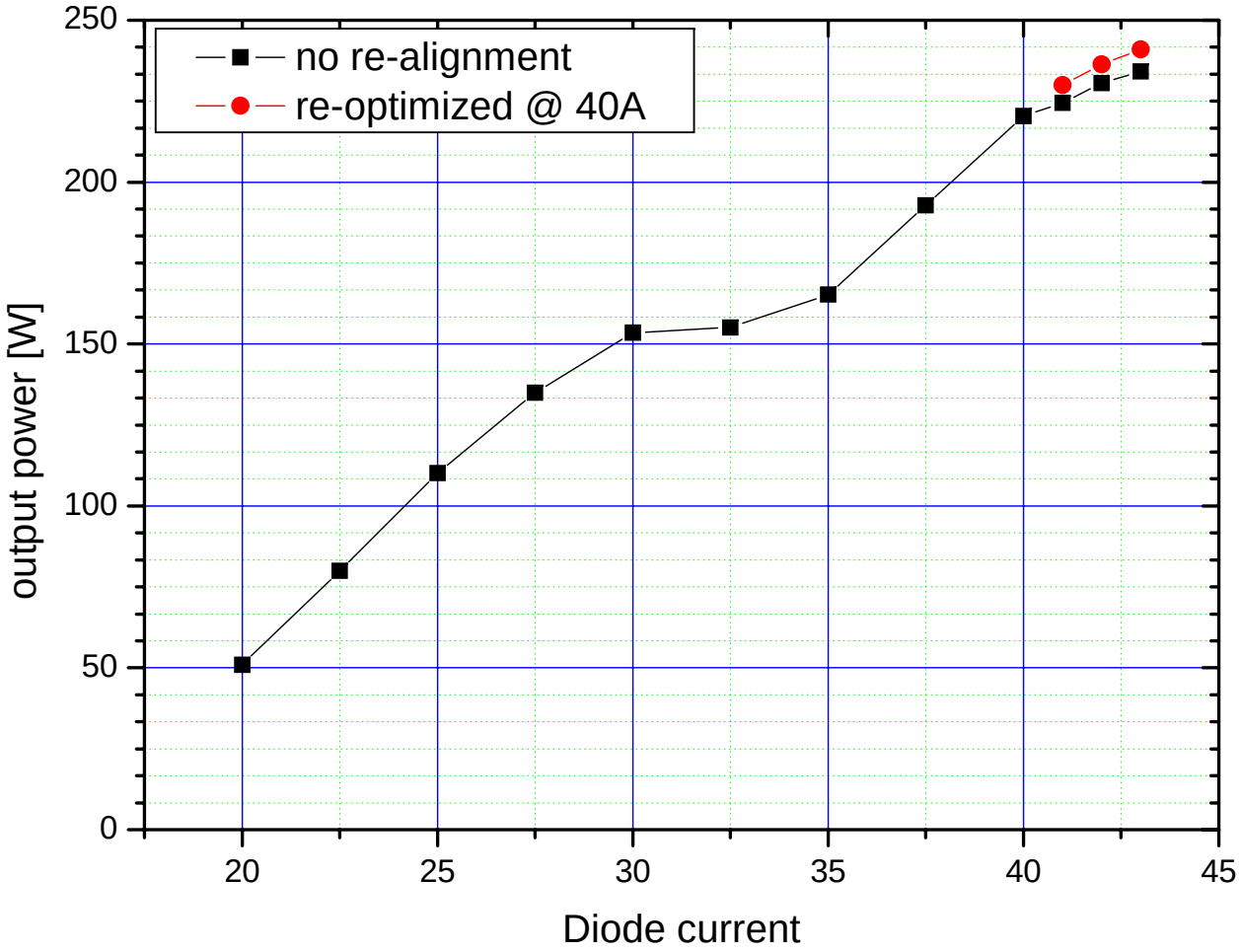
End-Pumped Rods



Summary

- different high power stages:
  - end-pumped slabs
  - end-pumped rods
  - fiber amplifier
- different topologies:
  - MOPA
  - injection locking
- Advanced LIGO pre-stabilized laser system
  - status of laser development
  - possible stabilization schemes

high power stage status Feb 2004



linear polarized
with birefringence
compensation