Status of the Advanced LIGO PSL development

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For the PSL team

Virgo/LIGO meeting, Cascina May 2007

LIGO-G070360-00-Z

PSL Functions

- deliver coherent radiation to allow interferometric detection of gravitational waves
  - » 180W laser with high reliability and low fluctuations
- reduce temporal and spatial fluctuations of the light
  - » first layer of power and frequency stabilization before light enters the input optics (IO) subsystem
  - » provide actuator-inputs for further frequency stabilization layers (GW band: modecleaner, long term drift: long interferometer arms)
  - » stabilize laser power downstream of the suspended modecleaner
- provide control and diagnostic tools and interfaces
- define and implement laser safety procedures

Advanced LIGO Laser – Requirements

Power / Beamprofile:

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

Drift:

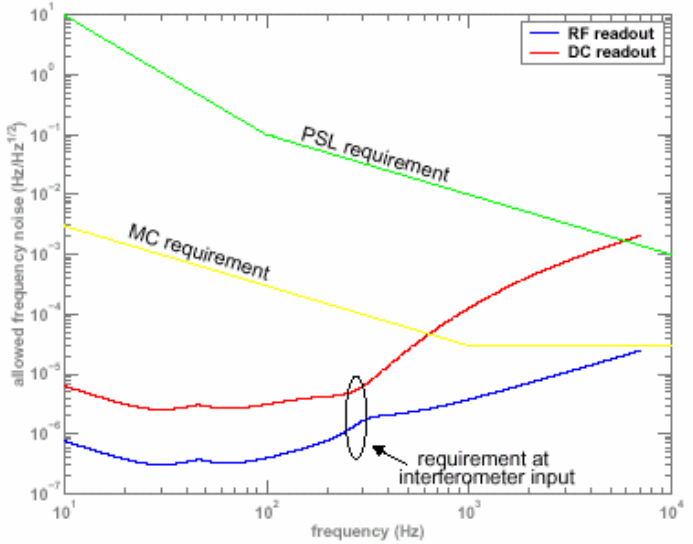
- 1% power drift over 24hr.
- 2% pointing drift

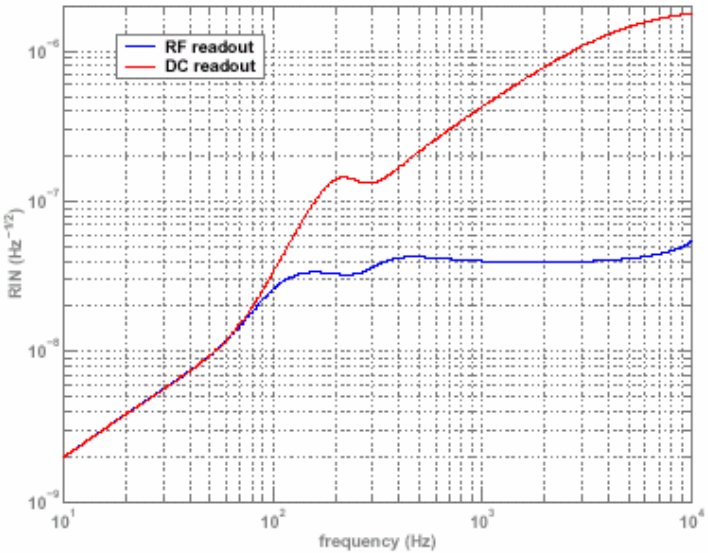
Control:

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

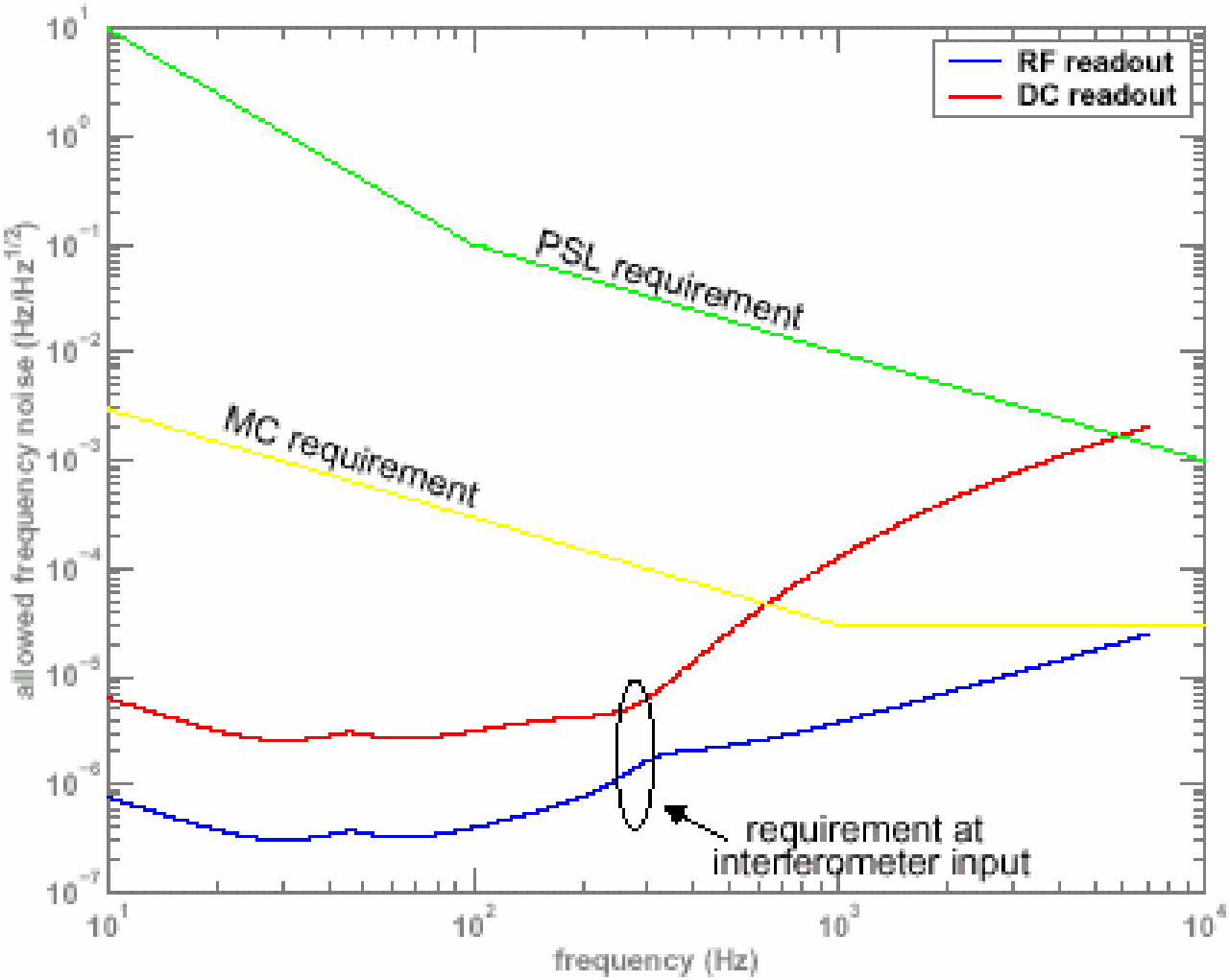
Prestabilized Laser PSL

- 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
  - passive modecleaning
  - active mode compensation?

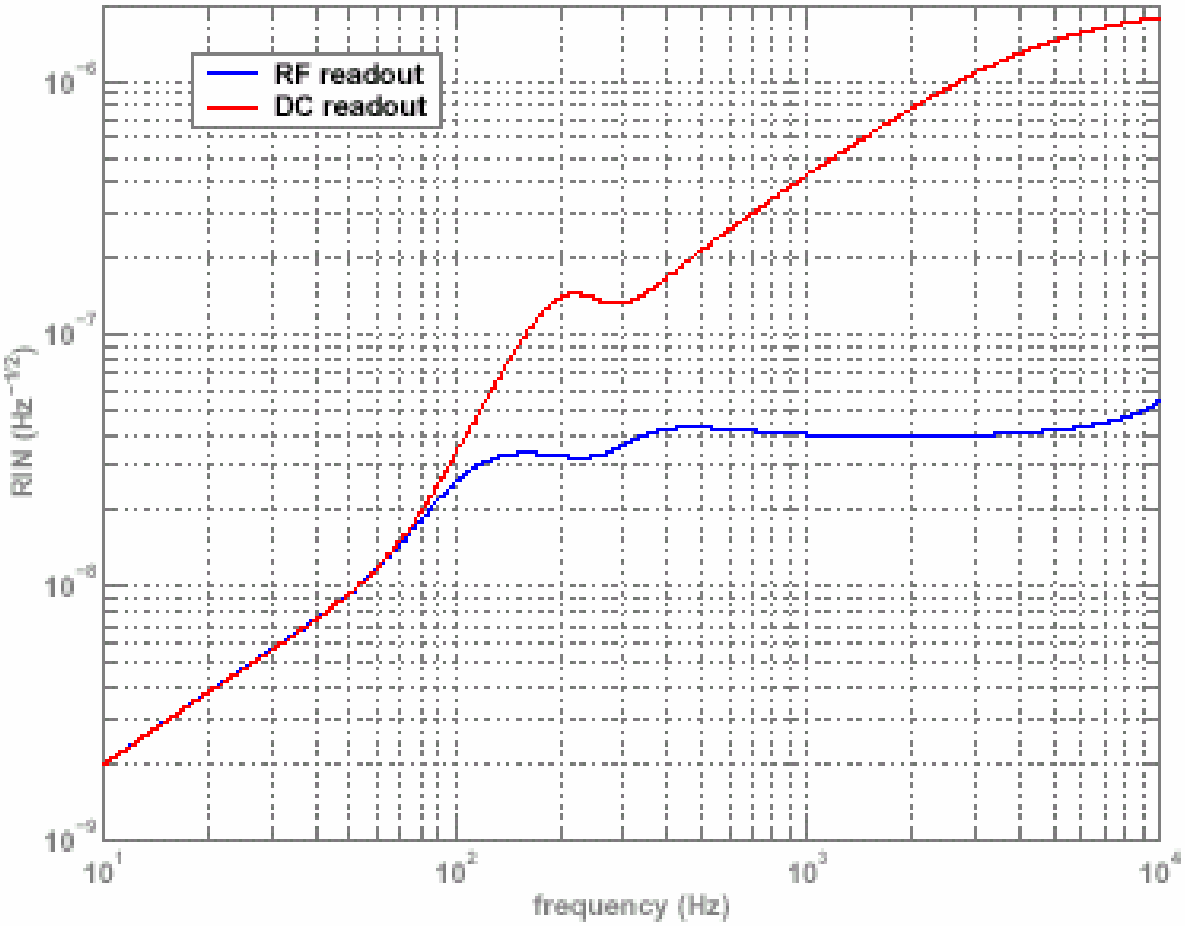




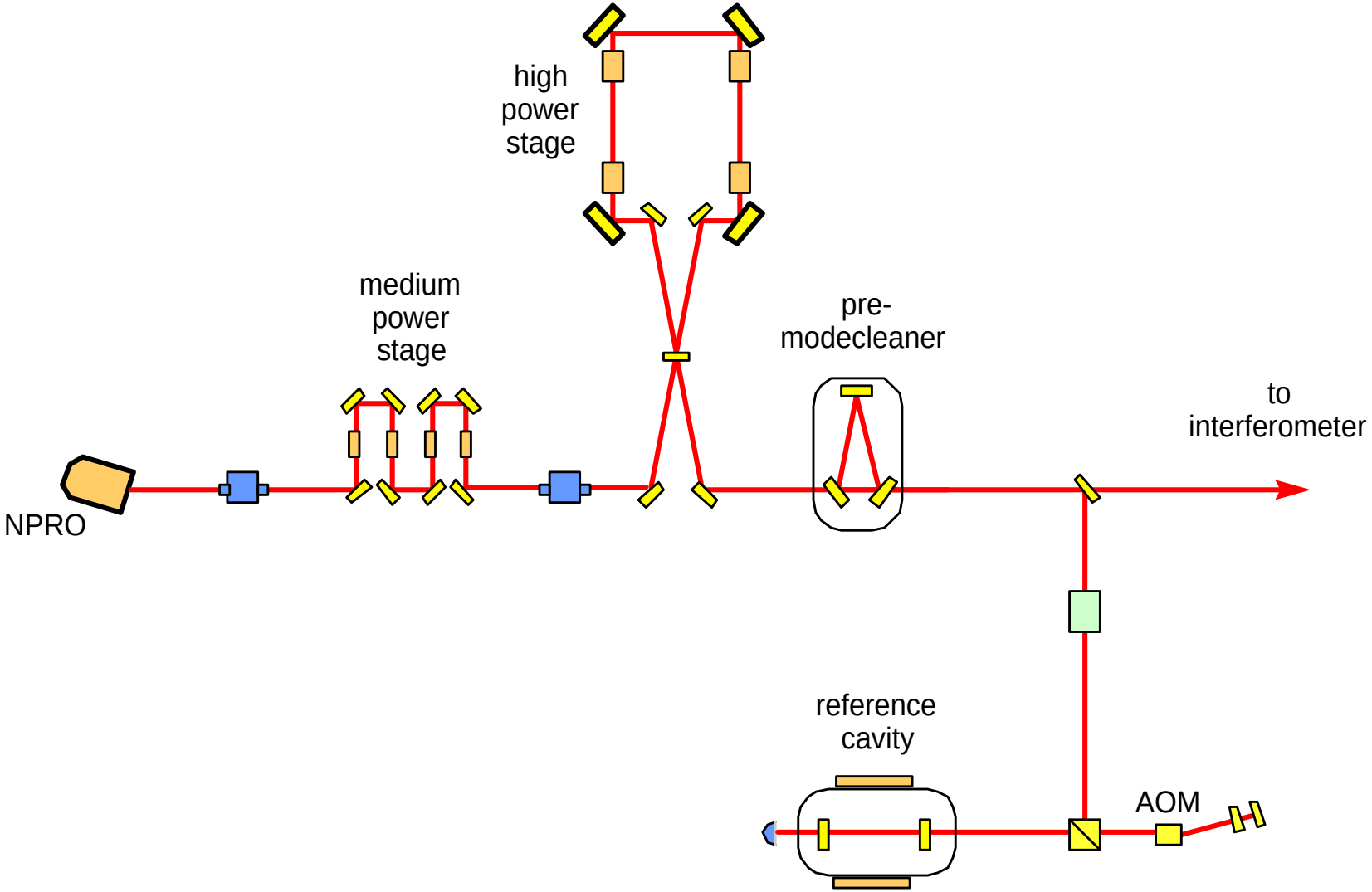
frequency noise requirement



intensity noise requirement



Advanced LIGO prestabilized laser



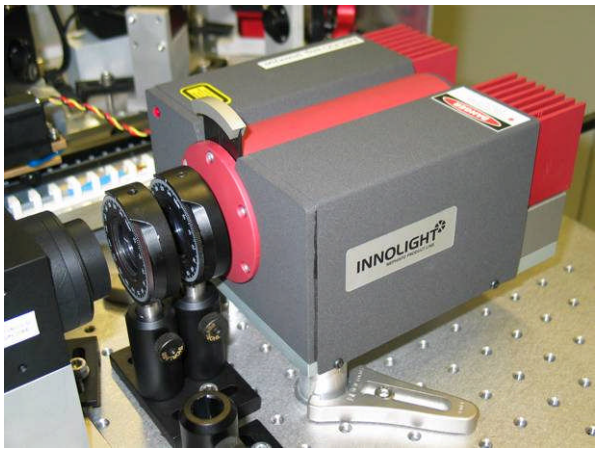
status May 2007

- AEI funding is approved
- contract between AEI and LZH is in place
- fully staffed (7 people @ LZH, 4 people @ AEI, spending money)
- LZH labs renovated
- first NPROs for the observatories arrived
- first Enhanced LIGO type laser will be delivered early summer
- MOU between AEI and LIGO Lab is in preparation

- new air condition
  - 15-20 air changes
  - higher temperature stability
  - Class 1000 Filter
- airlock
- particle counts:
  - floor: > 50.000
  - lab: ~ 2.000
  - table: 0
- 120 kVA UPS

Innolight Mephisto

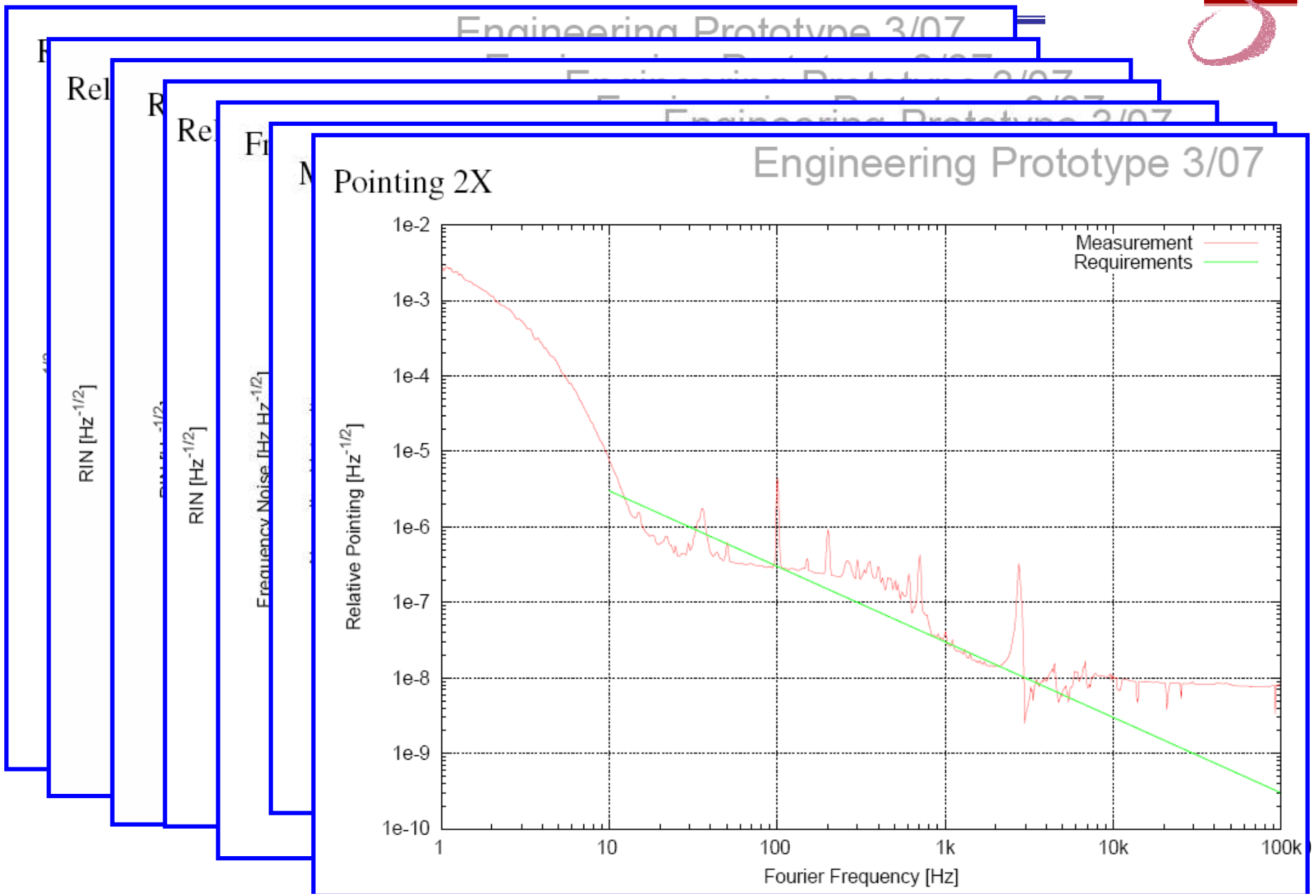
- 4 out of 8 Master lasers (2W NPROs) are delivered
- they have a special interface
- characterization program
  - power, slope, power in p-pol
  - RIN:
    - noise spectrum 1Hz – 100kHz,
    - time series (60min) rms
  - frequency noise
    - spectrum 1Hz – 100kHz
    - upper limit for drift
  - PZT and slow actuator calibration
  - beam quality
    - higher order mode content
    - beam pointing



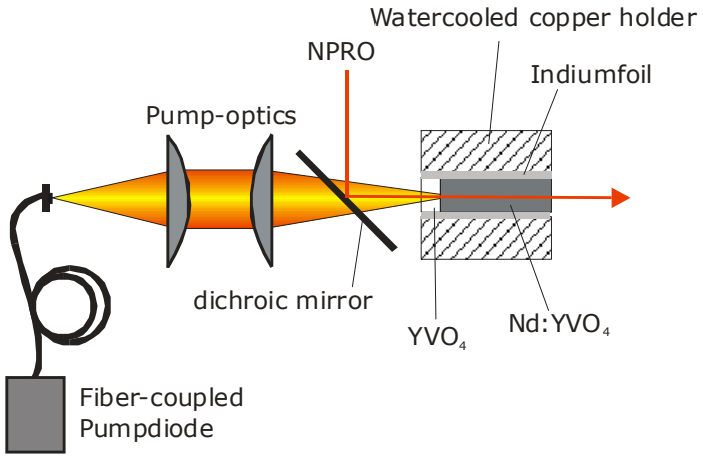
LD1 Power Monitor
GND
LD2 Power Monitor
GND
CTC1 Error
GND
n.c.
GND
n.c.
GND
LDTC1 Error
GND
LDTC2 Error
GND
Guard LDTC1
GND
Guard LDTC2
GND
n.c.
GND
n.c.
GND
NE Monitor
GND
Interlock

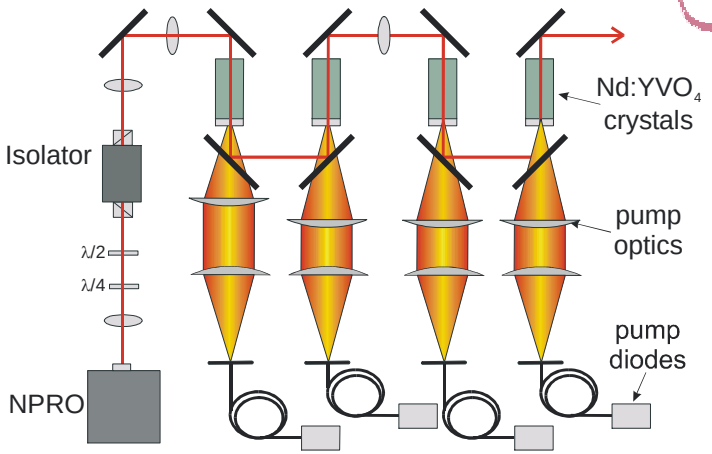
Set Temperature LD1
GND
Act. Temperature LD1
GND
Set Temperature LD2
GND
Act. Temperature LD2
GND
Set Temperature Crystal
GND
Act. Temperature Crystal
GND
Set Current
GND
Act. Current
GND
Status Laser ON
GND
n.c.
GND
Remote SW
GND
Remote SW ON
GND
Remote SW OFF

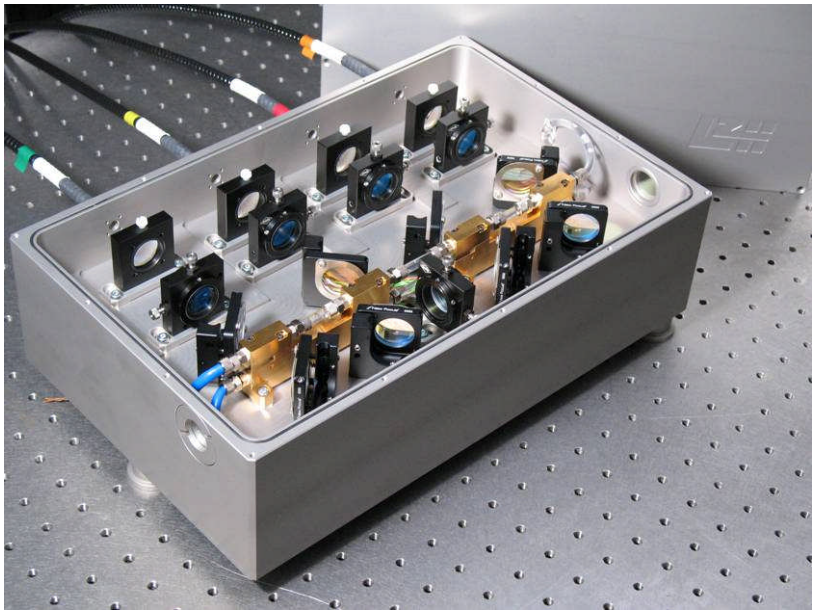
Advanced LIGO NPRO characterization



amplifier design



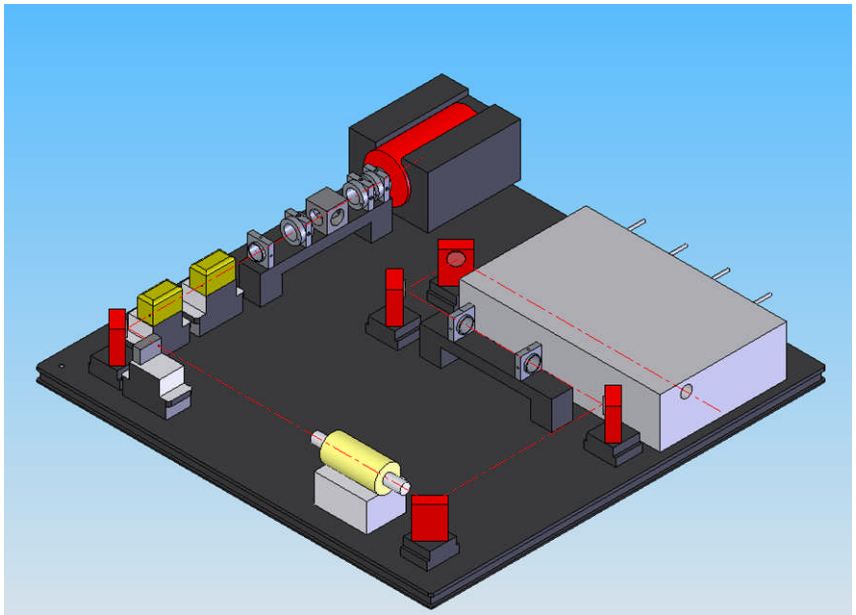




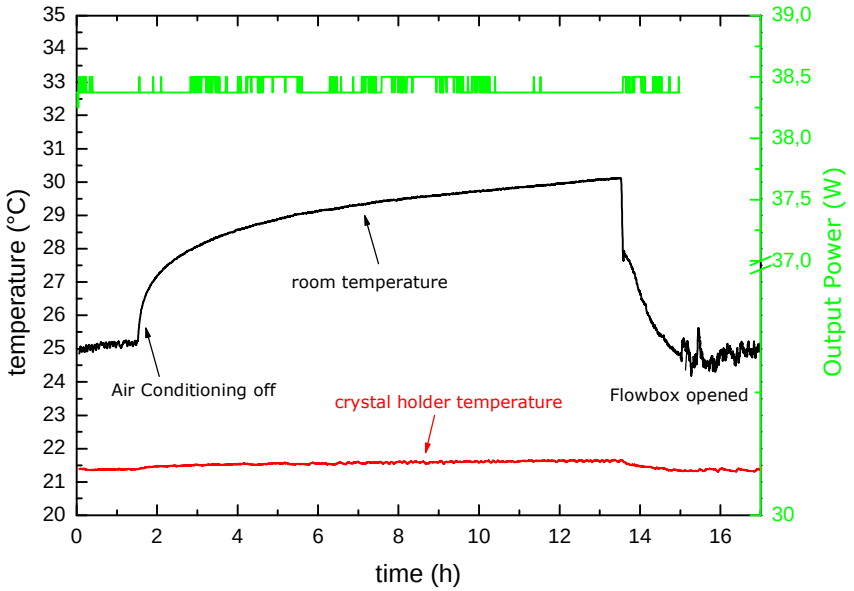
- Crystal:
  3 x 3 x 10 mm^3 Nd:YVO_4
  8 mm 0,3 % dot.
  2 mm undoped endcap
- Pump diode:
  808 nm, 45 W
  400 µm fiber diameter
  NA=0,22
- amplifier:
  38W for 2W seed and 150W pump

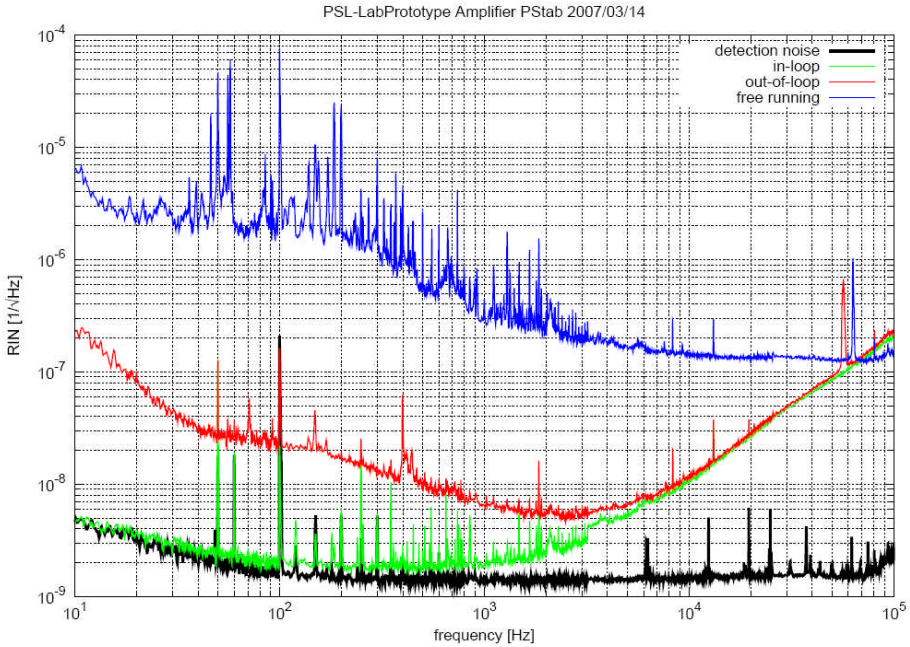
Frede et al, *Opt. Express* **22** p459 (2007)

Advanced LIGO 35W front-end

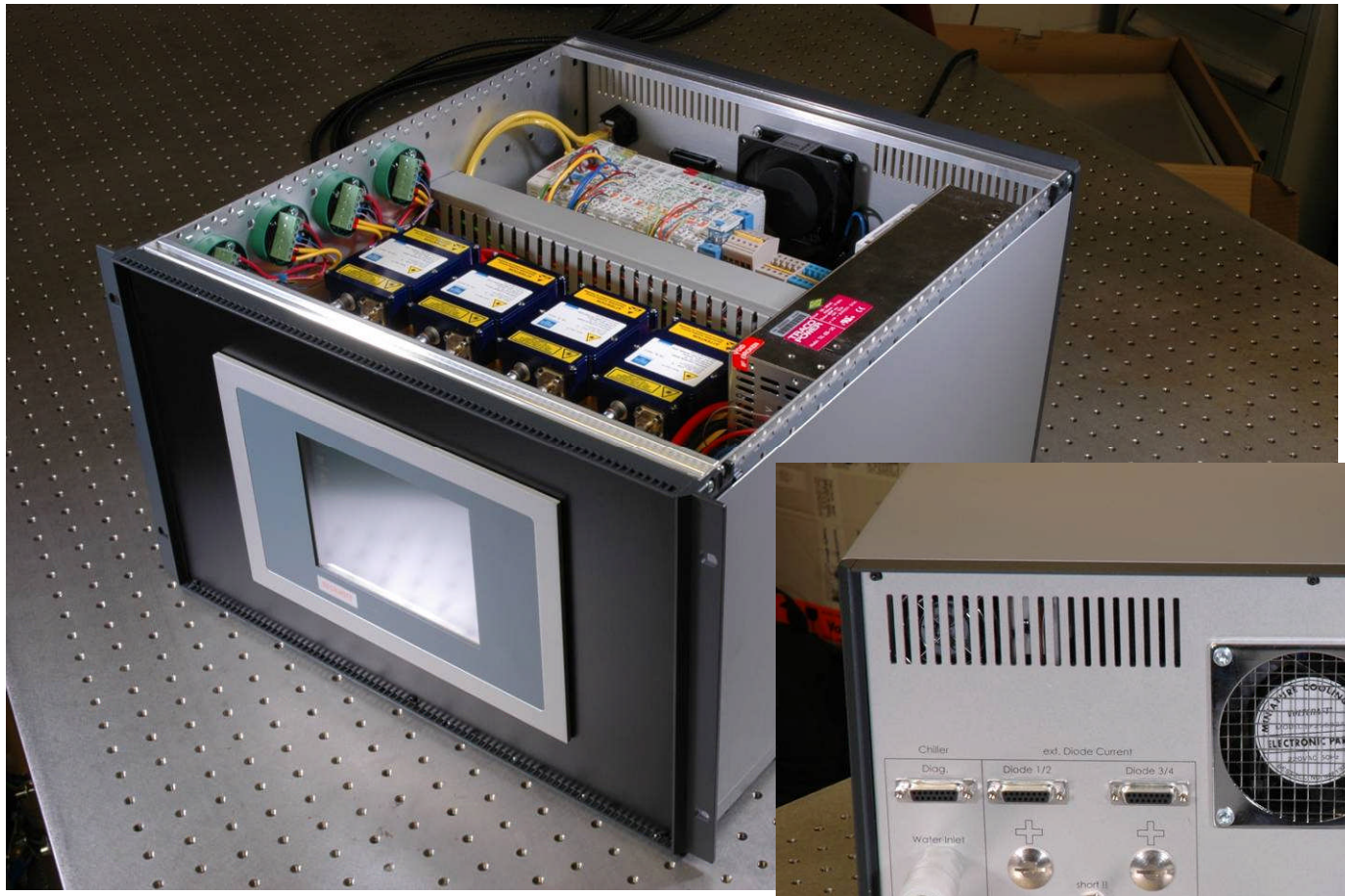


- front end will be assembled on breadboard and delivered in single housing
- AOM and isolators included
- NPRO and amplifier controlled via Beckhoff touchpad
- interface to EPICS

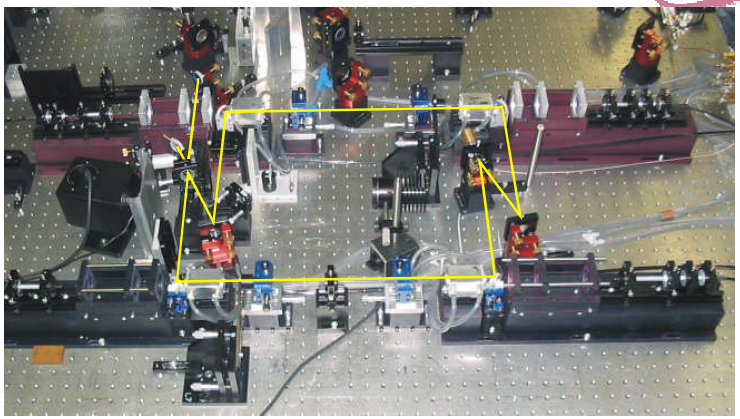




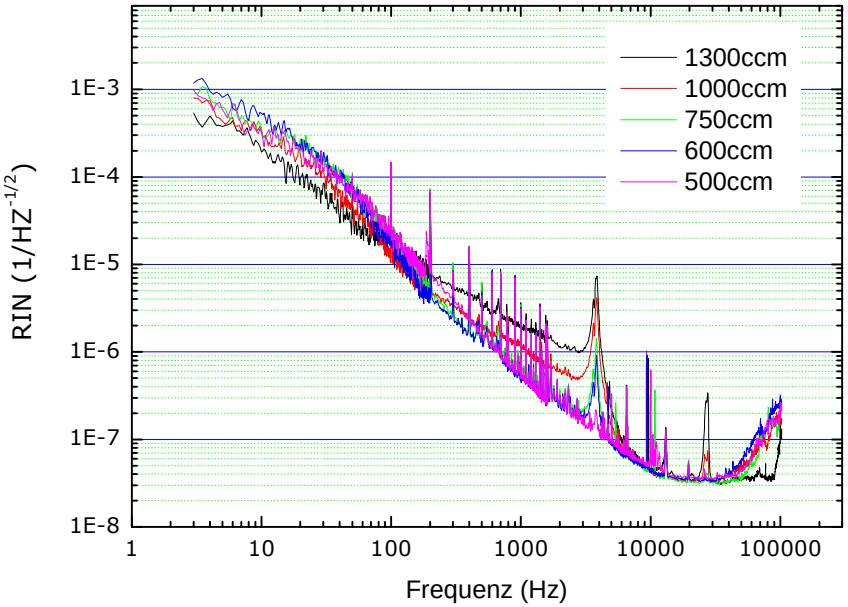
front end – pump power and control

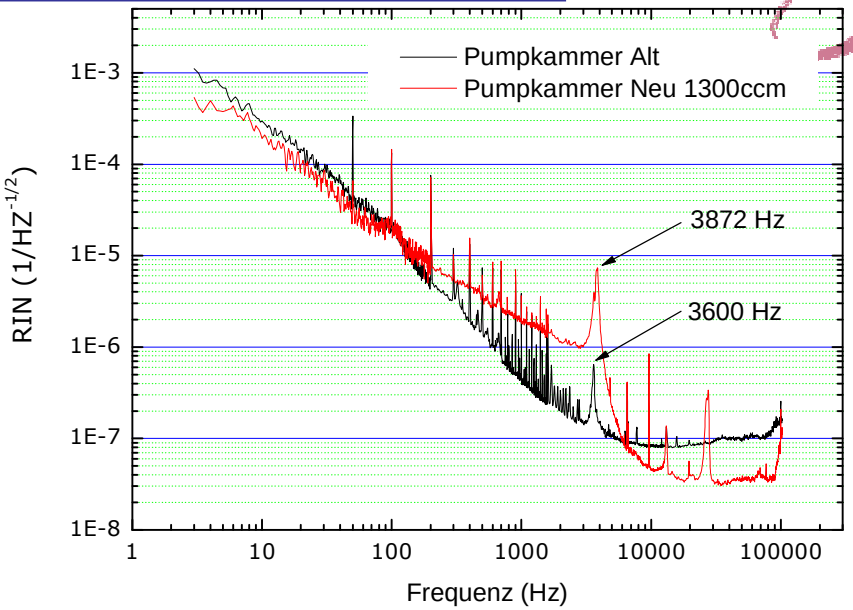


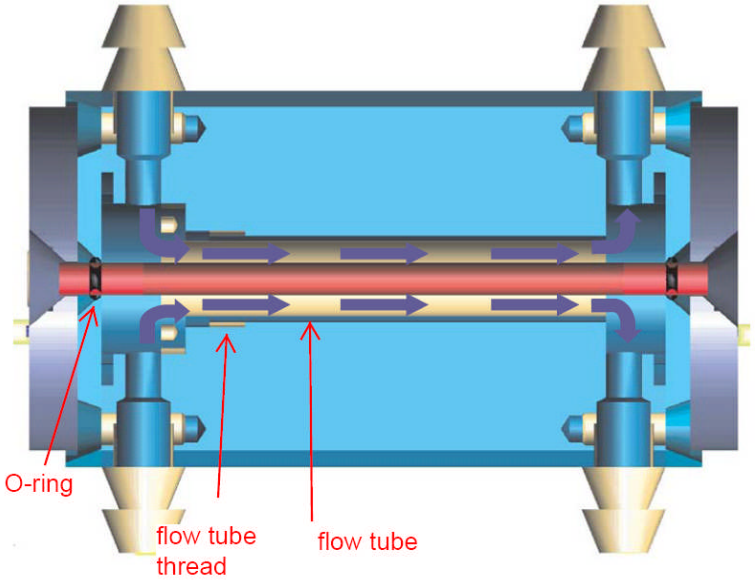
High Power Stage



pump-chamber design: RIN/ water flow

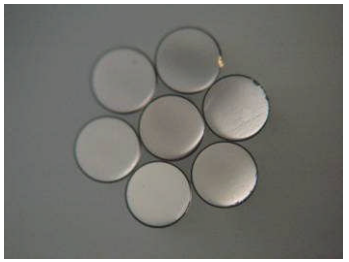


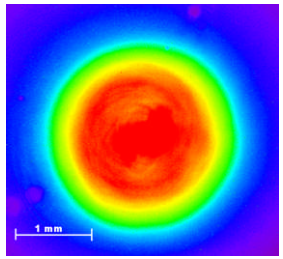


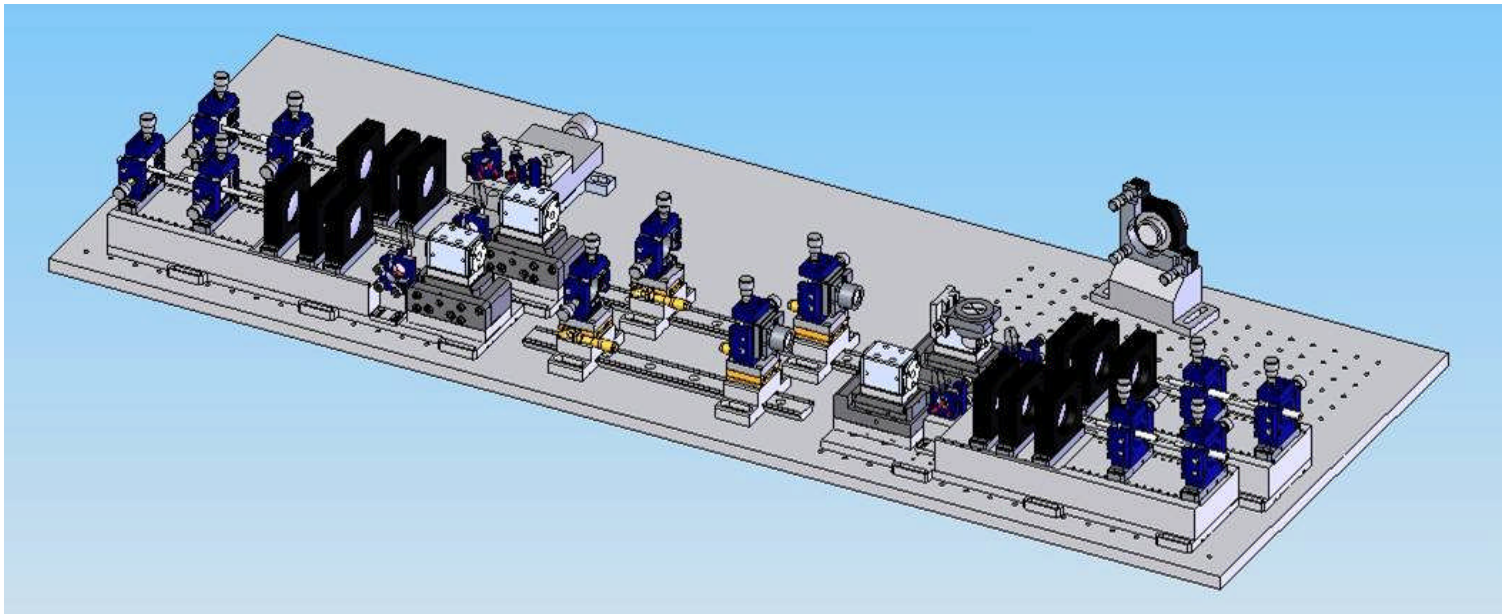


functional prototype

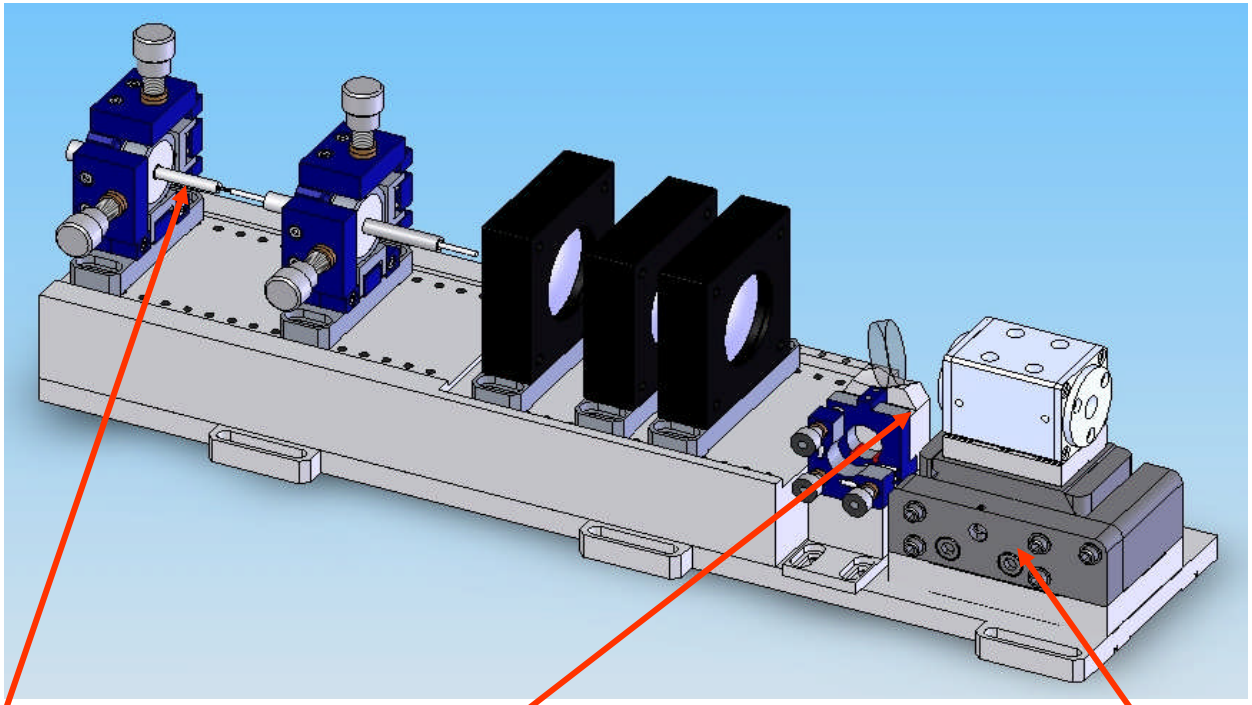
- 7 instead of 10 fibers
  - 7 x 45 W
- new homogenizer
  - higher pump brightness
- new laser head design
- whole resonator on base plate







improved laser head design

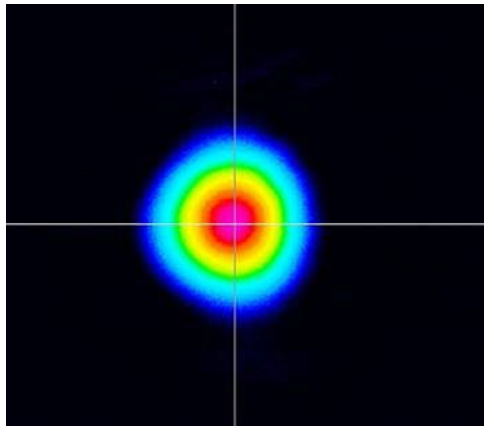


ceramic parts to prevent moving due to heat-load from spraylight

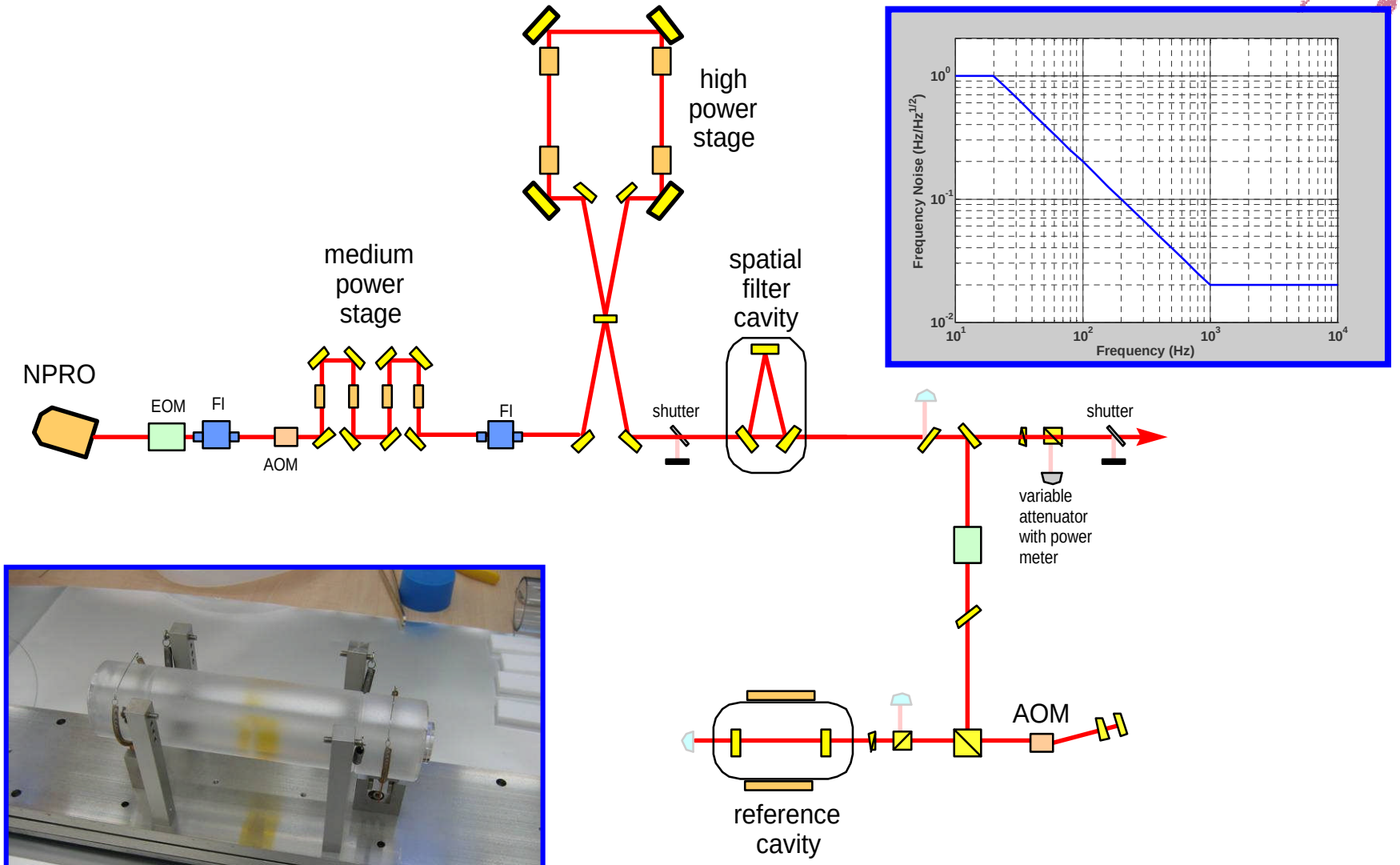
X-Y-Z translation and rotation stage for crystal alignment

status of functional prototype

- front end
  - components in house
- high power stage
  - mechanical design ready
  - components in mechanical workshop
  - diode boxes currently build
- standing wave resonator test
  - new fiber design works
  - high brightness pumping gives similar results as achieved with 10 diodes
  - 90W $TEM_{0,0}$ output power

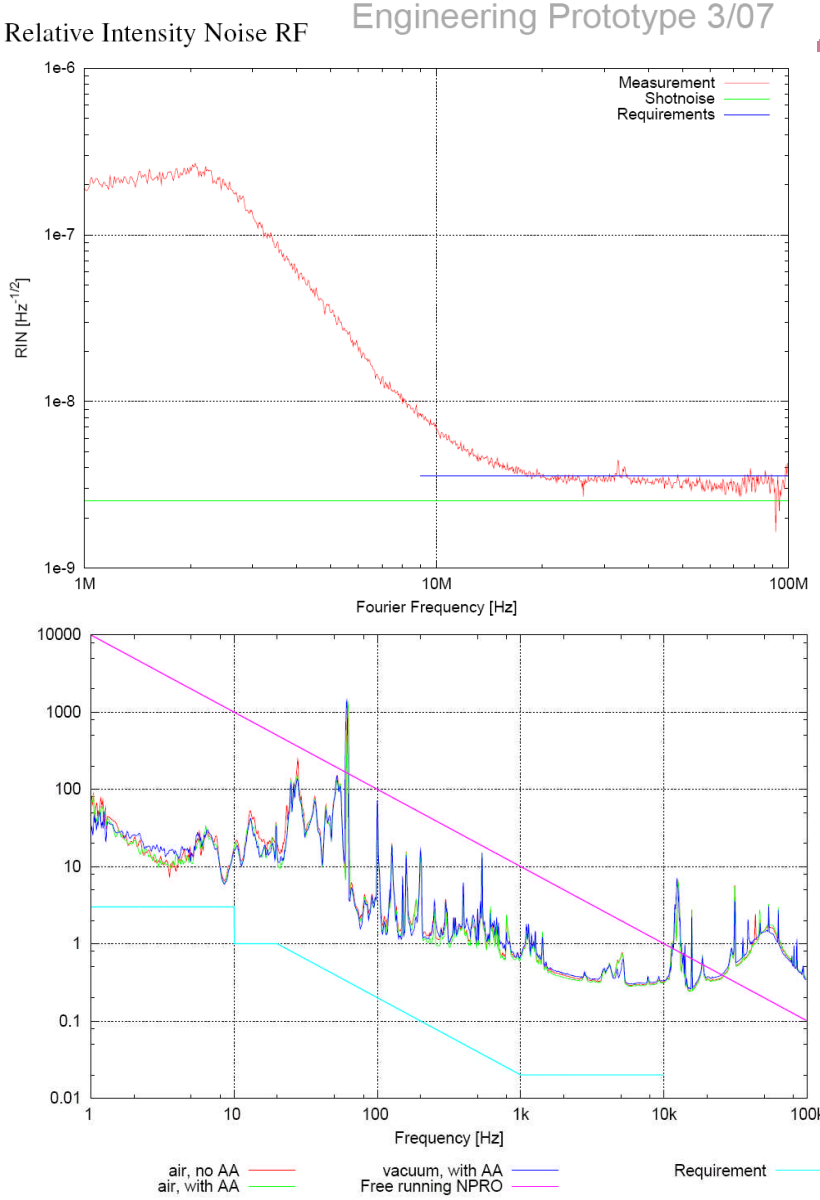


frequency stabilization

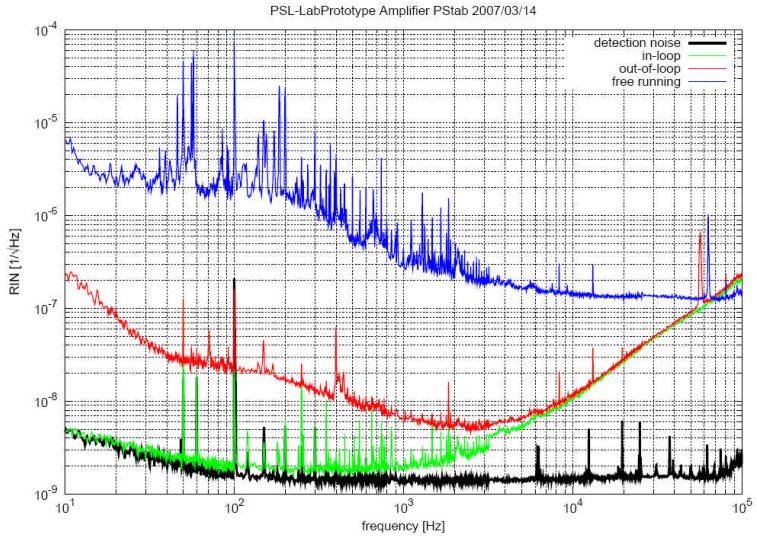


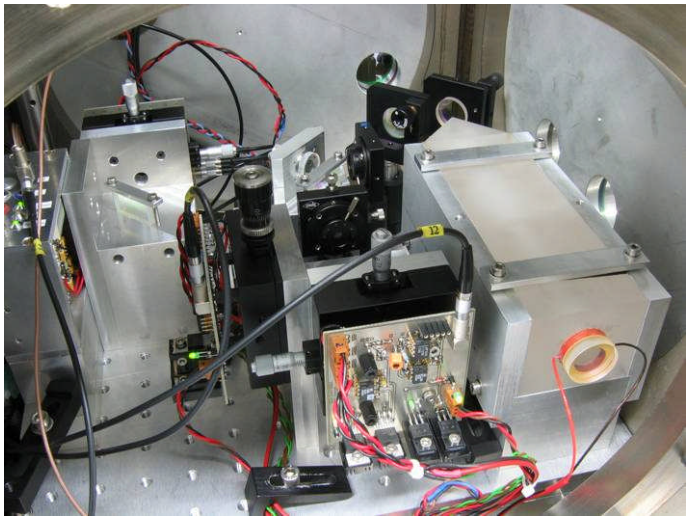
PMC design

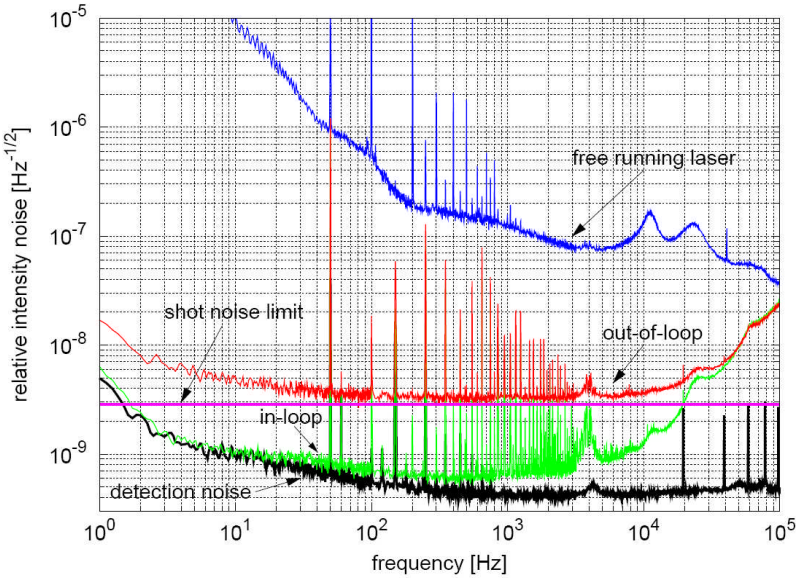
- thermal loading
  - PMC design based on thermal loading experiment by A. Bullington (Stanford)
  - assumption: less than 3ppm absorption
  - allow for a total of 10mW absorbed power
  - finesse 50 (3kW circulating power)
- in sealed housing, vacuum required ?
- rf filtering
  - 4dB @9MHz
  - sufficient? , increase length?

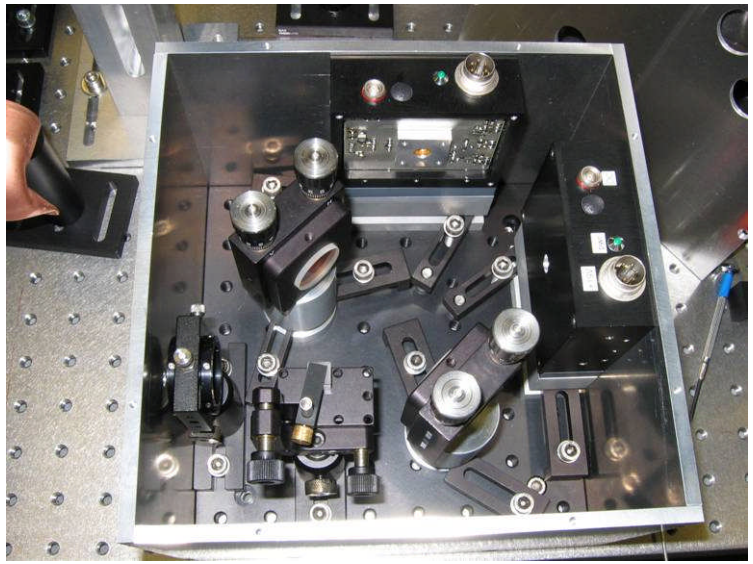


power stabilization



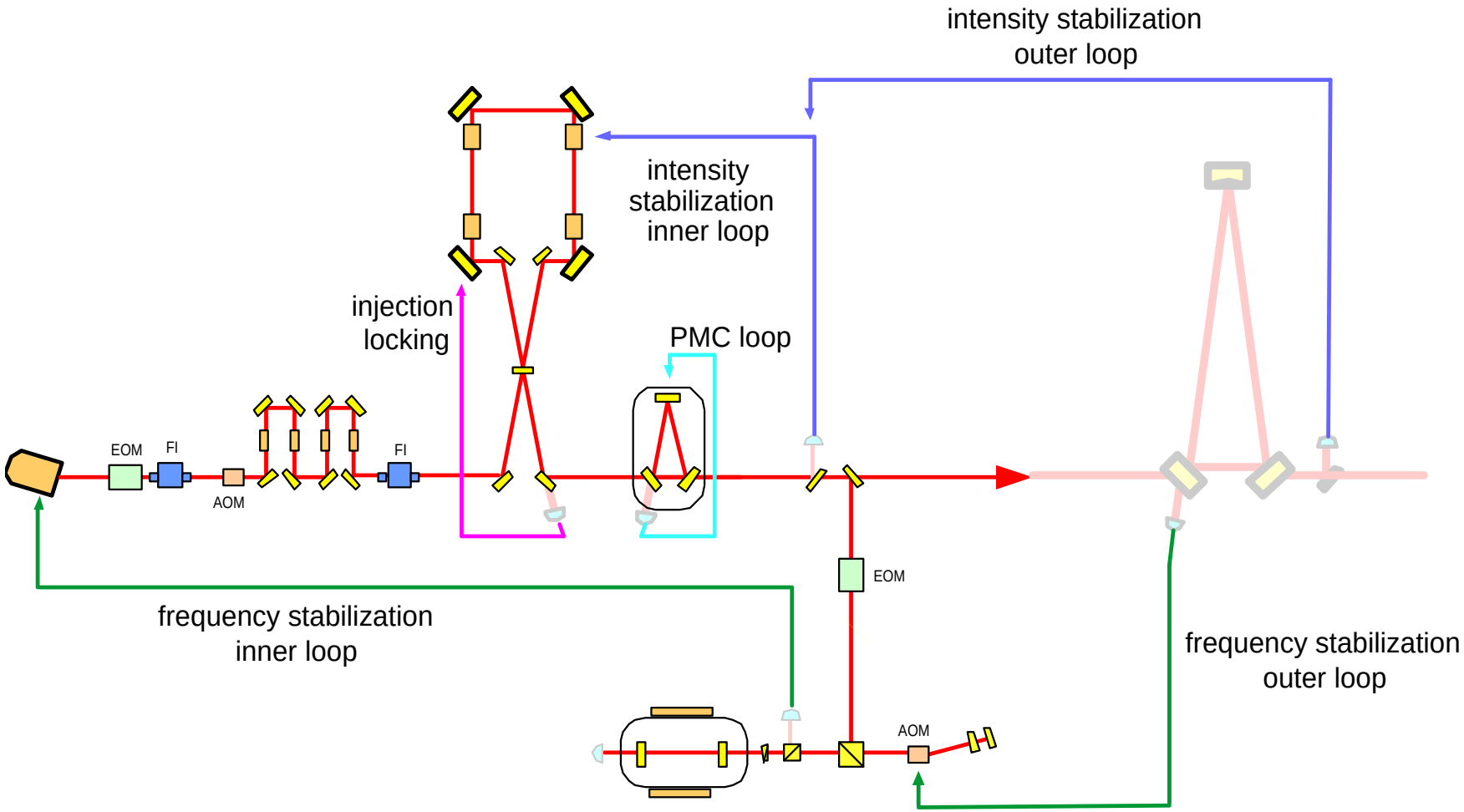




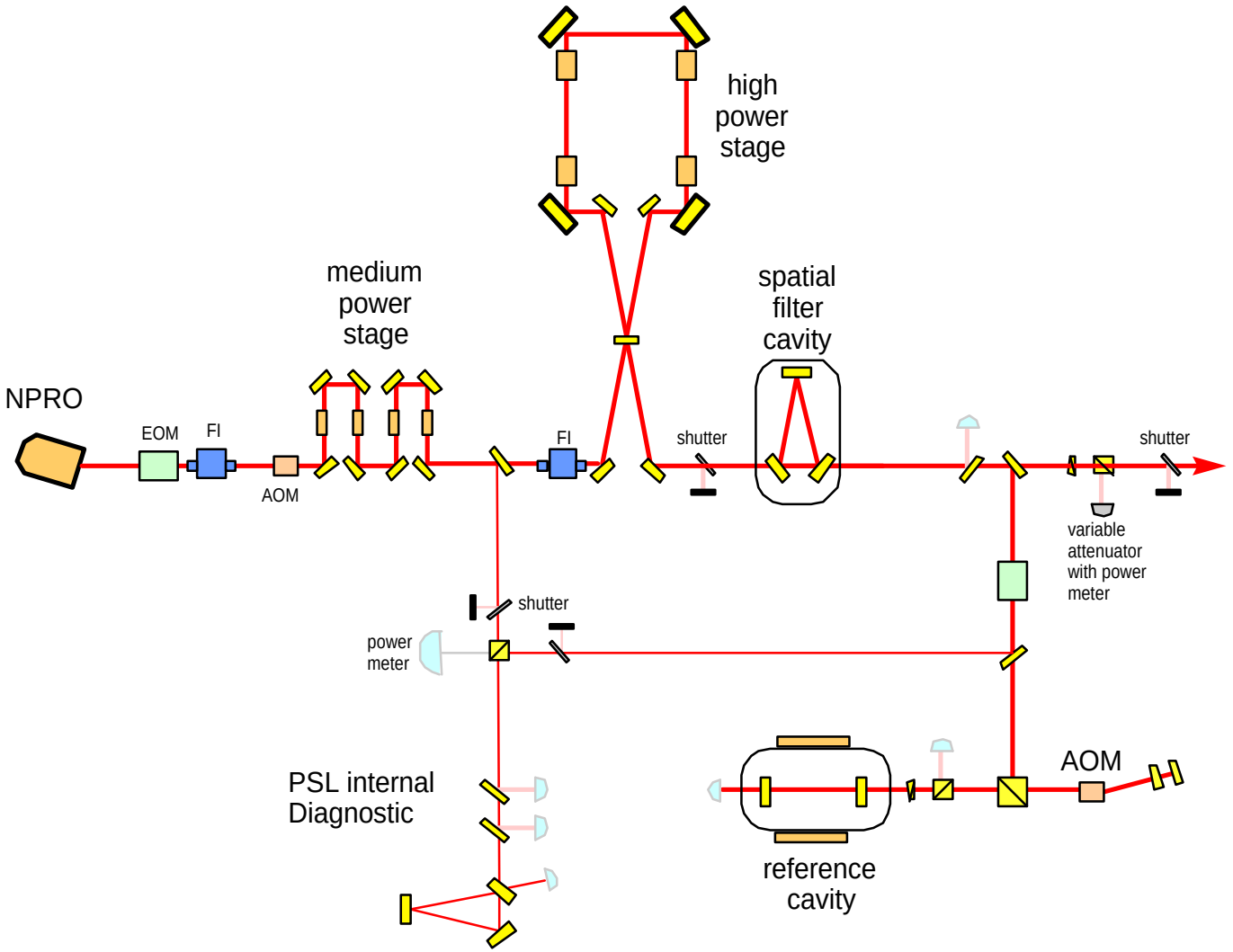


Seifert et al., Opt. Lett. 31 (2006) 2000

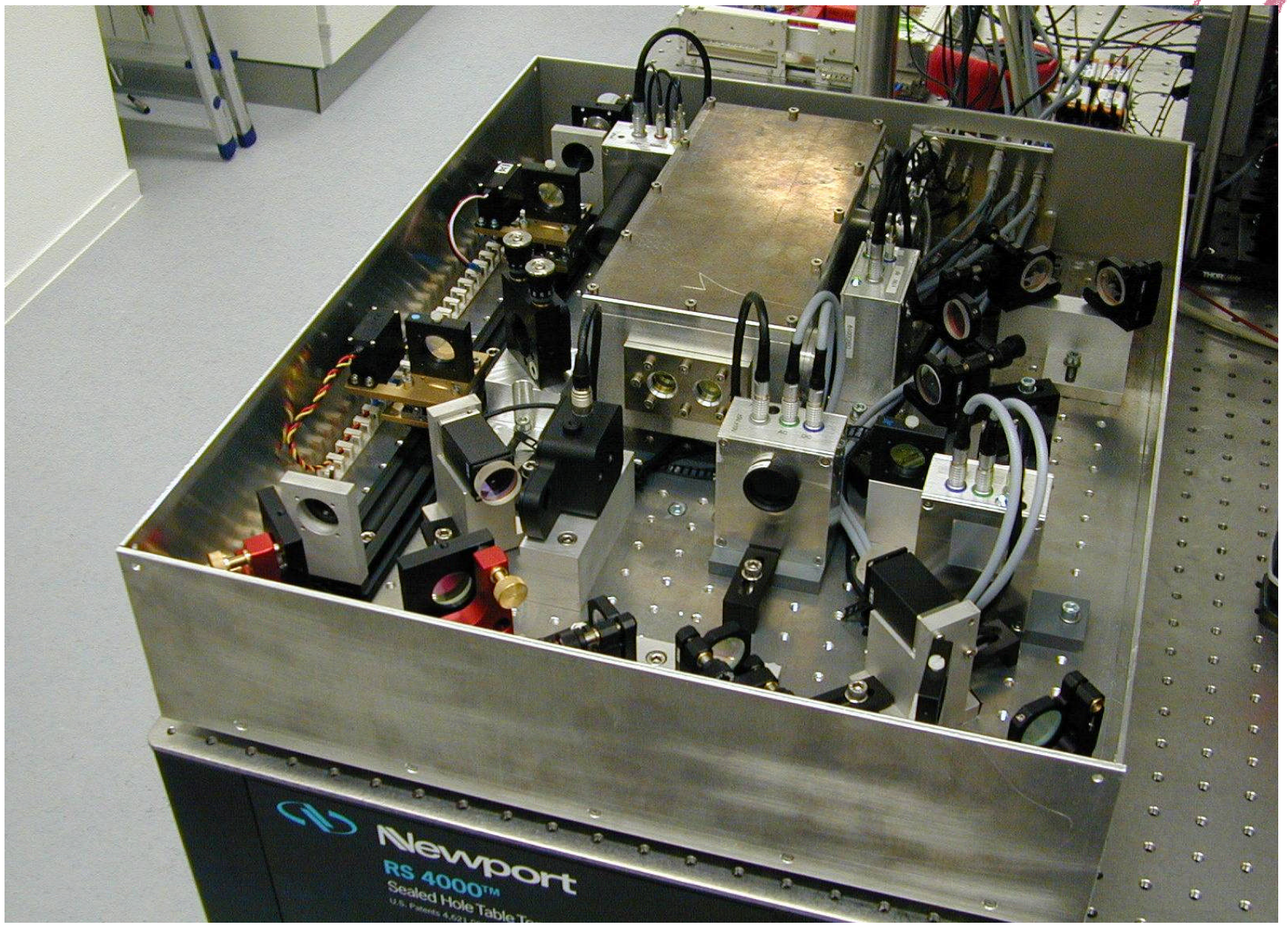
PSL - Stabilization scheme



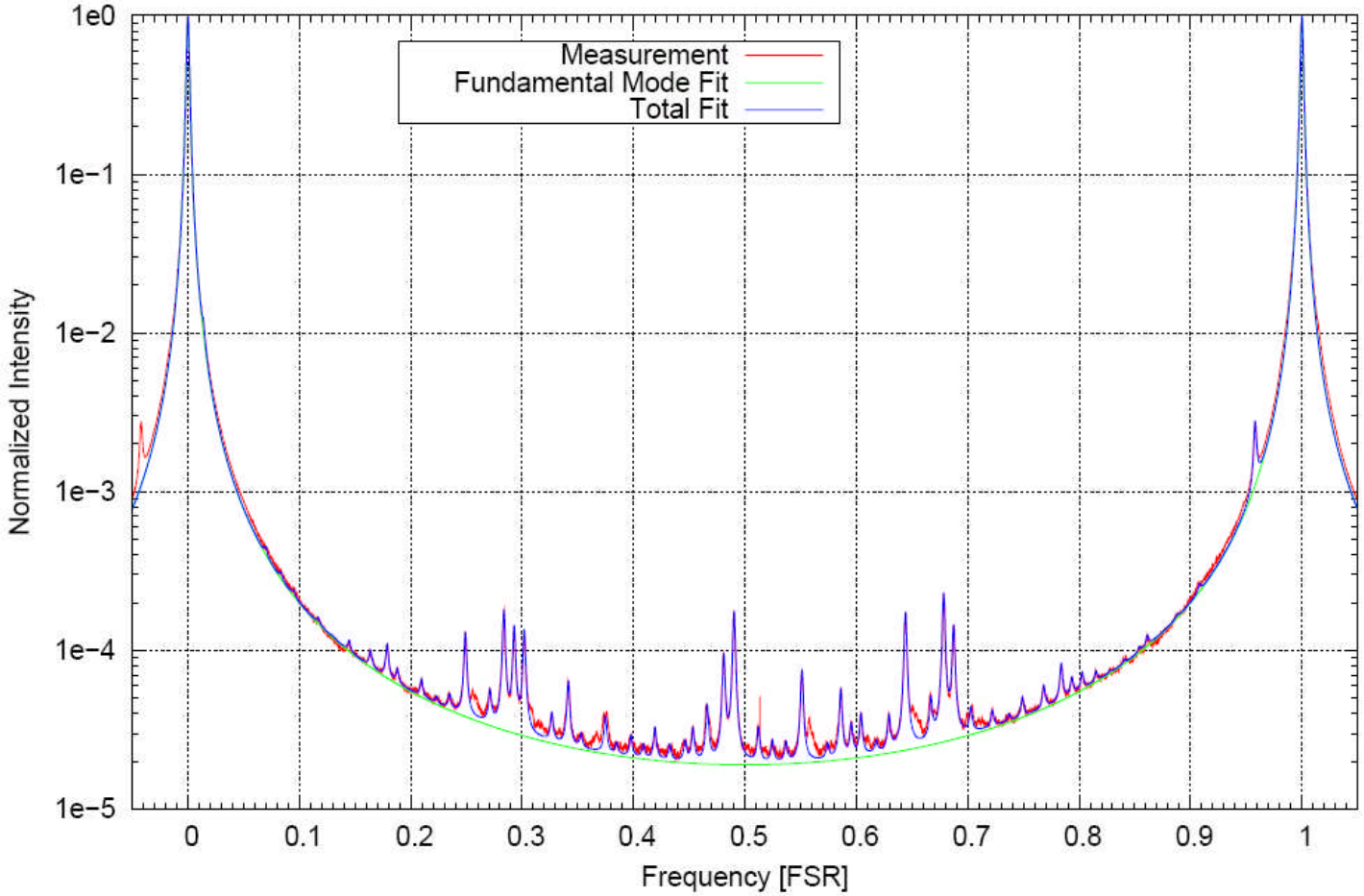
diagnostic bread board



beam diagnostic setup

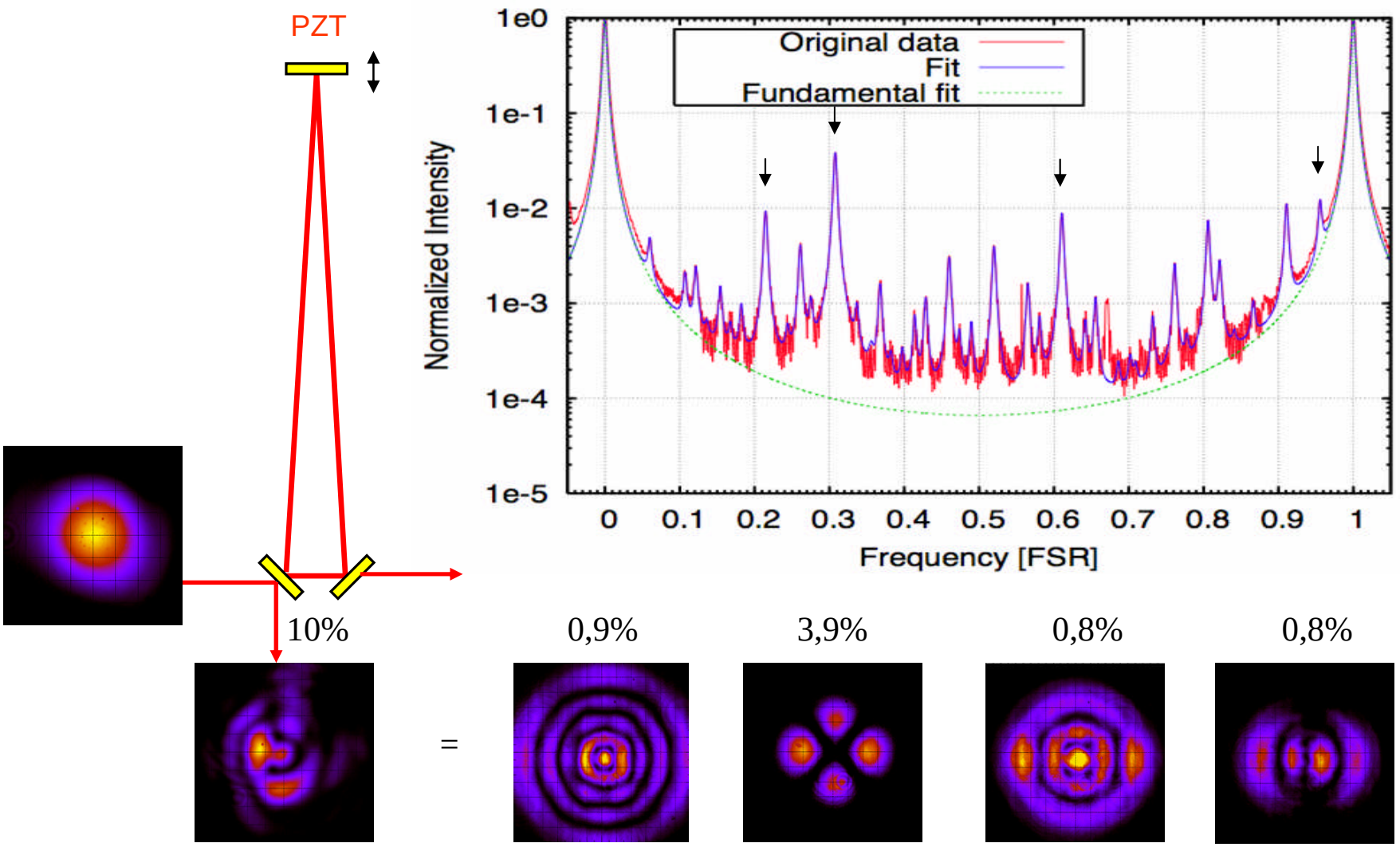


NPRO (filtered by a fiber and PMC)

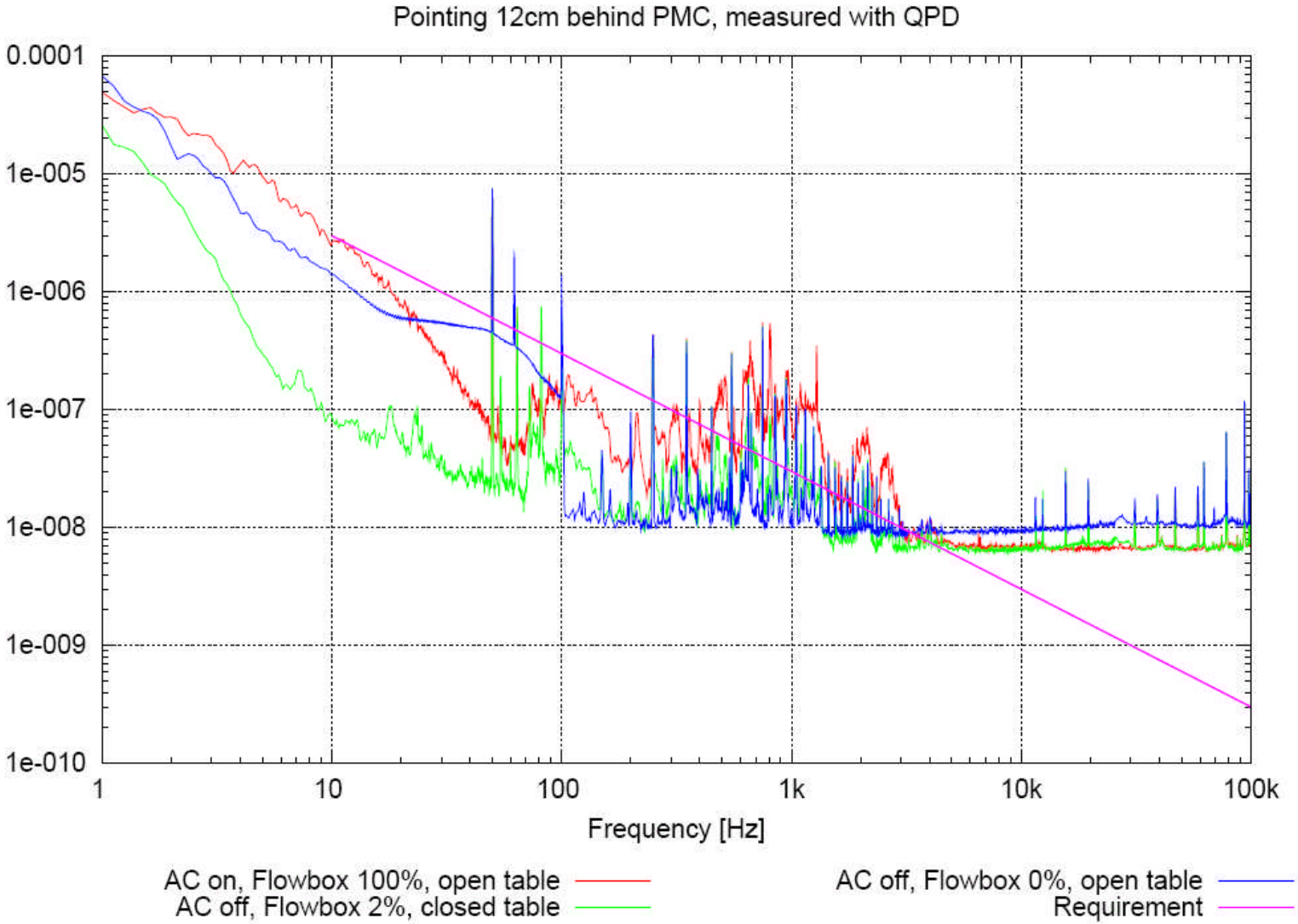


Finesse: 366 ±5
higher order mode power: 0.56% ±0.3%

Gaussian mode expansion



beam pointing



[svn://pat/diss/Data/2007-02-16/behindpmcparticles.plt, rev. 791, 13 Mar 2007, Patrick Kwee, kwee@bigfoot.de]

location and control - Advanced LIGO