

# Pre-stabilized Laser System (PSL)

Technical Status

NSF Review of Advanced LIGO Project

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and the AdvLIGO PSL team



- 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 interfaces and diagnostic tools
- define and implement laser safety procedures

# PSL Requirements

## Power:

- » 165W in gaussian TEM<sub>00</sub> mode
- » less than 5W in non- TEM<sub>00</sub> modes

## prestabilization

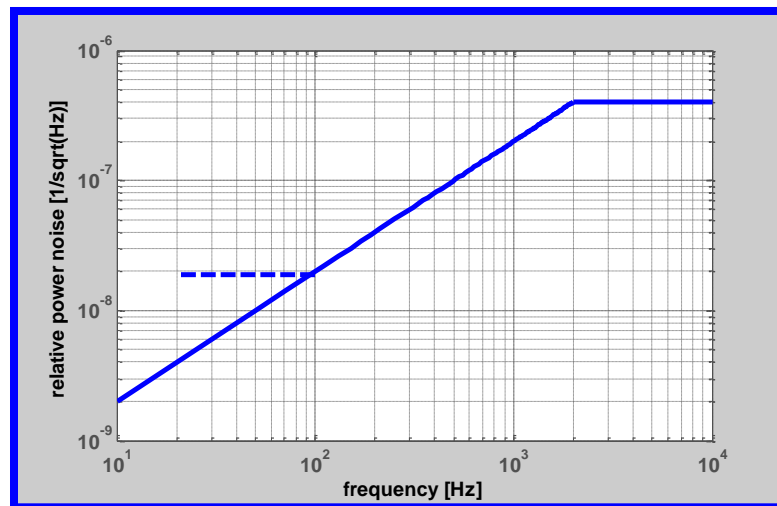
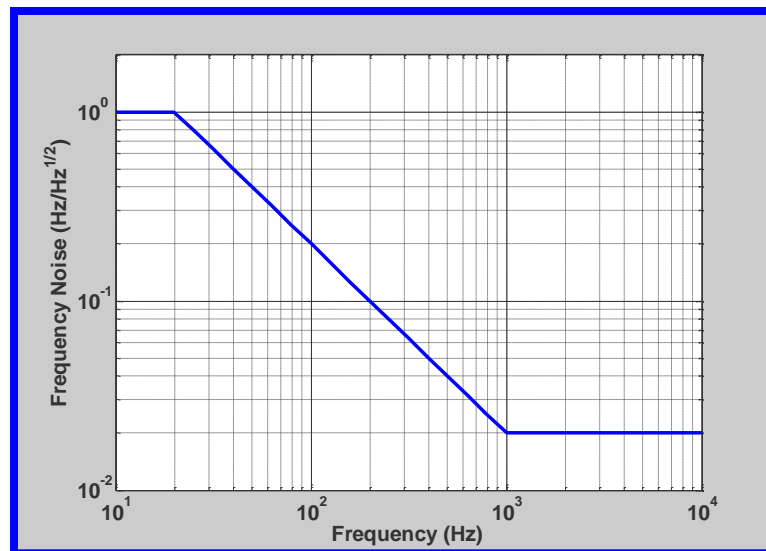
- » frequency noise
- » power noise
- » pointing fluctuations

## actuators PSL-external control:

- » power actuator
- » frequency actuator

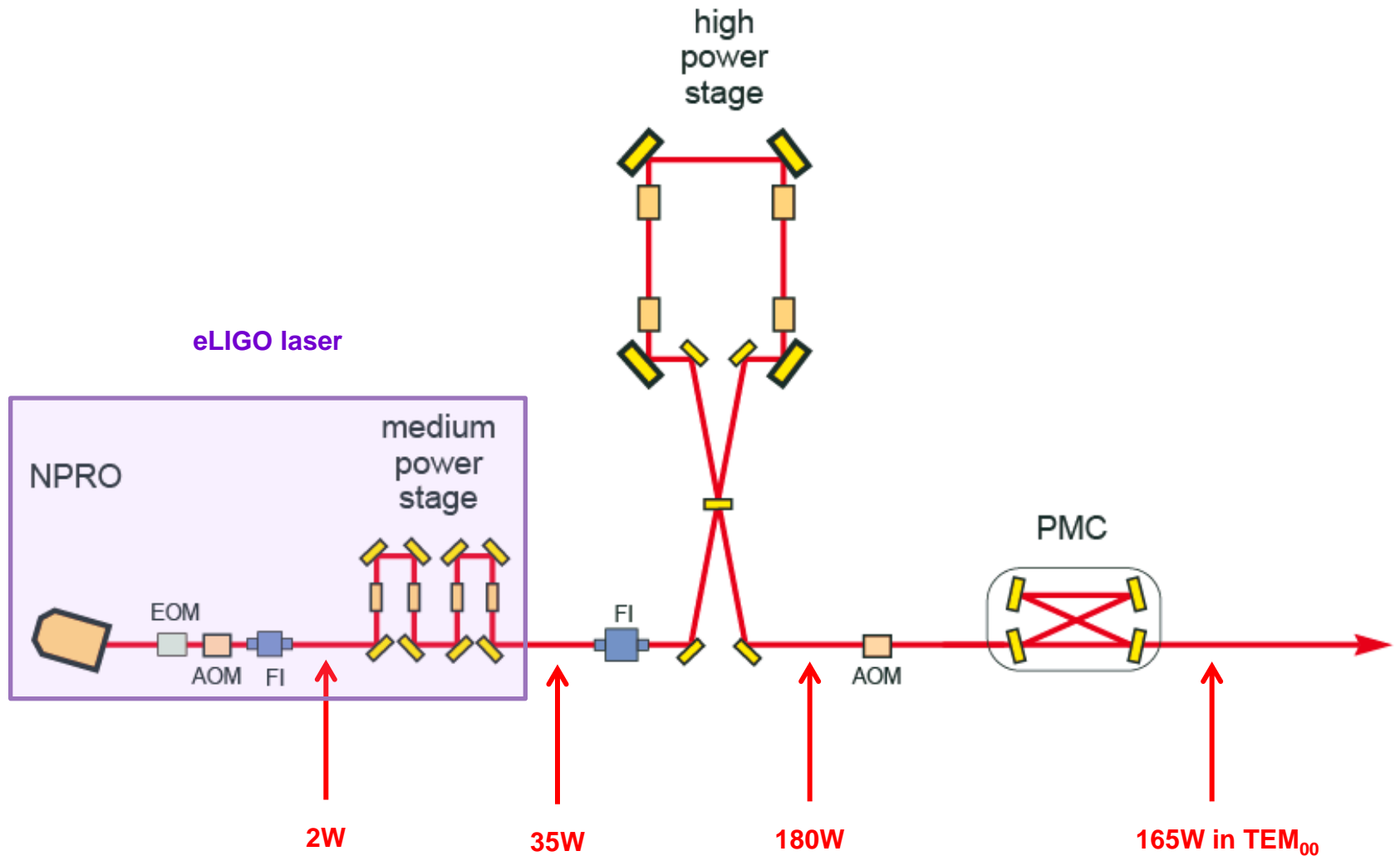
## Drift:

- » 5% power drift over 24hr
- » 100kHz frequency drift over 100s



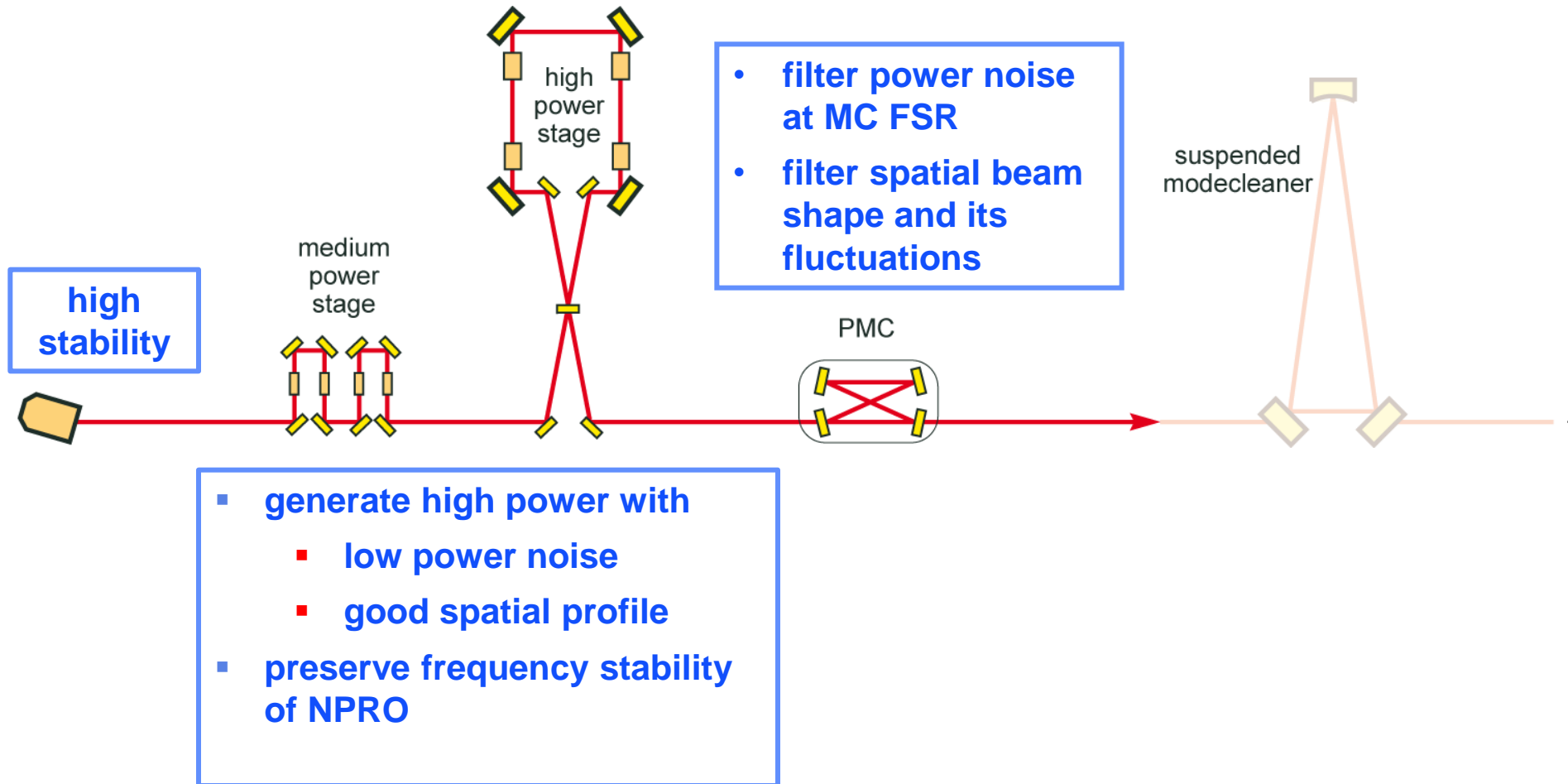


## advanced LIGO laser - layout



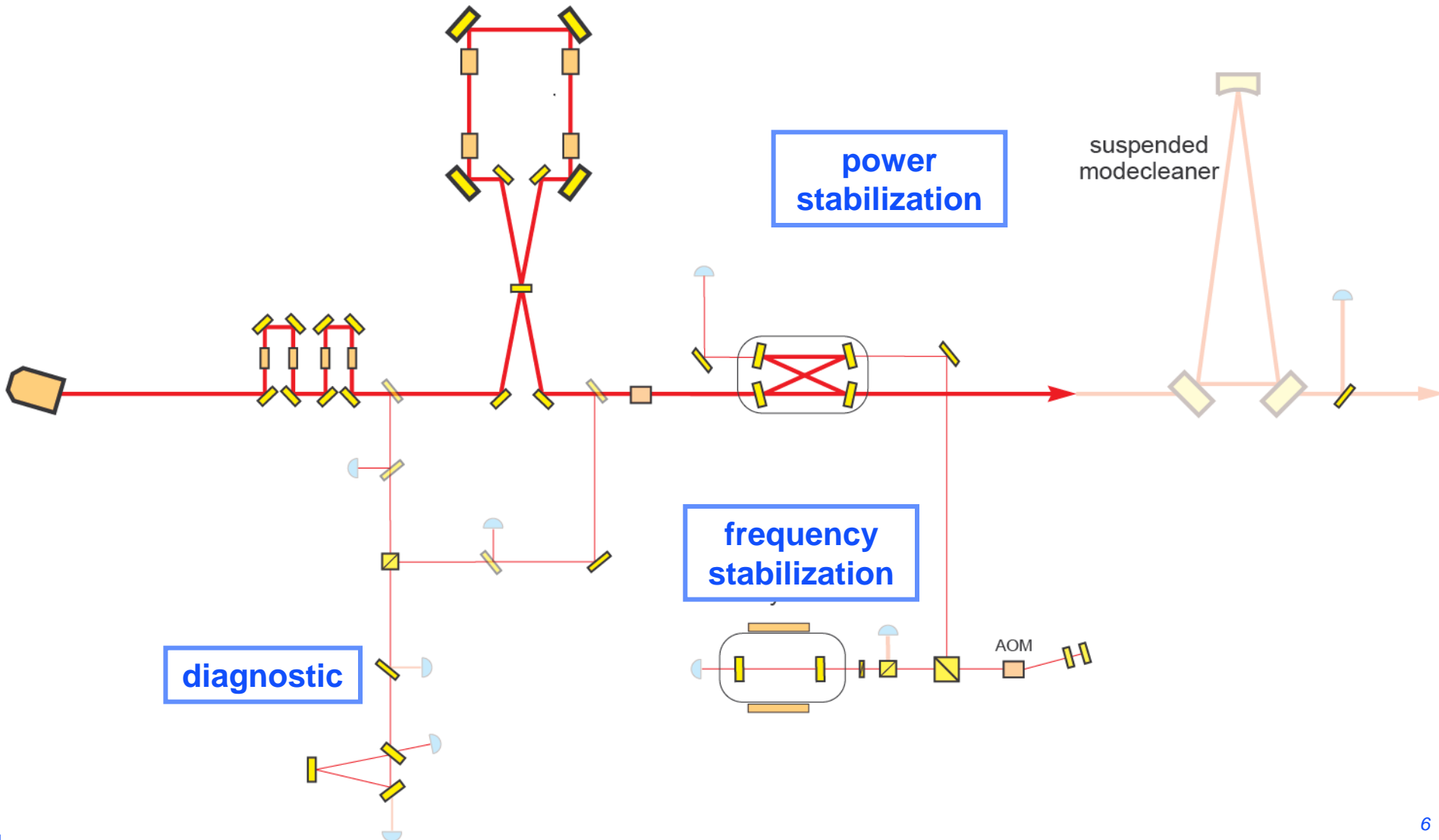


## purpose of PSL components I

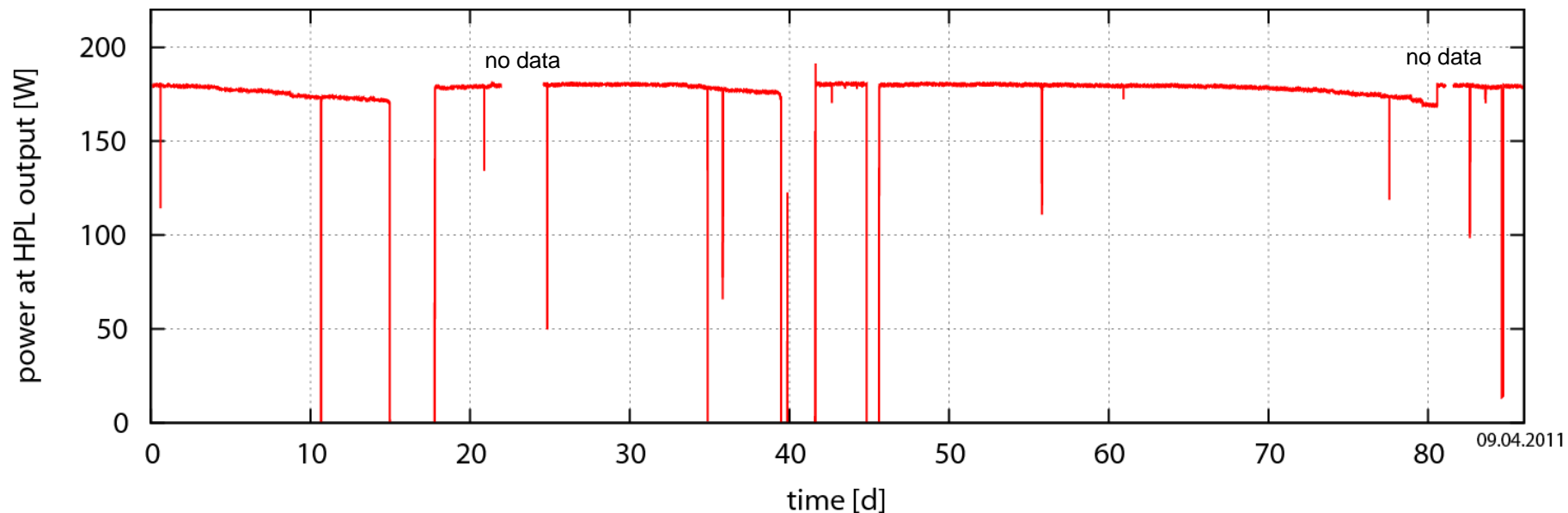




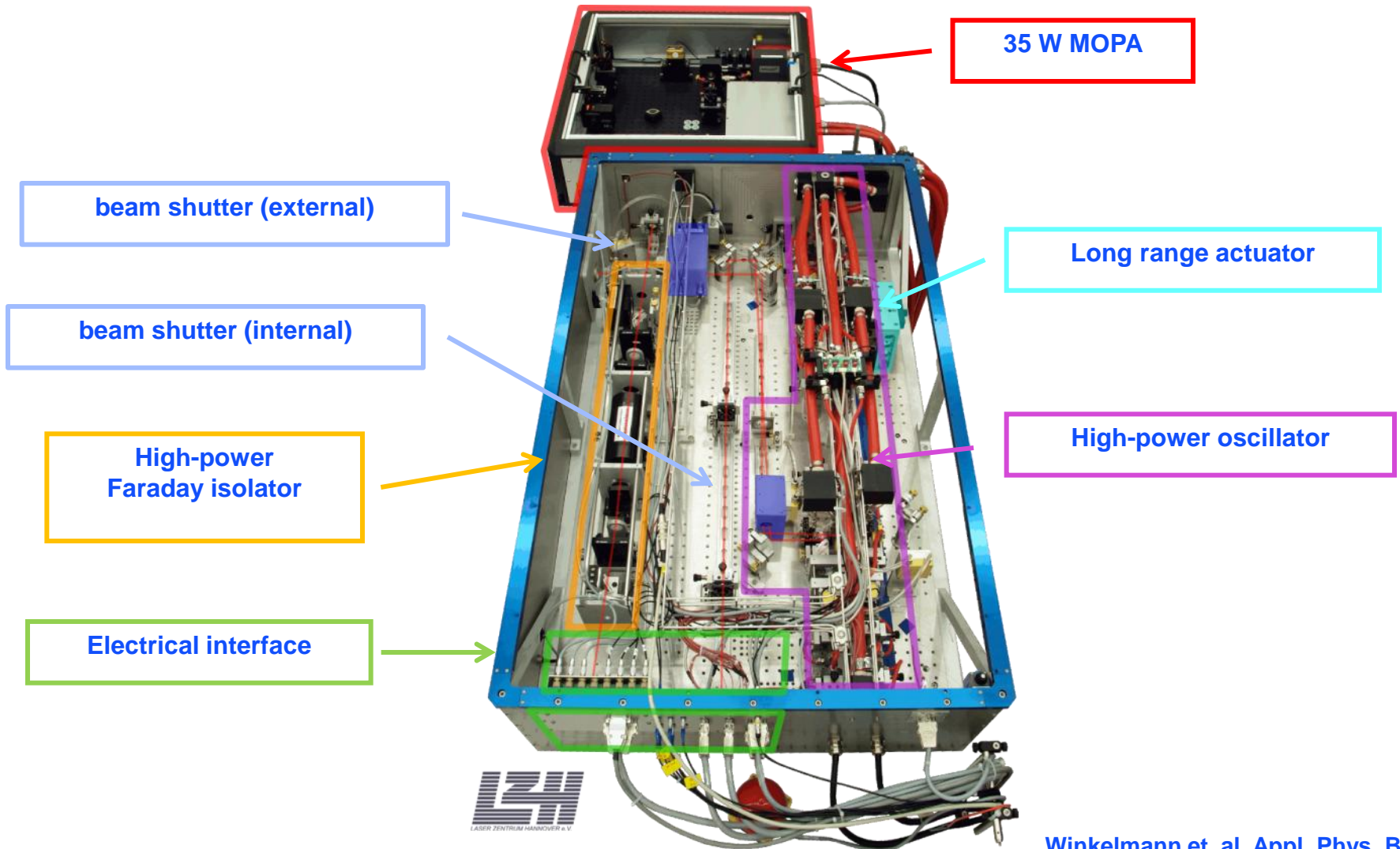
## purpose of PSL components II



# performance of the PSL Reference System @ AEI



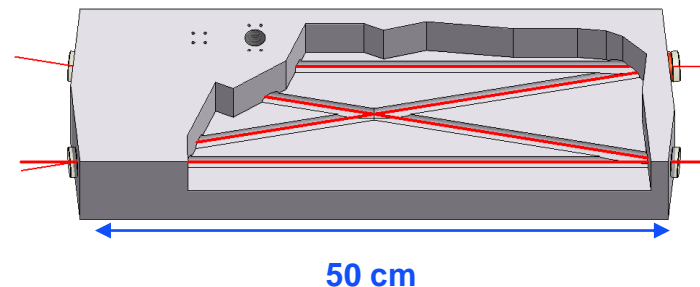
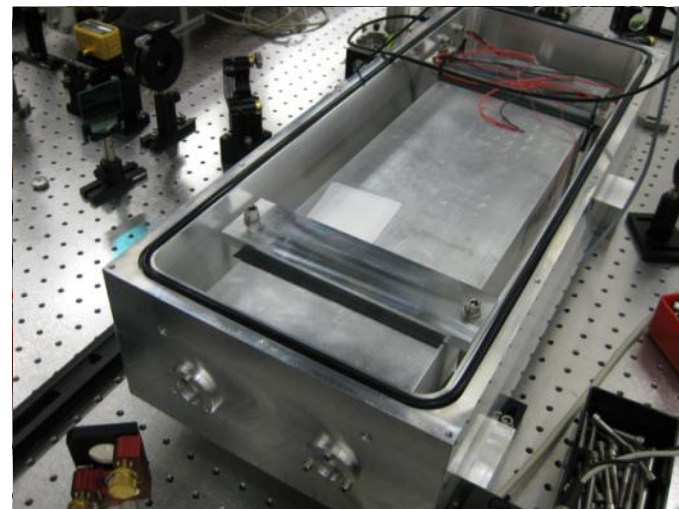
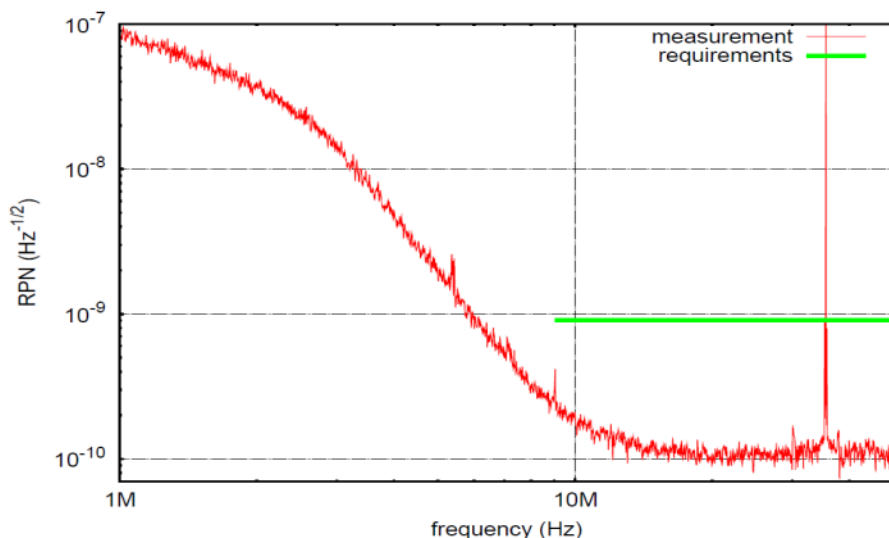
# 200W high power laser



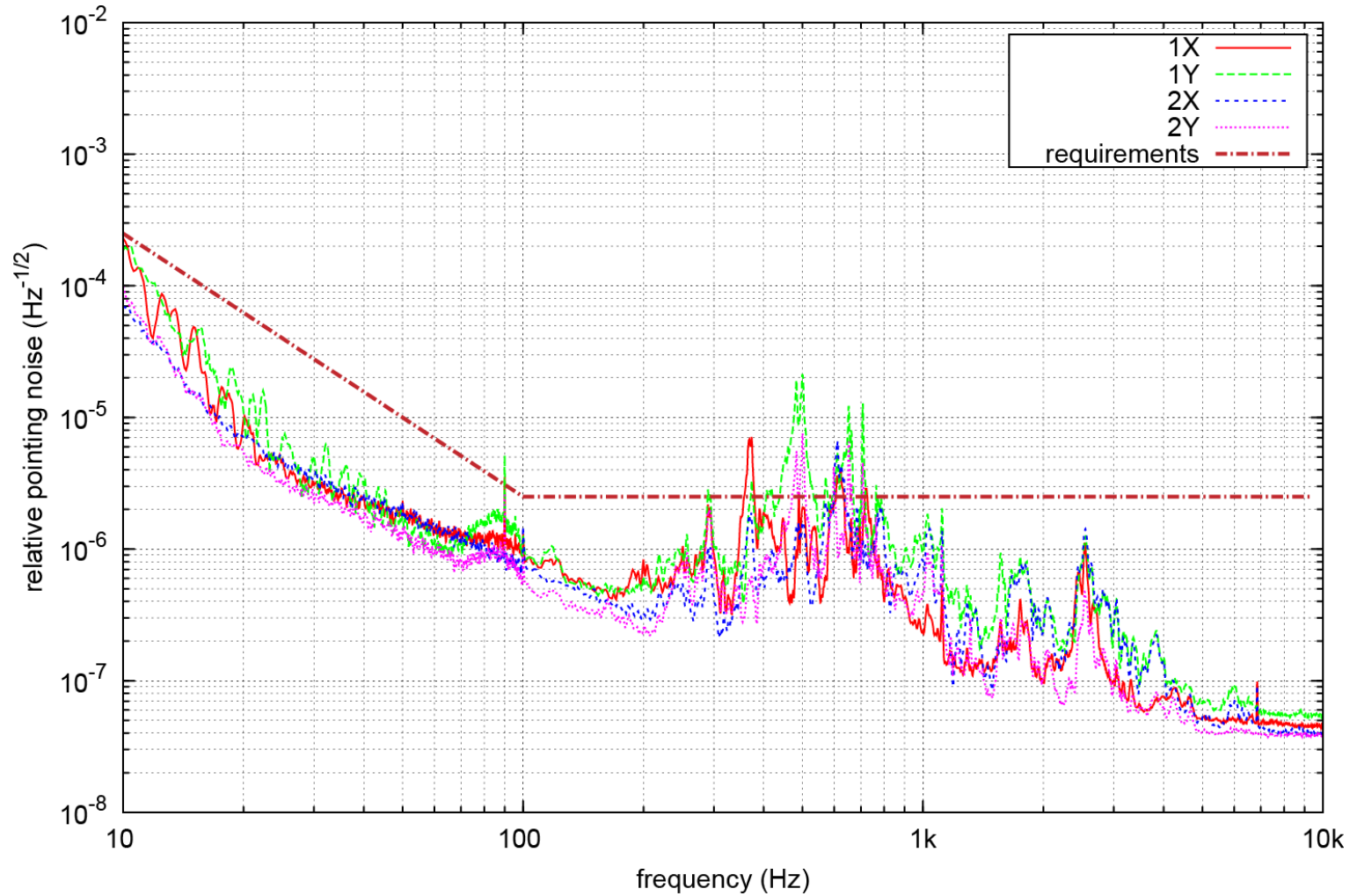


## new pre-mode-cleaner

- bow tie configuration, round-trip length of 2m
- Finesse of 124, circulating power 9kW (200W input)
- Linewidth 575 kHz (HWHM)
- Length control with automatic lock acquisition
- PZT actuator / thermal actuator to off-load PZT

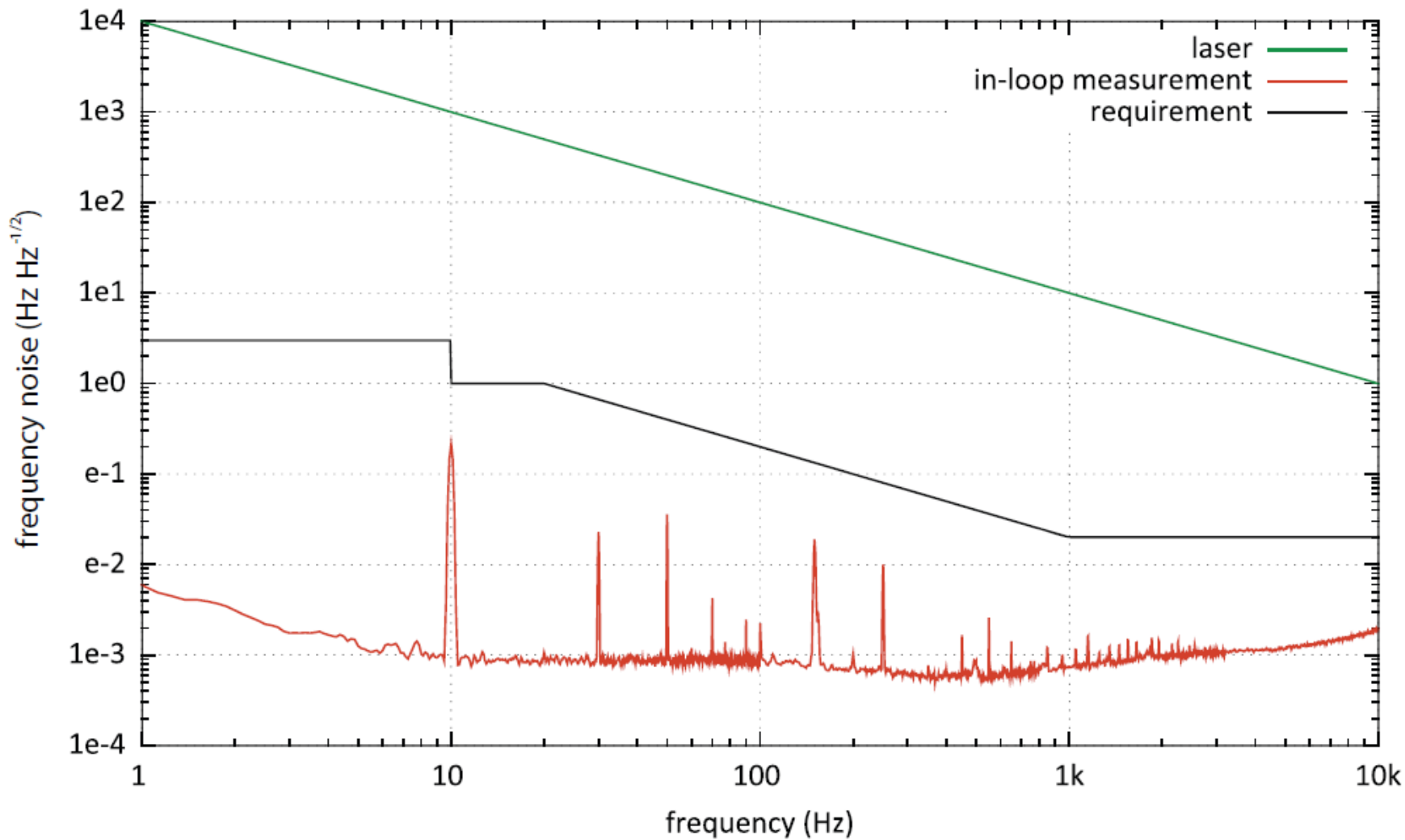


# alignment fluctuation downstream of PMC



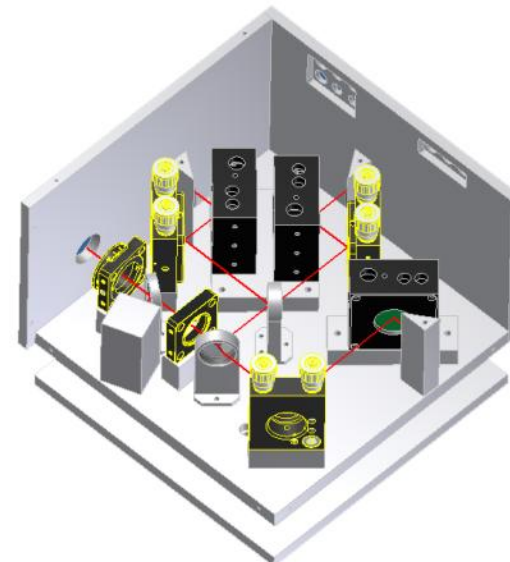
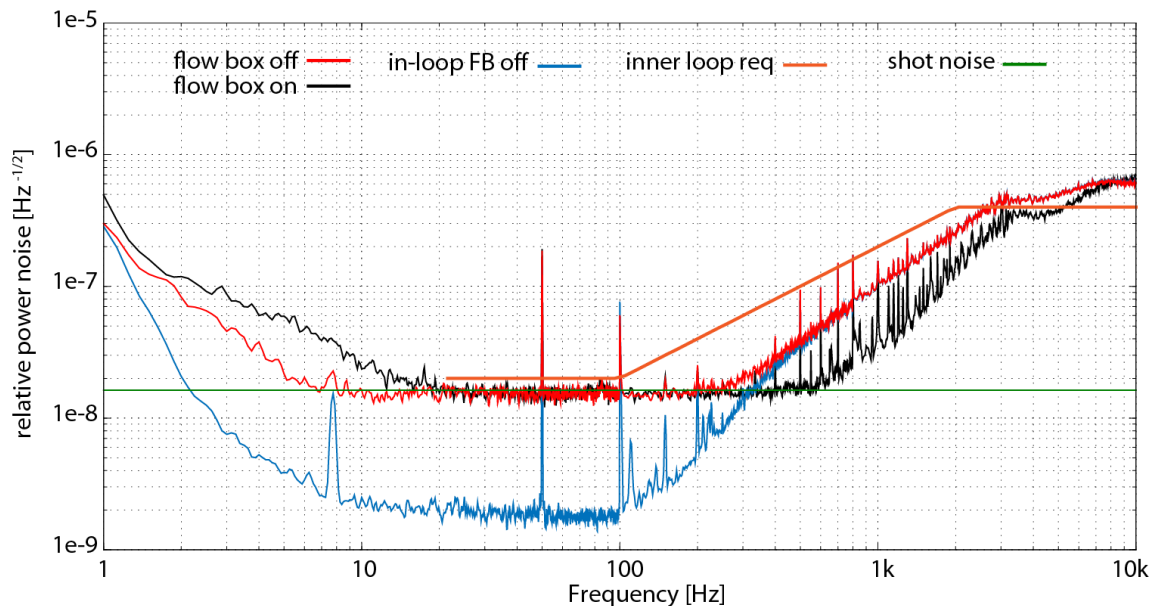


## frequency noise in-loop performance

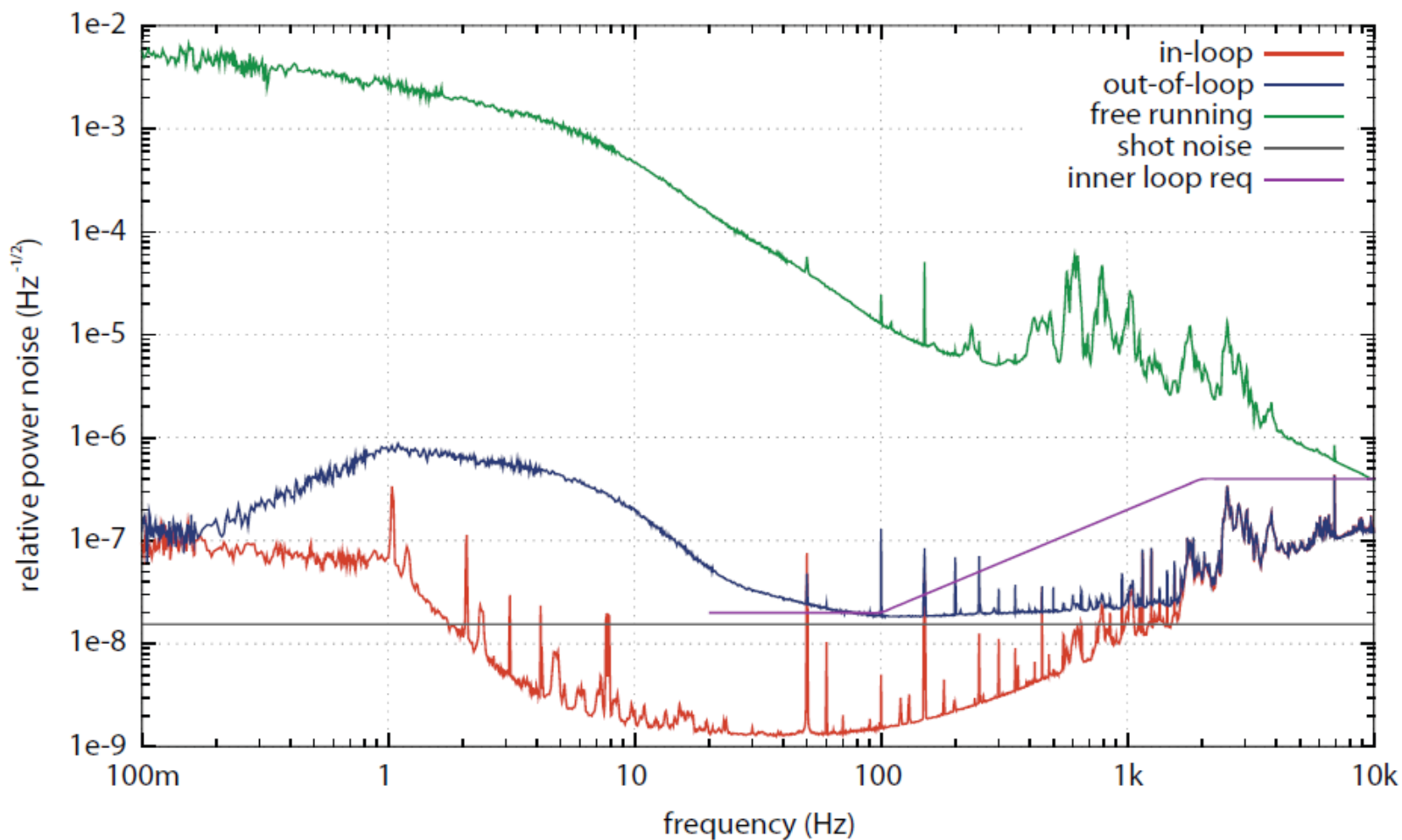


# ISS – inner loop (on PSL table)

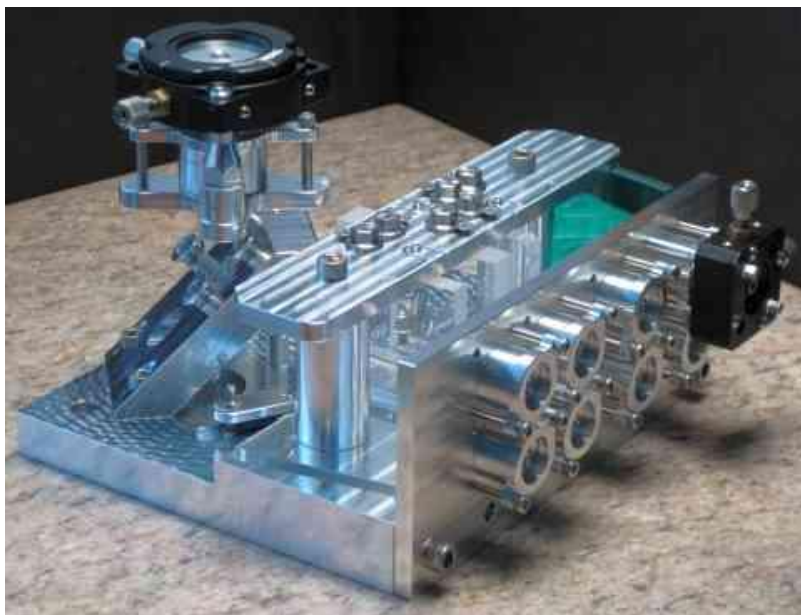
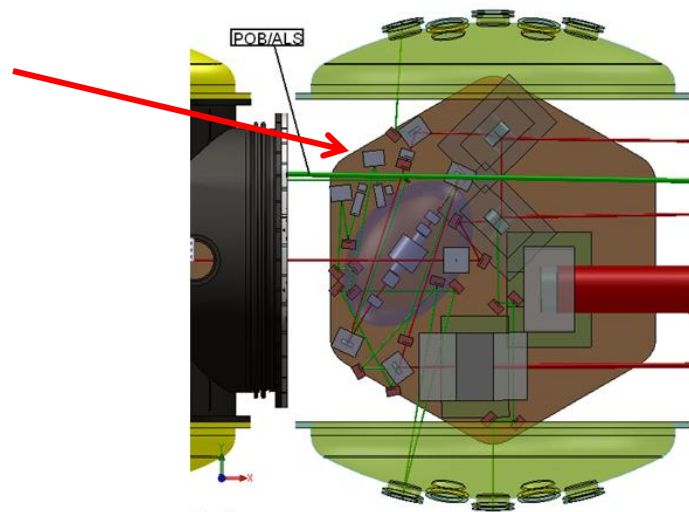
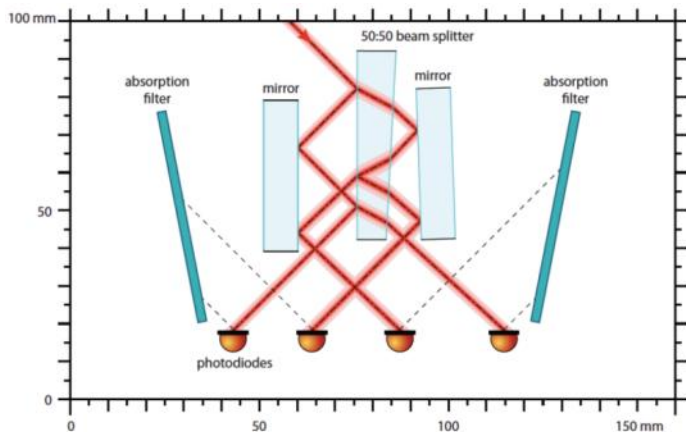
- **sensing box with in-loop, out-of-loop and quadrant photodiode**
  - low-scattering design
  - quadrant diode for alignment and pointing control
- **power stabilization sensor meets aLIGO inner-loop requirement**



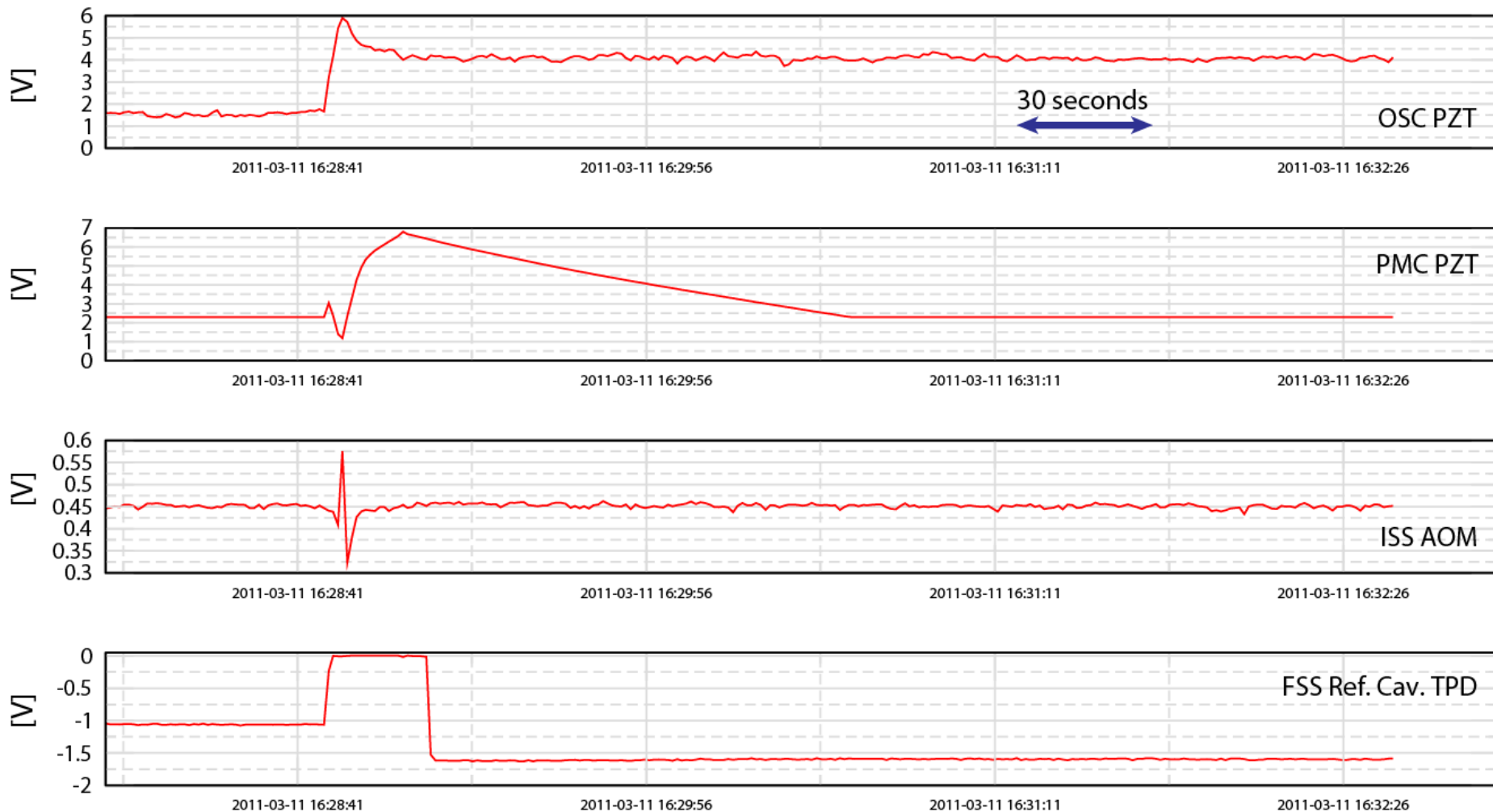
# power noise behind PMC



## ISS- outer loop (sensing in HAM2)



- four photodiodes per detector
- each aligned to lowest pointing coupling
- 50mA photocurrent per photodiode
- in dust-free environment with reduced pointing fluctuations
- aLIGO parts expects to arrive soon

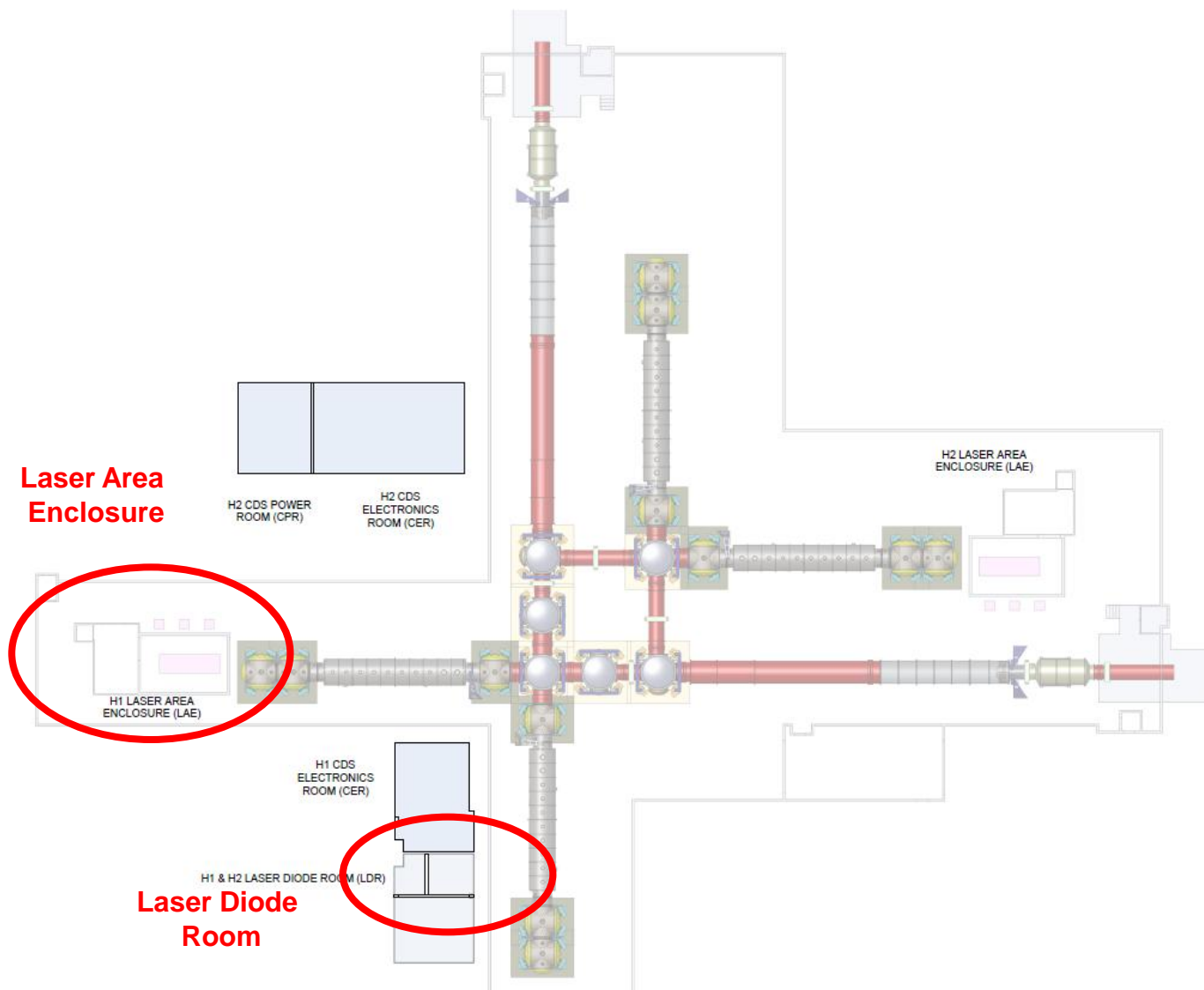


# first observatory laser arrived at LLO in Jan 2011





# installation in two locations: laser-diode-room and laser room



## LLO - installation laser diode room



- chiller and water lines installed and tested
- all laser diodes (#32) installed and tested
- optical fibers to laser room connected and tested
- safety interlock system tested and accepted by laser safety officer



# LLO Laser Area Enclosure

- laser room with HEPA filtered circulating air system and acoustic shielding
- high flow during installation and maintenance
- low flow to keep positive pressure in science mode
- ante room for preparation work, material transfer and storage

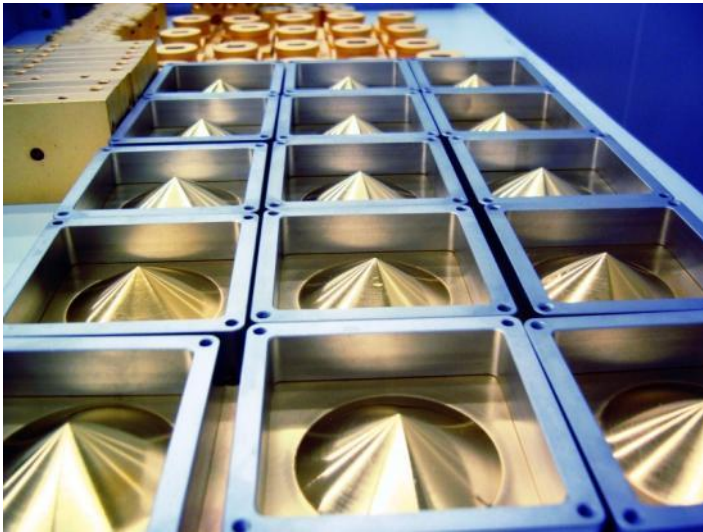


## current installation status LLO

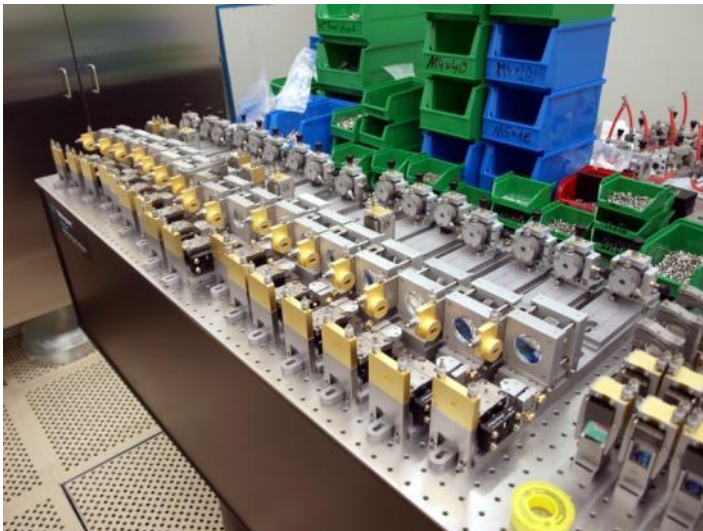
- 35 W laser installed and characterized
- 200W laser installed and under characterization
- diagnostic breadboard installed and operable
- pre-modecleaner placed on table
- all optical mounts assembled and in position
- stabilization electronics installed and connected to realtime control and data acquisition system

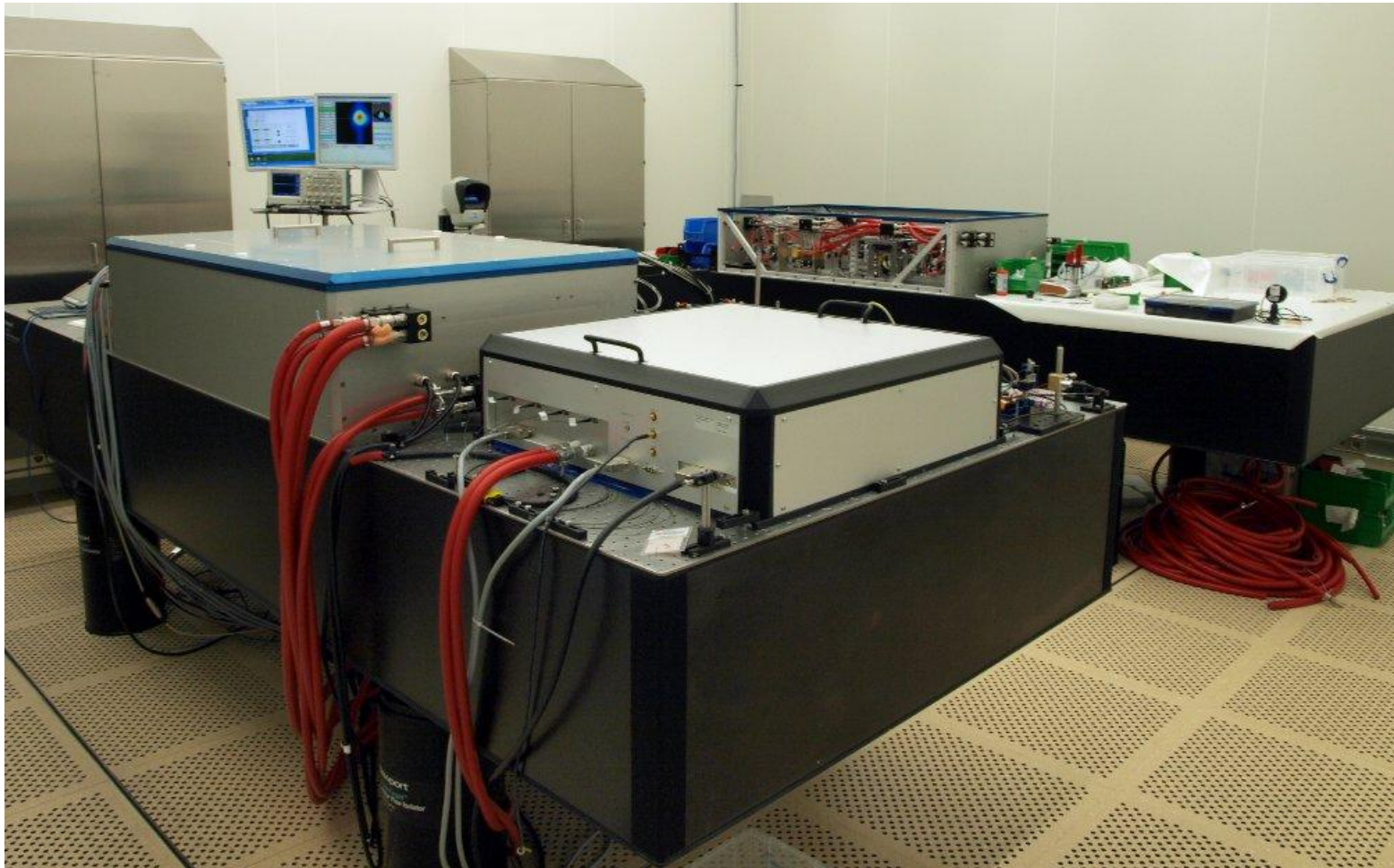


# HPL production continues at LZH



- almost all parts delivered
- all HPL components pre-assembled
- second HPL in final test phase (since two weeks)
- third HPL assembled

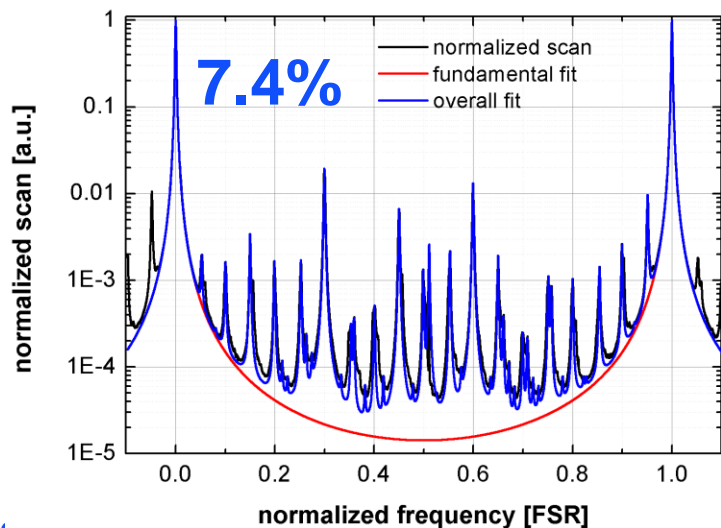
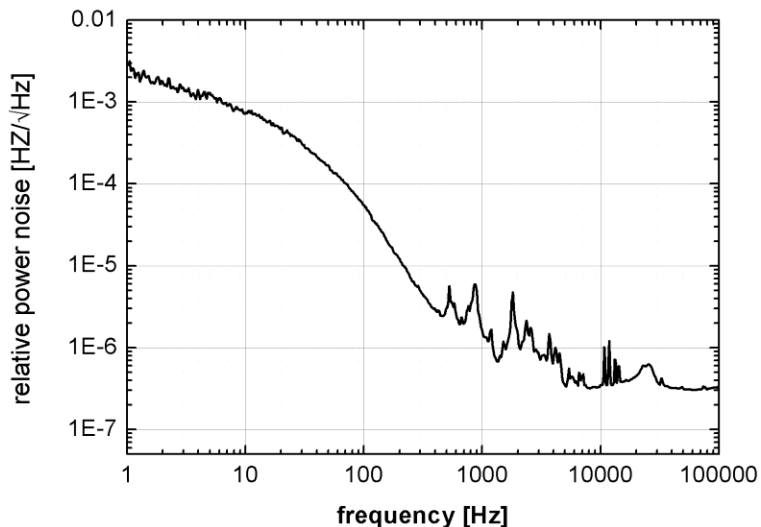




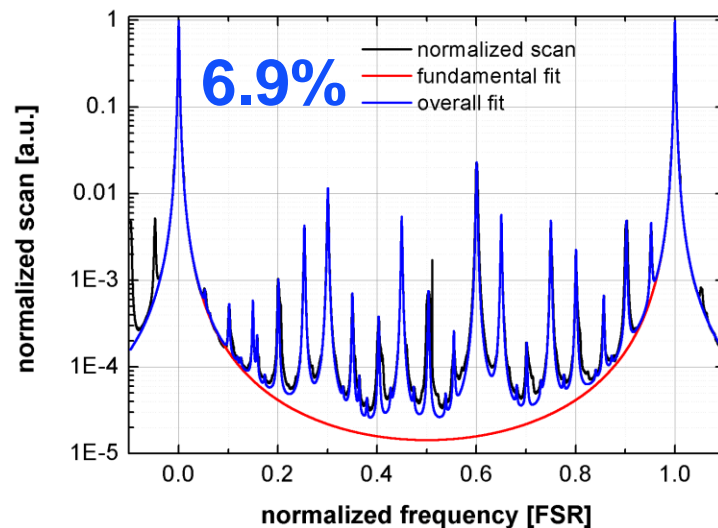
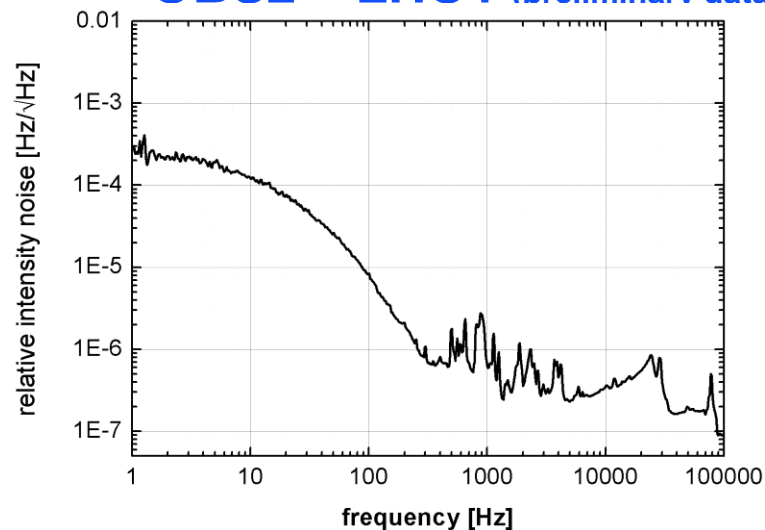


## power noise and higher order mode content

### OBS1 – LLO1



### OBS2 – LHO1 (preliminary data)



## status summary

- we fully commissioned one PSL at AEI (Reference System)
  - » laser and all control loops operational
  - » fully automated lock acquisition (including FSS)
  - » could demonstrate to compensate diode aging
  - » continue long term operation test
- installation of aLIGO PSL at LLO underway
  - » Laser Area Enclosure (LAE) finished
  - » laser diodes, chiller and Beckhoff control installed
  - » 35W and 200W laser in operation
  - » commissioning of is stabilization progressing well
  - » realtime control and data acquisition fully functional
- fabrication of H2 laser finished, will be shipped mid June 2011
- all components for photo diode array for outer loop ISS delivered



# PSL - project organization

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- AEI scope
  - » laser will come as a ready-to-install package to LIGO sites
  - » refurbishment of the 35W lasers used for eLIGO
- LIGO scope / Advanced LIGO project
  - » laser area enclosure (cleanliness, laser safety) and laser diode room
  - » power supplies and data acquisition and controls computer hardware
  - » outer loop power stabilization.
  - » Safety procedures and interfaces
- AEI and LIGO
  - » once rooms and infrastructure is ready, laser will be installed and stabilization will be commissioned
  - » reuse laser tables and frequency stabilization (with new interface cards)



## Hannover

- » AEI (5 FTE)
  - Kwee, Pickenpack, Pöld, Krämer, Willke
  - support mechanical and electronic workshop (1.5 dedicated FTEs )
- » LZH (3 FTE)
  - Weißels, Winkelmann, Puncken, Kluzik, Damjanic
- » neoLASE (2 FTE)
  - Frede, Schulz, Jansen

## LIGO

- King, Savage, Fyffe, Rodruck
- technical support
- CDS support



- quality management
  - » diagnostic breadboard will be used for fast and frequent performance tests
    - after fabrication in Hannover
    - after installation at sites
    - during operation
  - » same personnel for laser fabrication as for development (Winkelmann, Puncken, Wessels)
  - » electronic fabrication by neoLASE (LZH spin off company, personnel that developed laser (Frede, Schulz) and wrote control software (Veltkamp))
- risk registry
  - » PSL has no entry in major threat list
  - » all „high risk entries“ retired to med / low
- near term plan
  - » install LLO laser
  - » finish laser and PSL fabrication until Oct 2011
  - » install H2 laser at LHO (Oct-Dec 2011)
  - » continue long term performance test of Ref. Sys. at AEI



- As a Project, we follow the standards suggested by ANSI Z136.1 (2007).
  - » Laser safety is important!
  - » Established Project-wide laser safety policies and procedures.
- Standard Operation Procedure (SOP) in place for PSL operation at LLO
  - » access control to Laser Hazard Areas
  - » tested protective eye wear is provided
  - » safety interlock system fully functional and accepted by LLO laser safety officer

## PSL summary

- finished detailed characterization of the aLIGO PSL reference system, could demonstrate almost all requirements
- infrastructure modifications are finished at LLO and have started at LHO
- first aLIGO PSL was shipped to LLO and is currently commissioned
- fabrication of the second aLIGO PSL is finished, installation will start at LLO in October 2011

