PEOPLE MATTER

research
development
consulting

LASER ZENTRUM HANNOVER e.V.

Advanced LIGO laser development

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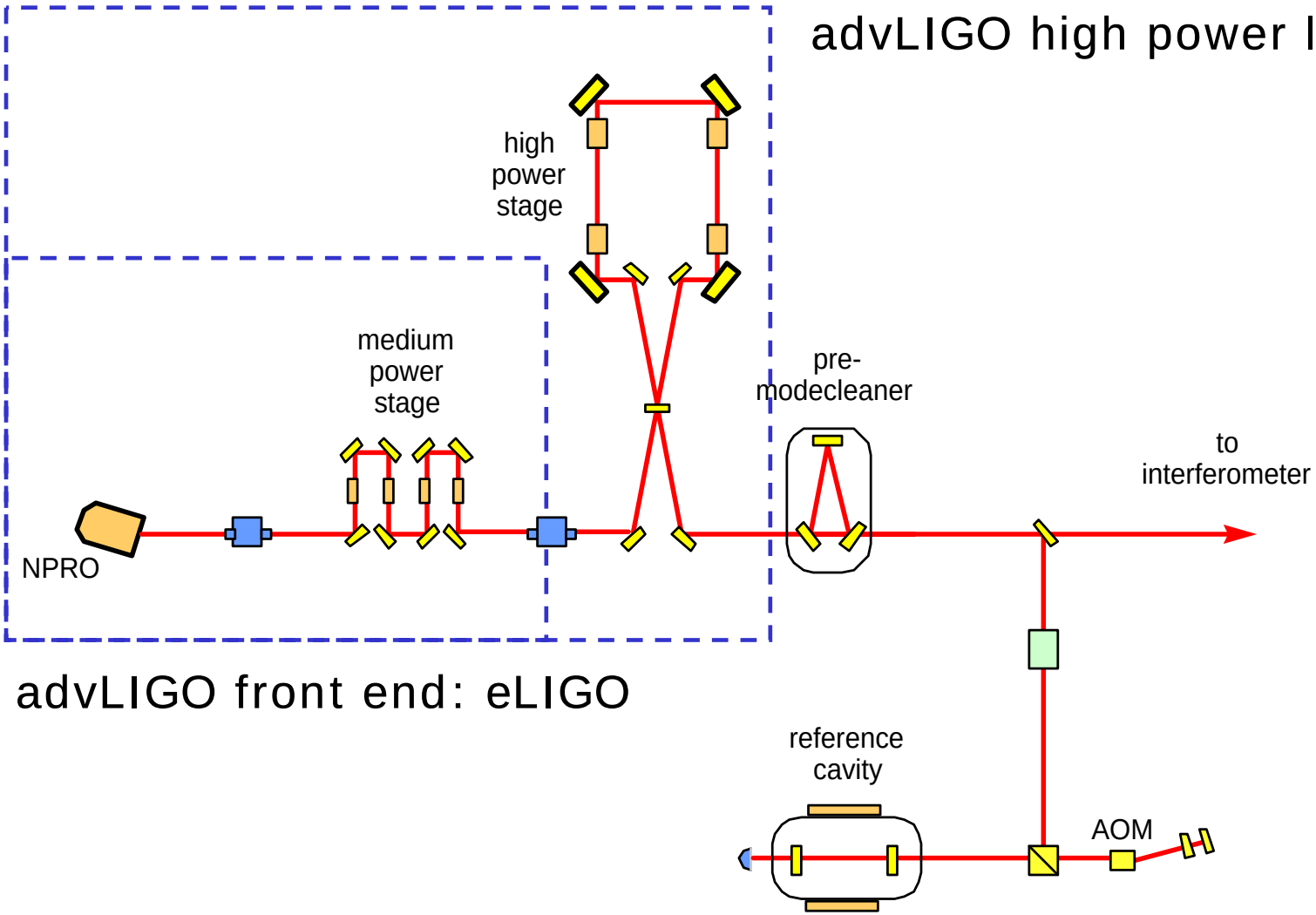
LIGO-G070712-00-Z

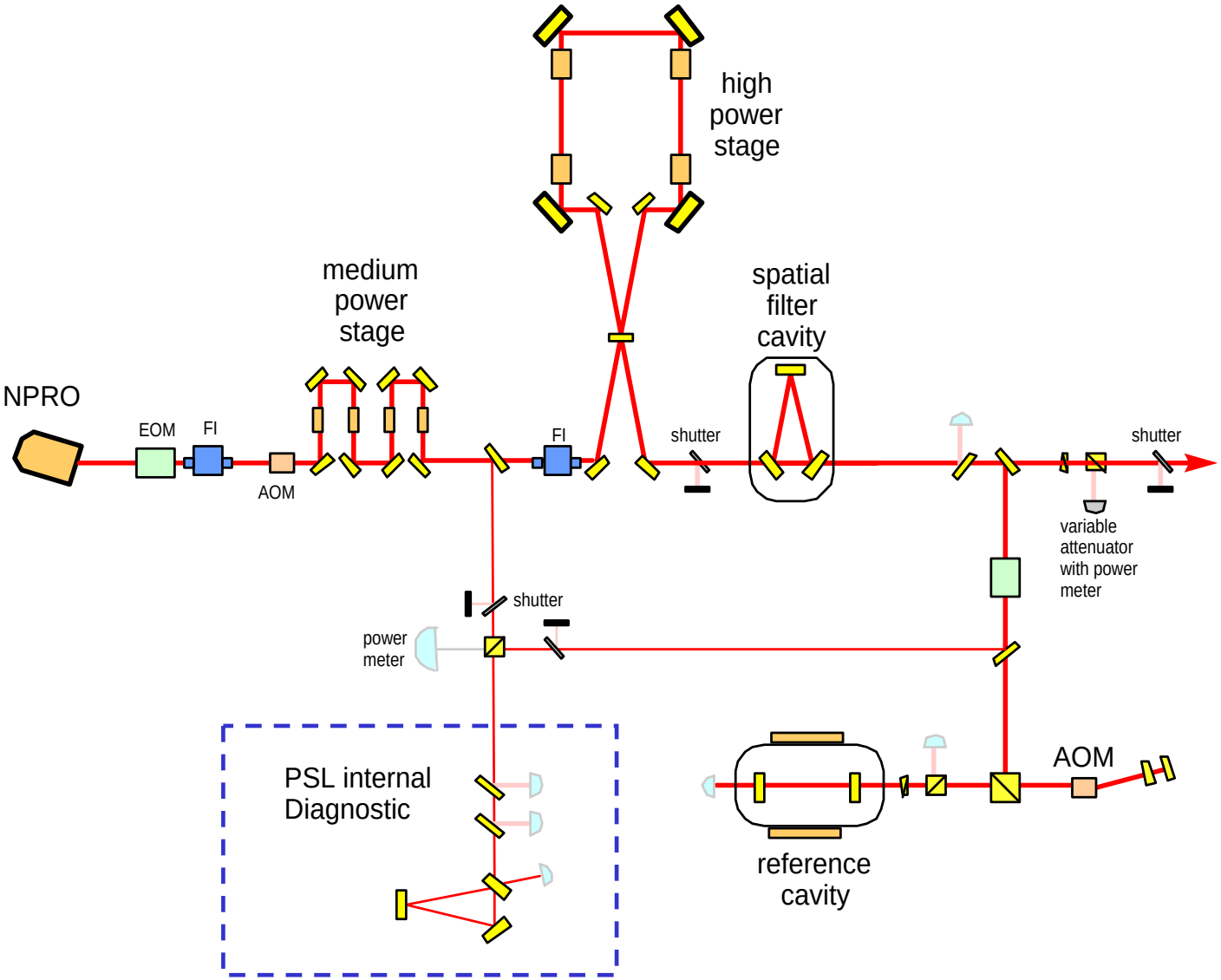
Outline

- Overview – what is the advLIGO PSL ?
- advLIGO front end – eLIGO
- High power laser

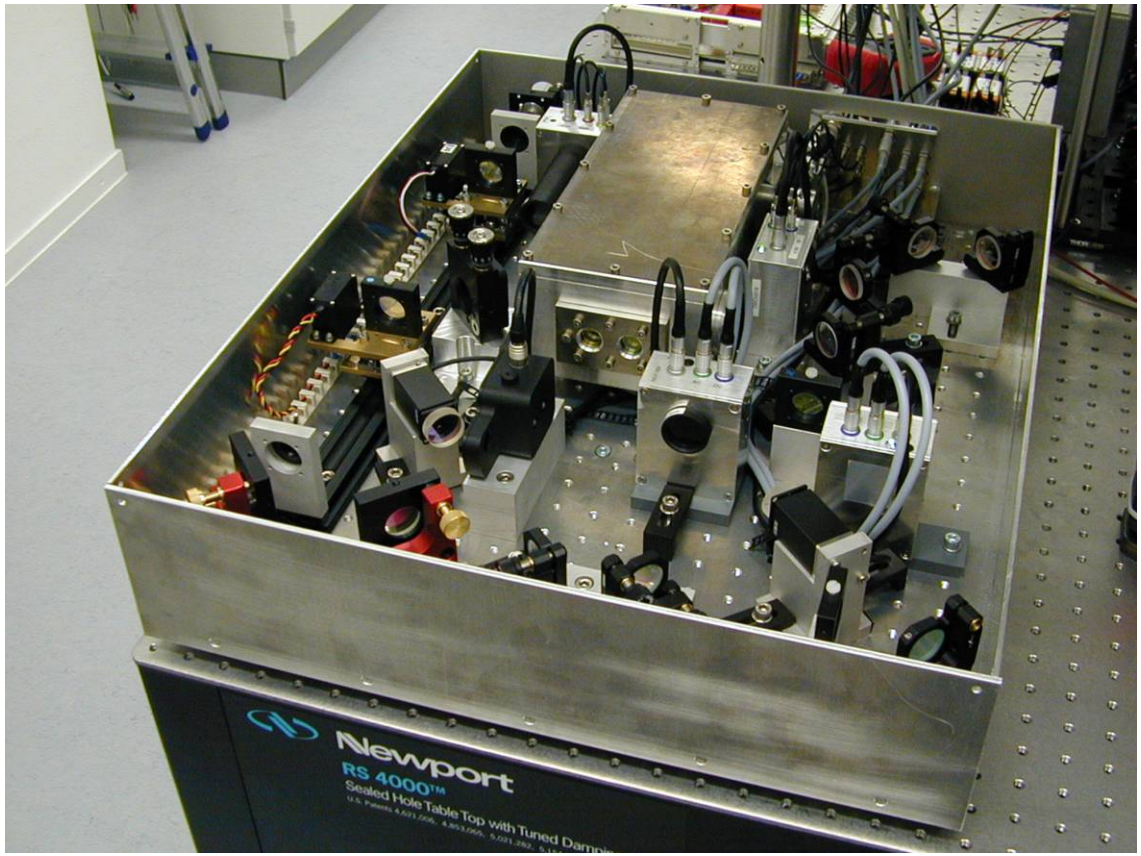
Advanced LIGO prestabilized laser: Optical layout



Diagnostic Breadboard

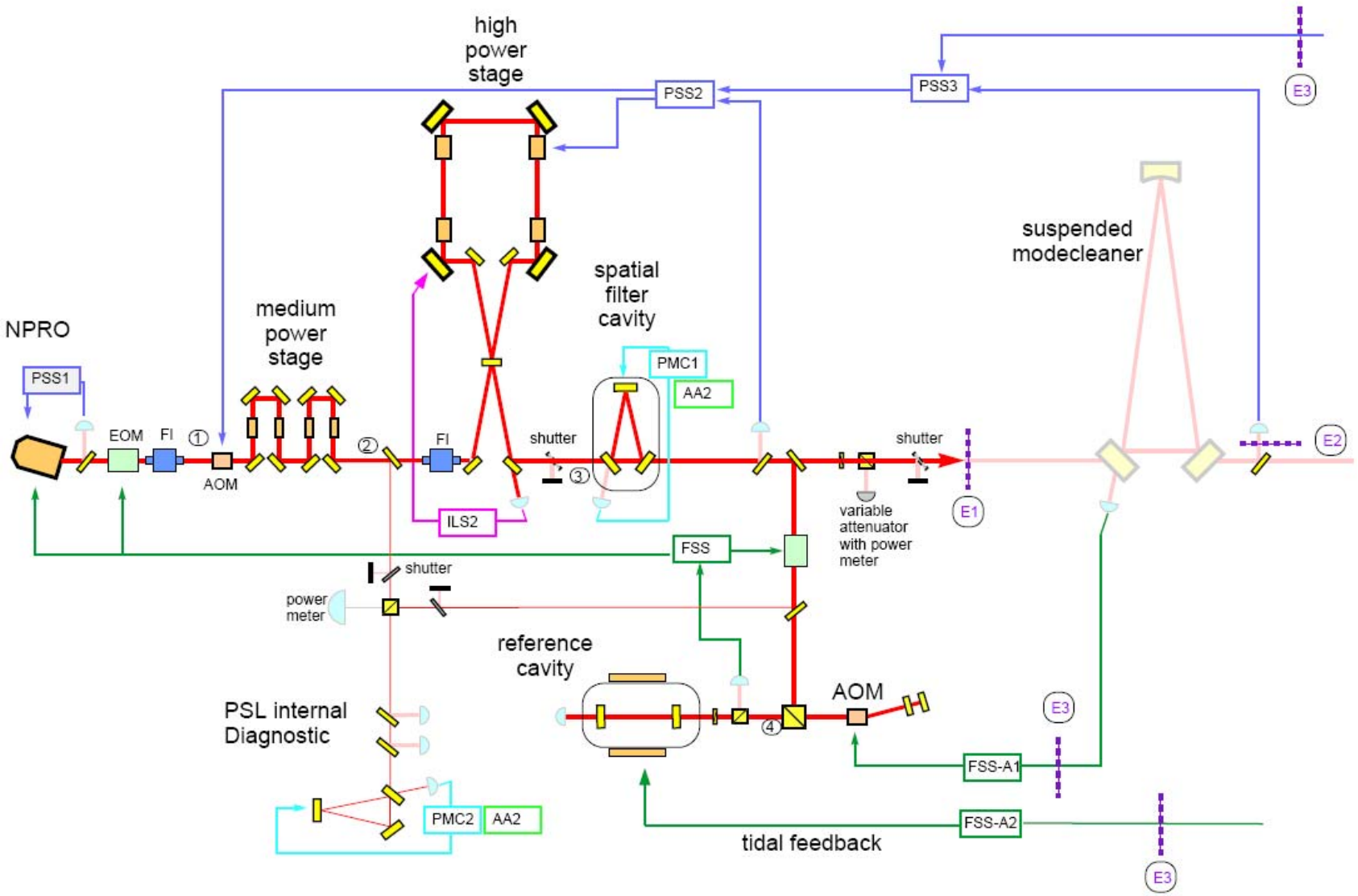


Diagnostic Breadboard

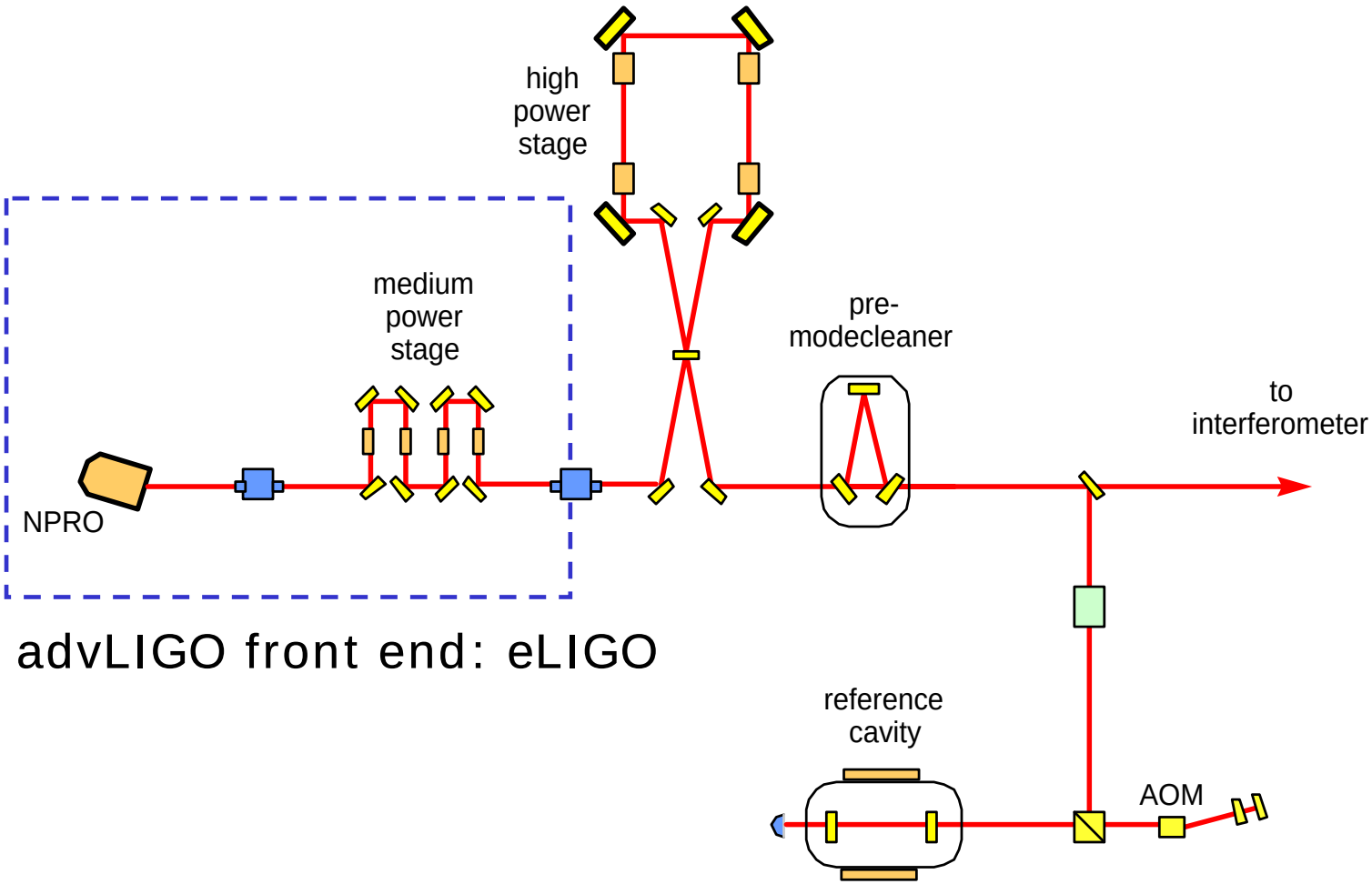


- Automated diagnostic system developed at AEI
- Separate talk by Patrick Kwee, Wednesday, 18:00

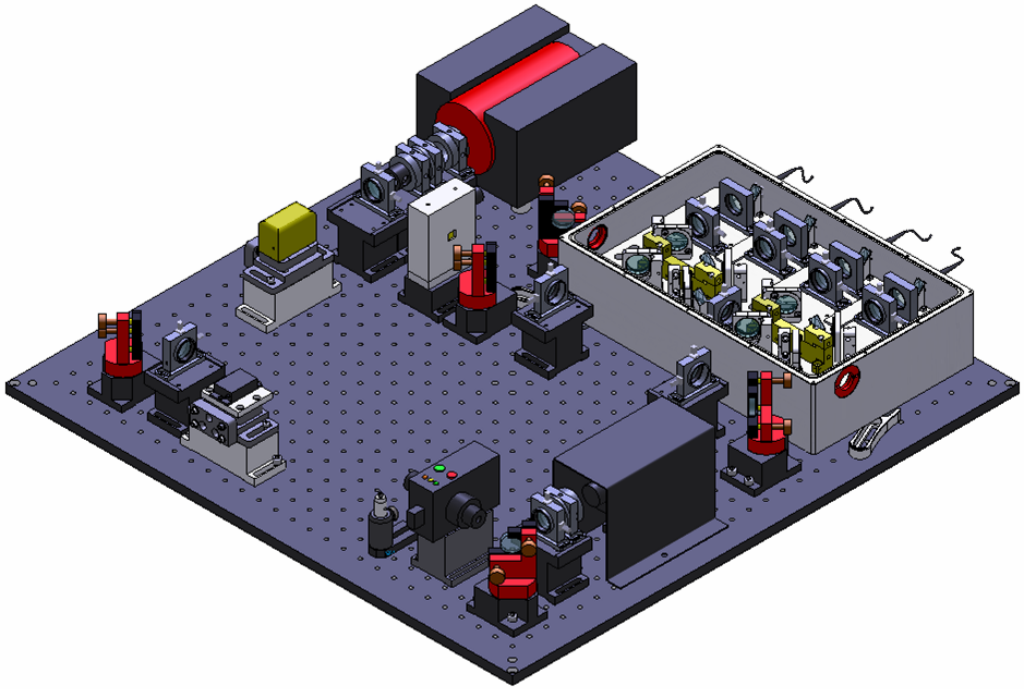
Advanced LIGO prestabilized laser



Advanced LIGO prestabilized laser front end: eLIGO



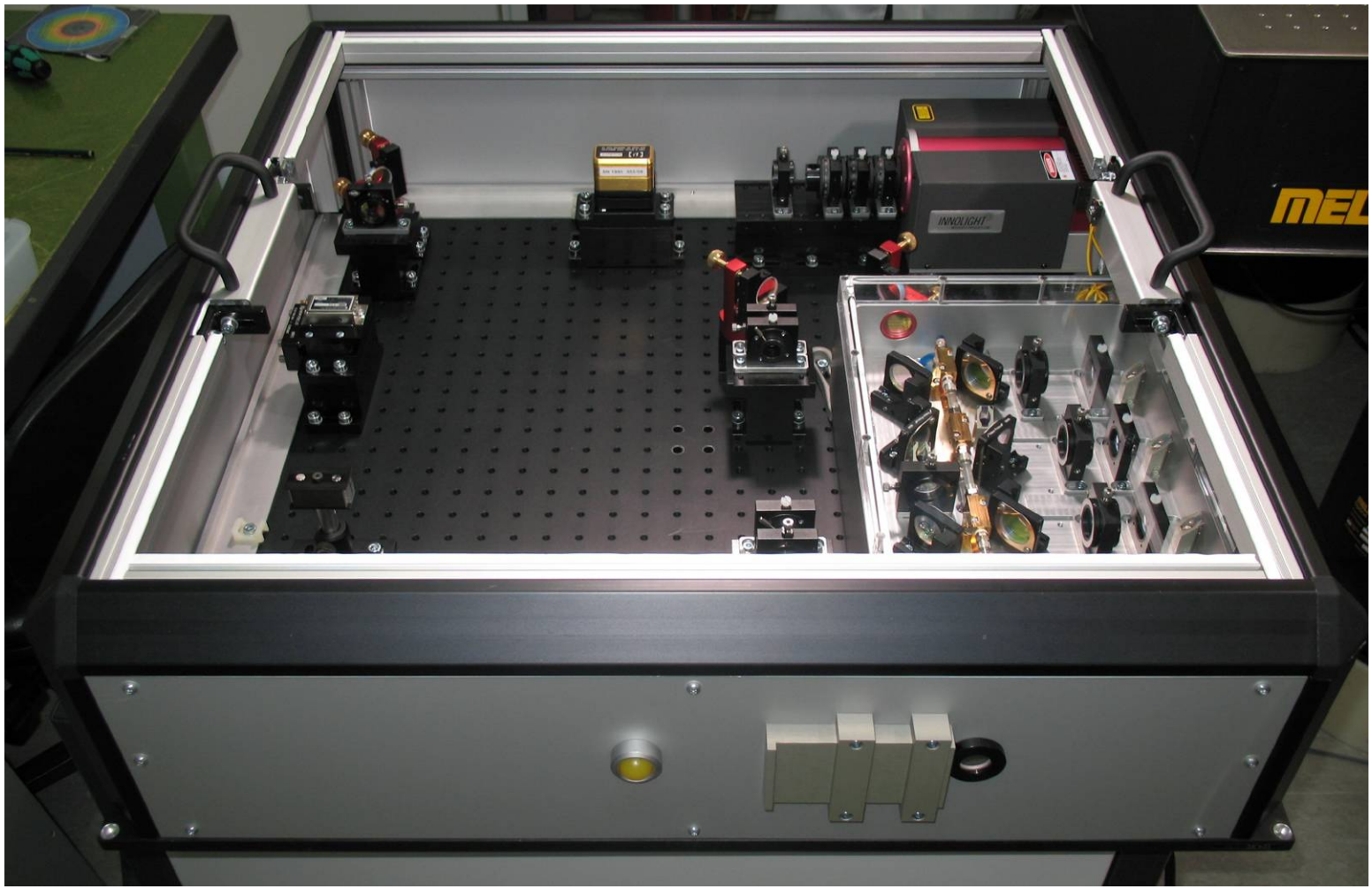
The advLIGO front end: eLIGO



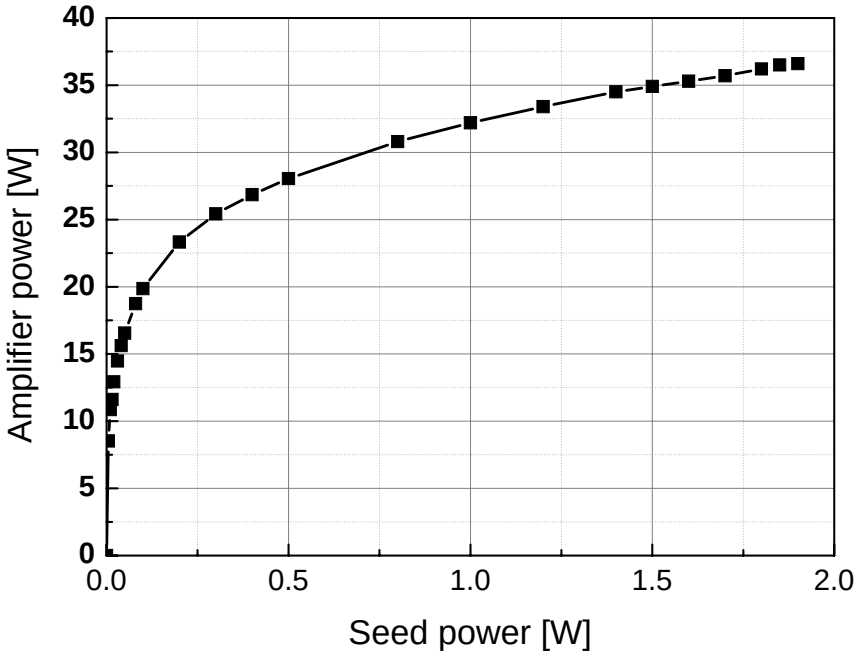
- 4-stage Nd:YVO amplifier
- > 35 W output power
- Assembled on breadboard and delivered in single housing
- AOM, EOM, isolator, and shutter included
- NPRO and amplifier controlled via Beckhoff touchpad

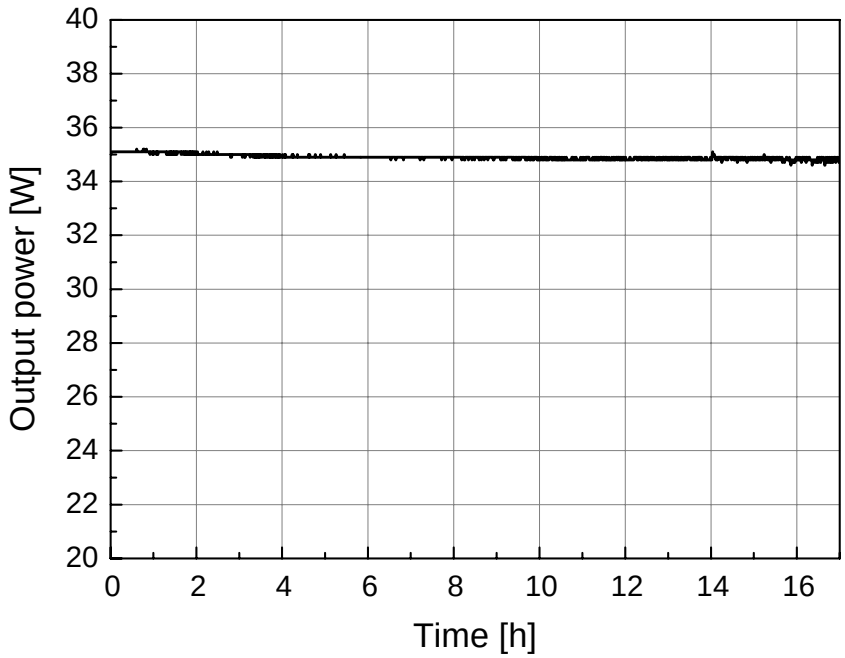
Current status:
- Engineering Prototype at Caltech
- Reference System built

eLIGO Reference System

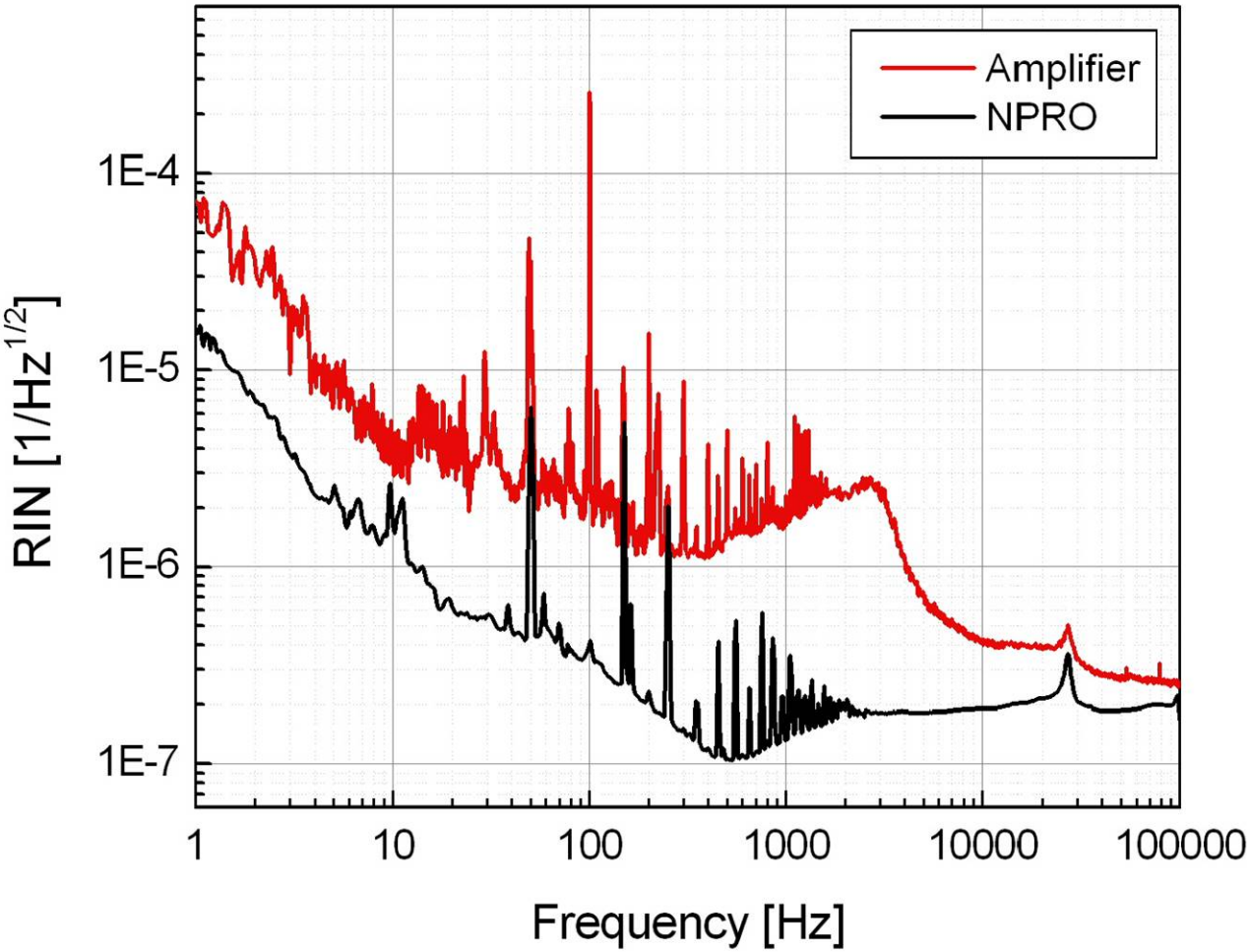


eLIGO Reference System: Output power



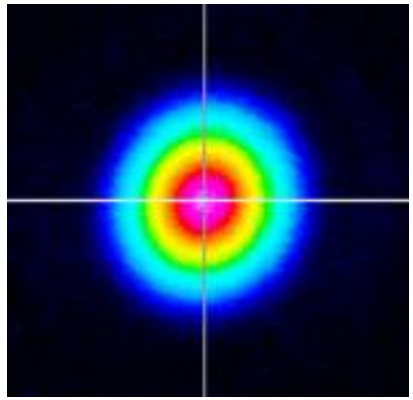


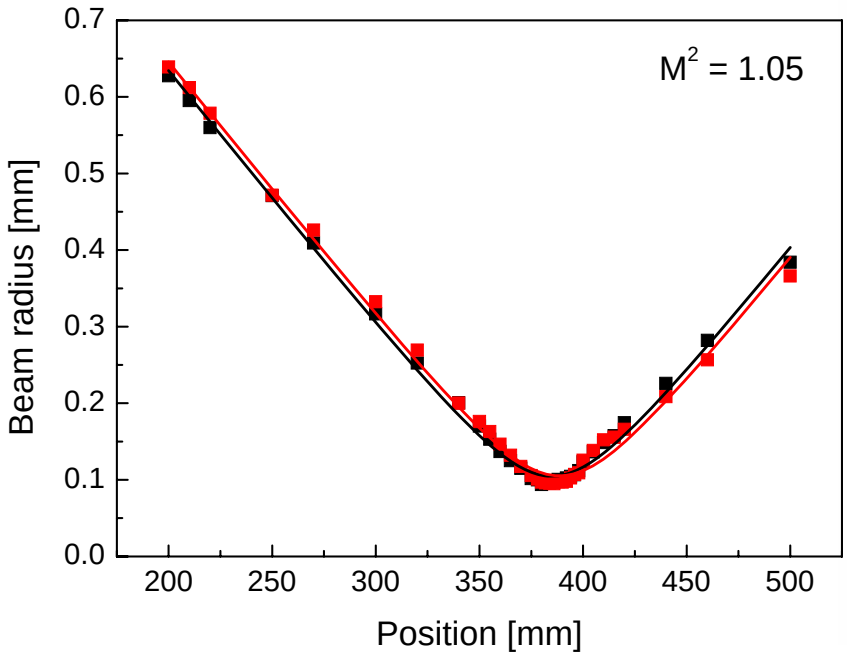
eLIGO Reference System: RIN

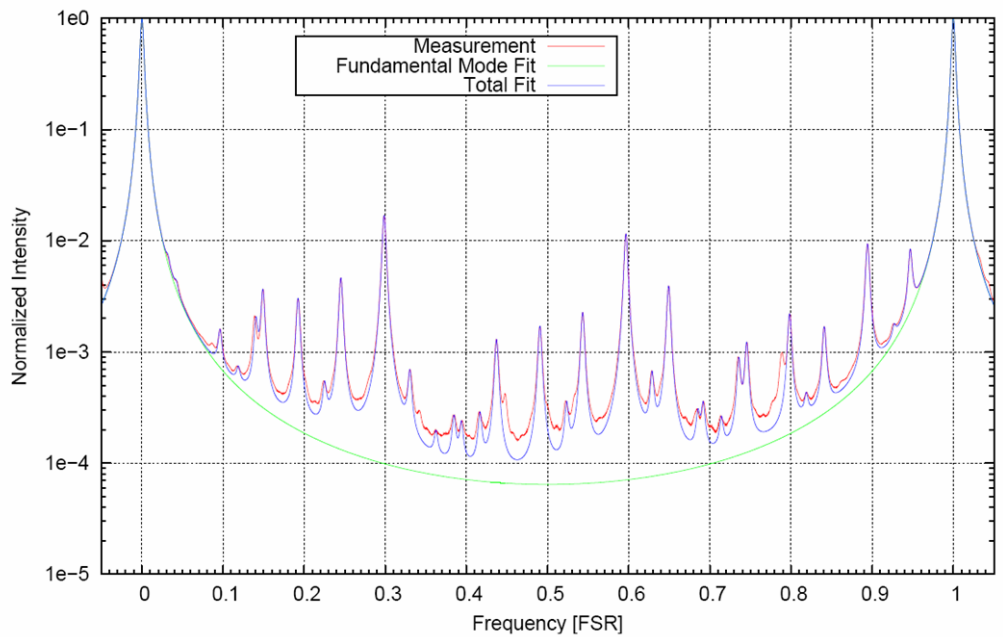


eLIGO Reference System: Beam quality

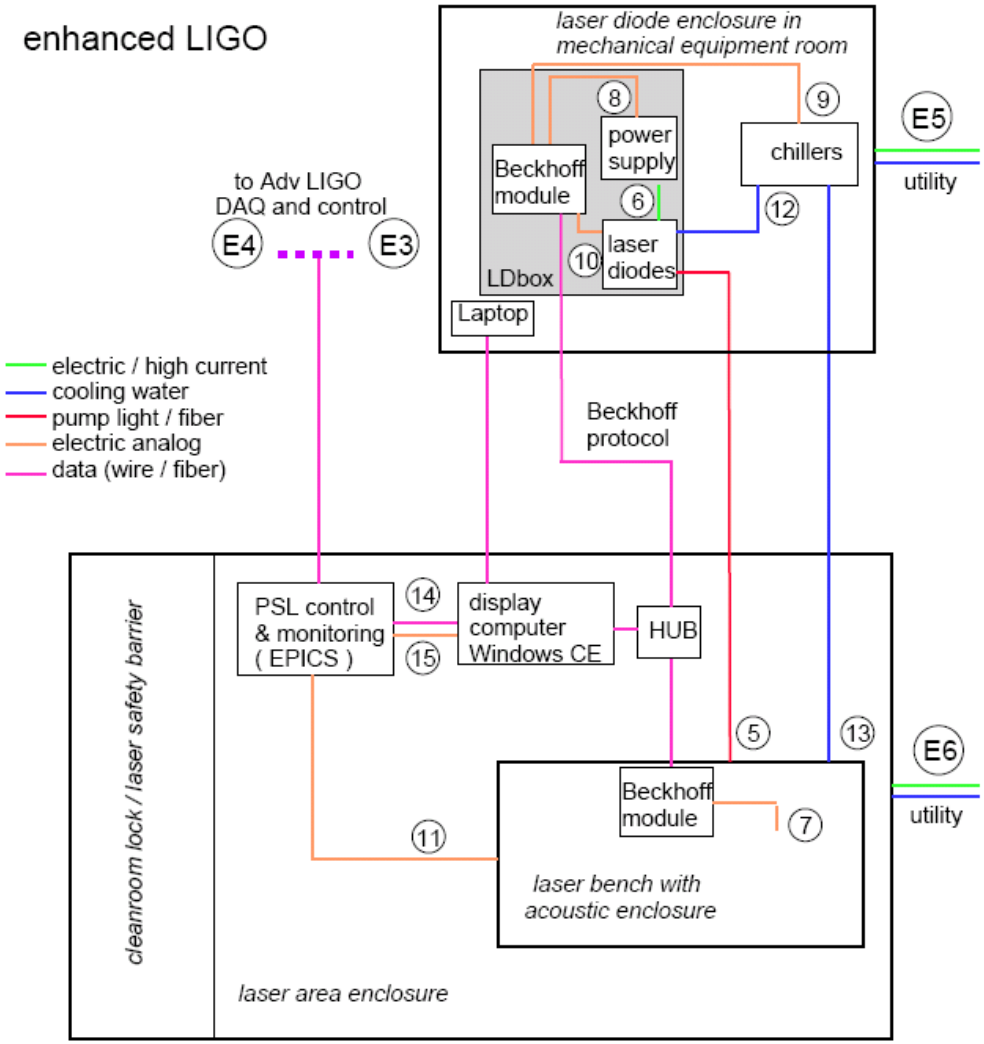
- Beam quality: M^2 = 1.05
- $TEM_{0,0}$ mode content @ 37 W: 93%







eLIGO: Location and Control



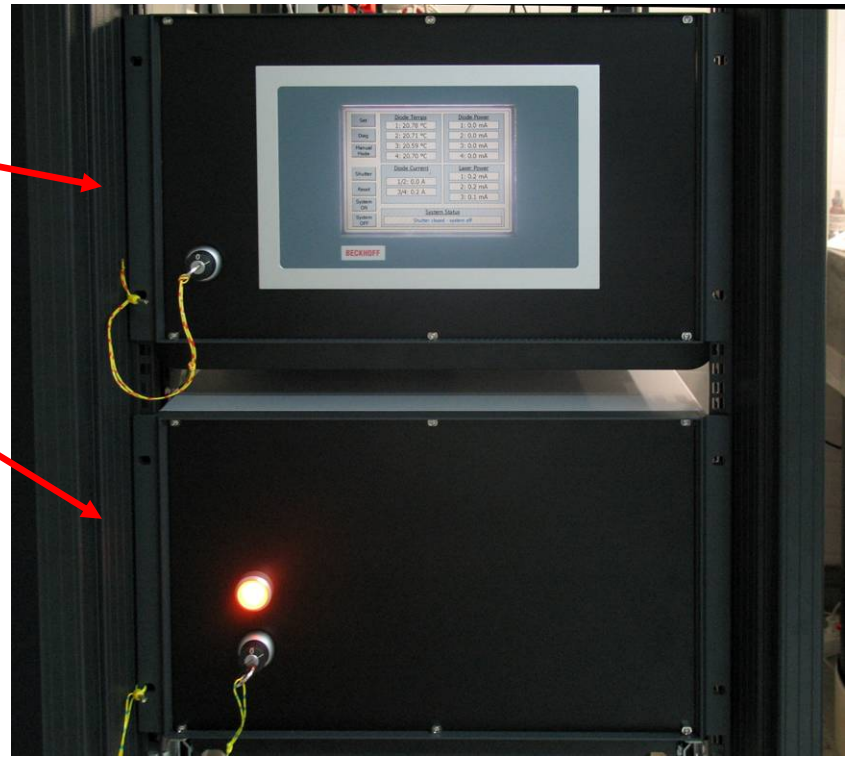
Electronics split up in 2 boxes:

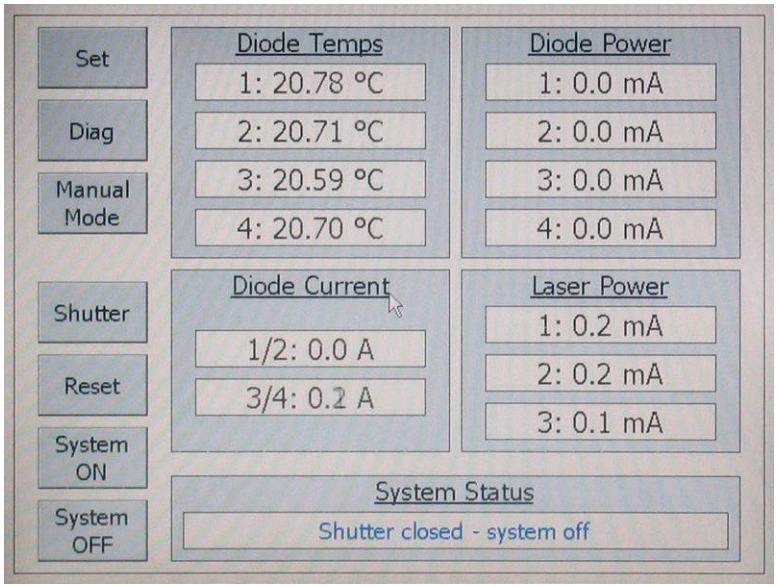
- Diode box
- Control box with touchpad and interface to PSL computer

eLIGO: Control electronics

Control box

Diode box





Visualization with touchpad

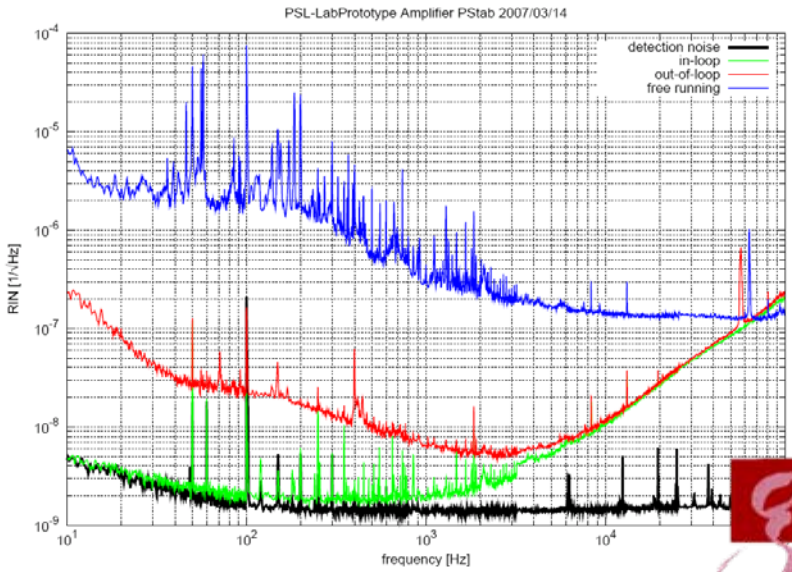
What's next: eLIGO

- eLIGO Reference System now at AEI
  - ➢ Lab Tour today 19:00
  - – Observatory 1: End of 2007
  - – Observatory 2: February 2008

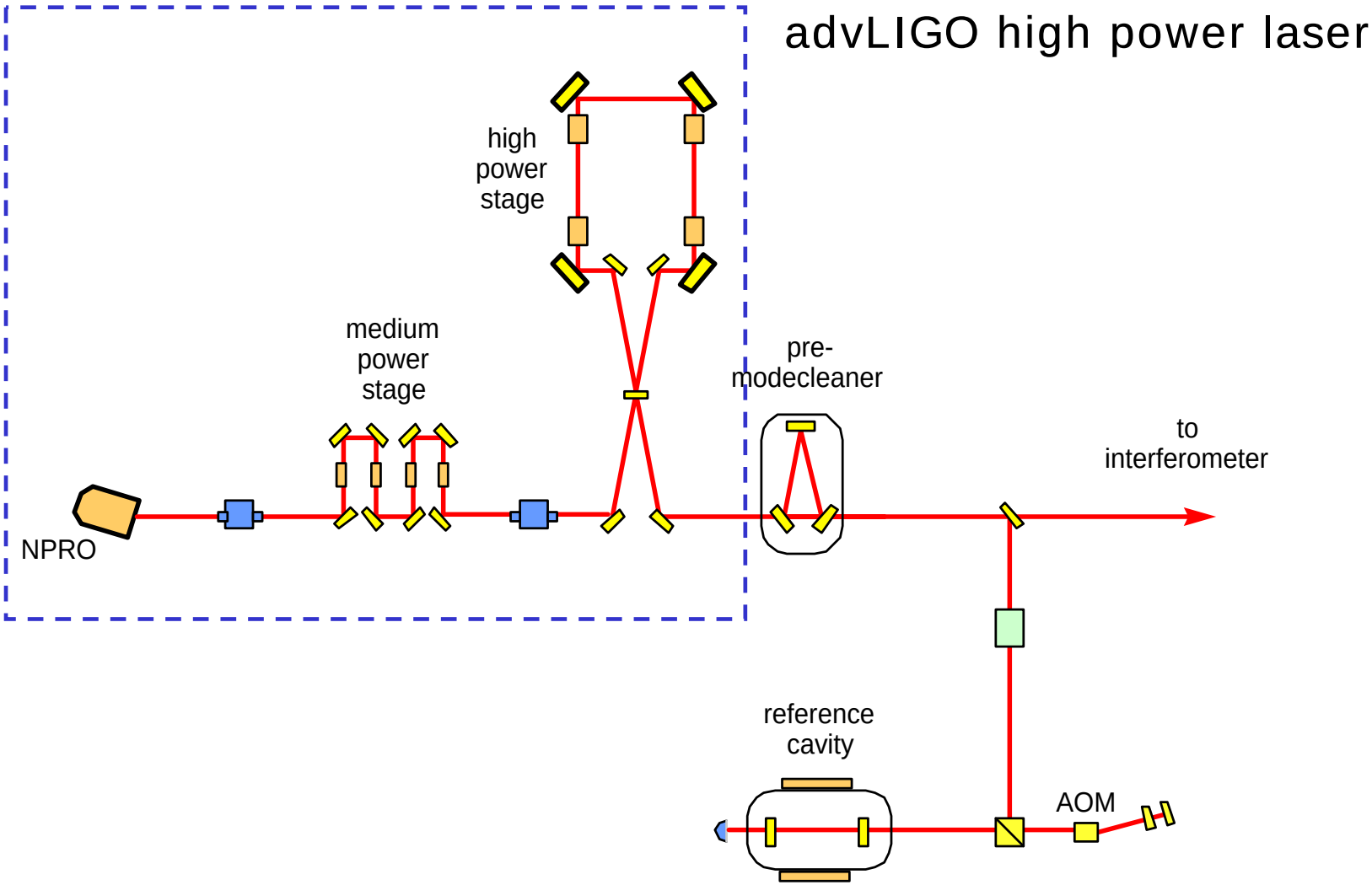
- Implementation and test of all stabilization loops (power and frequency)

- Test of interface Beckhoff – PSL computer

- Longterm test

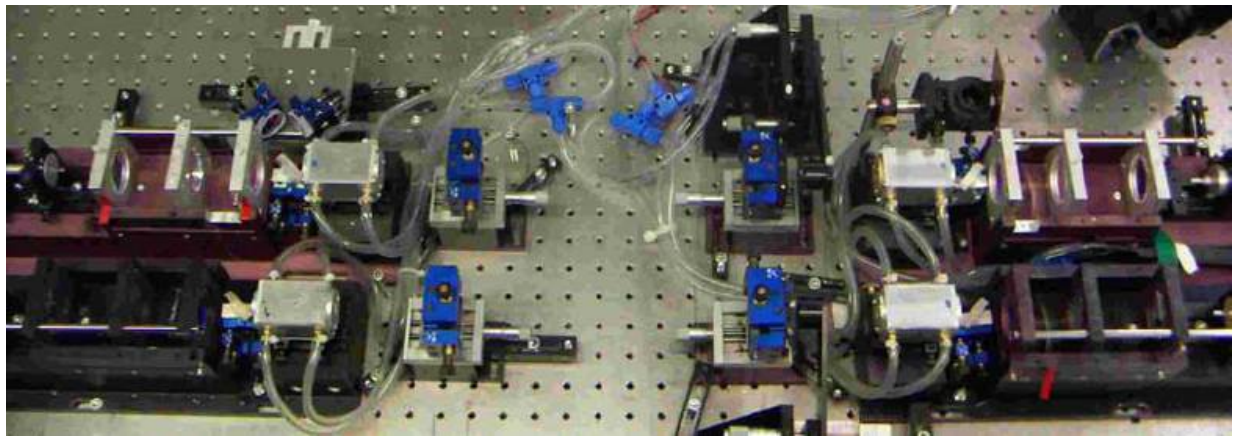


Advanced LIGO PSL: high power laser



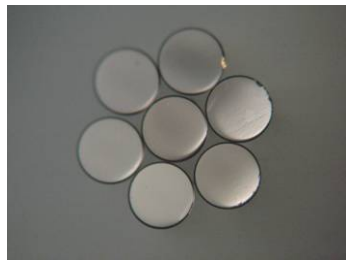
Looking back: the Laboratory Prototype

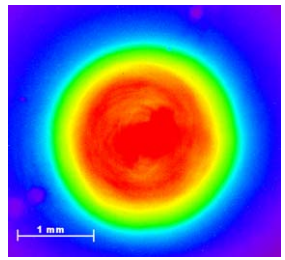
- 150 W output power
- 85% (~130 W) in $TEM_{0,0}$
- Optical – optical efficiency: 15%
- Problems:
  - Had to be readjusted at start-up
  - Long start-up time > 30 min for good beam profile

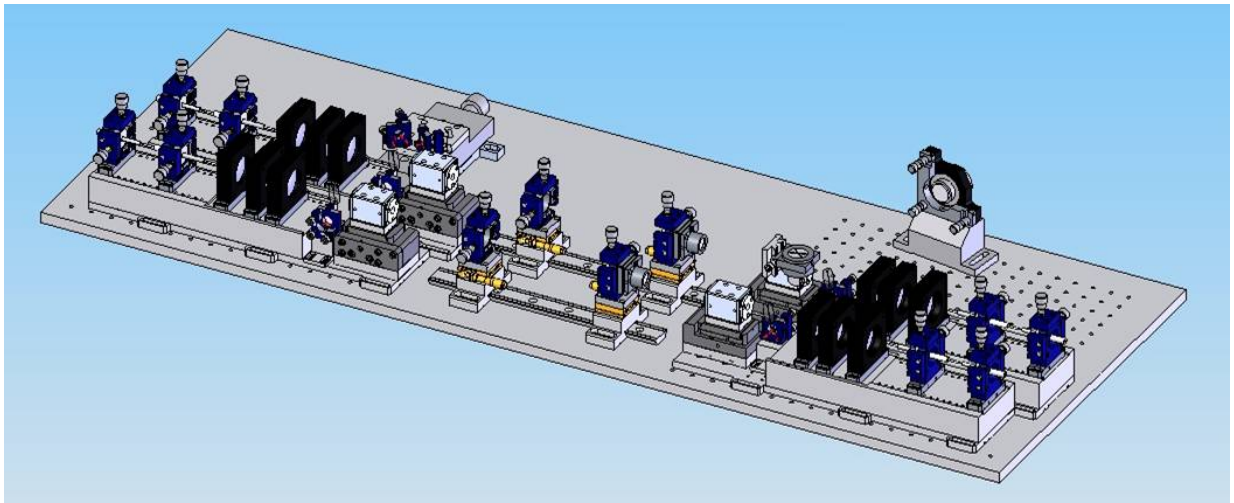


The next stage: the Functional Prototype

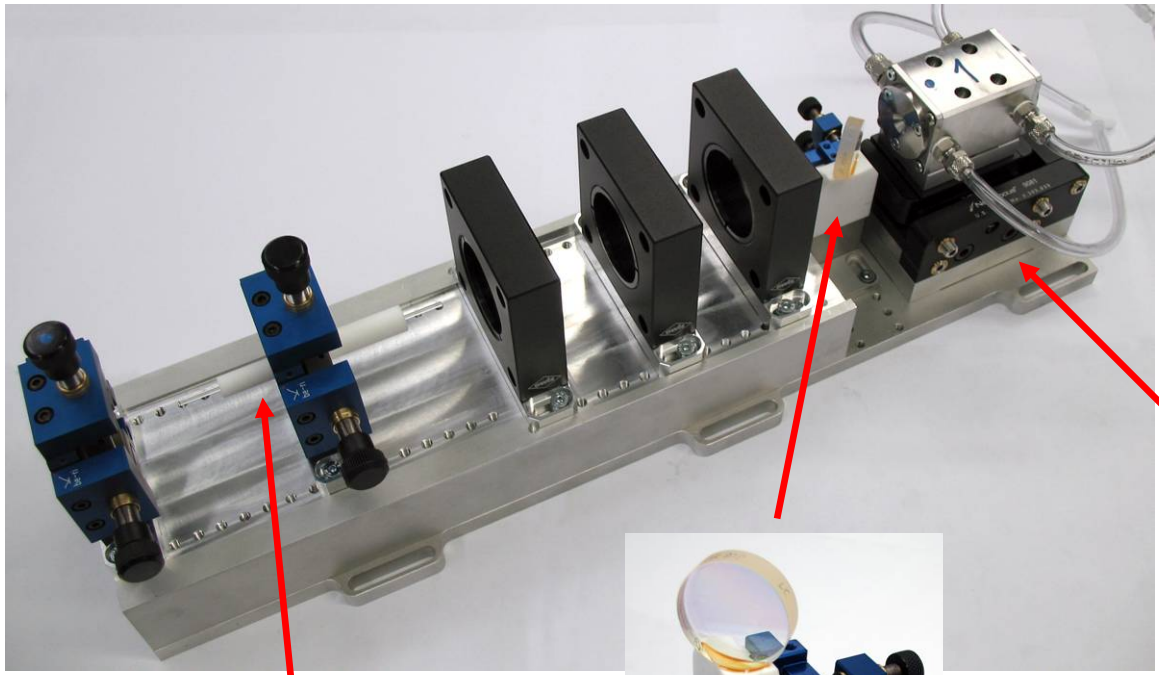
- 7 instead of 10 fibers
  - 7 x 45 W
- New homogenizer
  - Higher pump brightness
- New laser head design
- Whole resonator on base plate

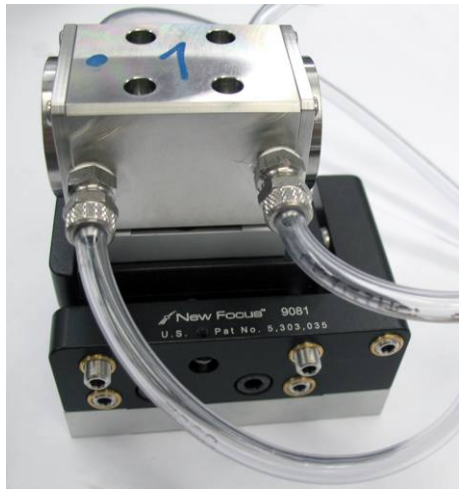


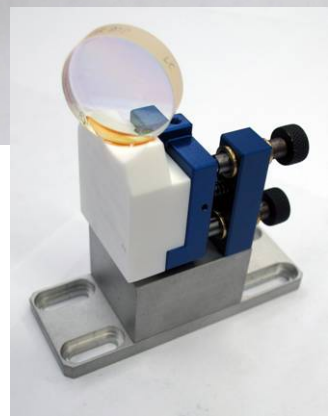


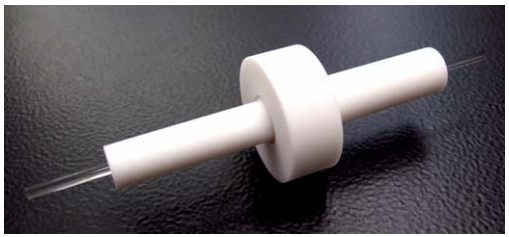


Improved laser head design









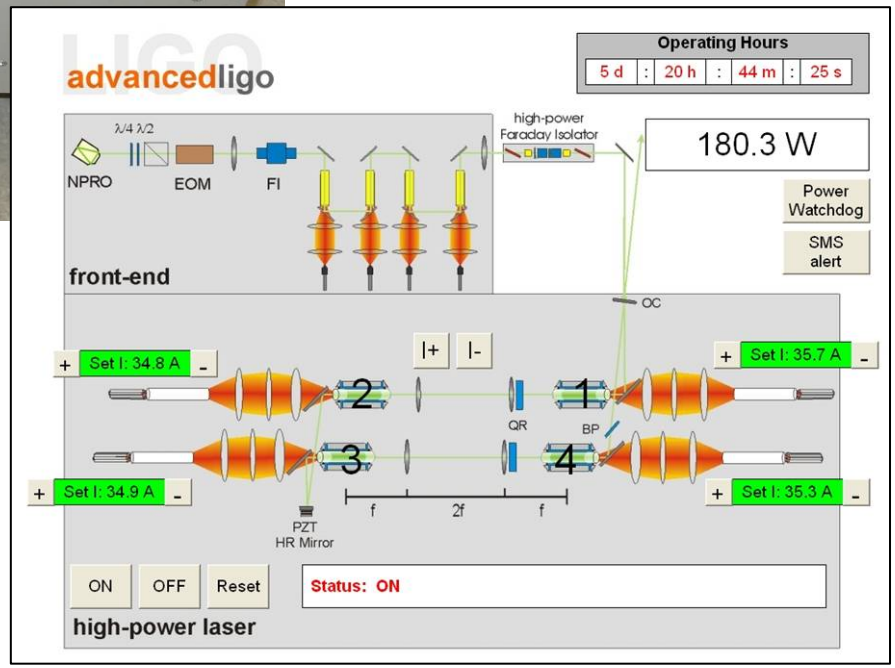
X-Y-Z position and rotation stage for crystal alignment

ceramic parts to prevent moving through heat-load by straylight

Pump power and control

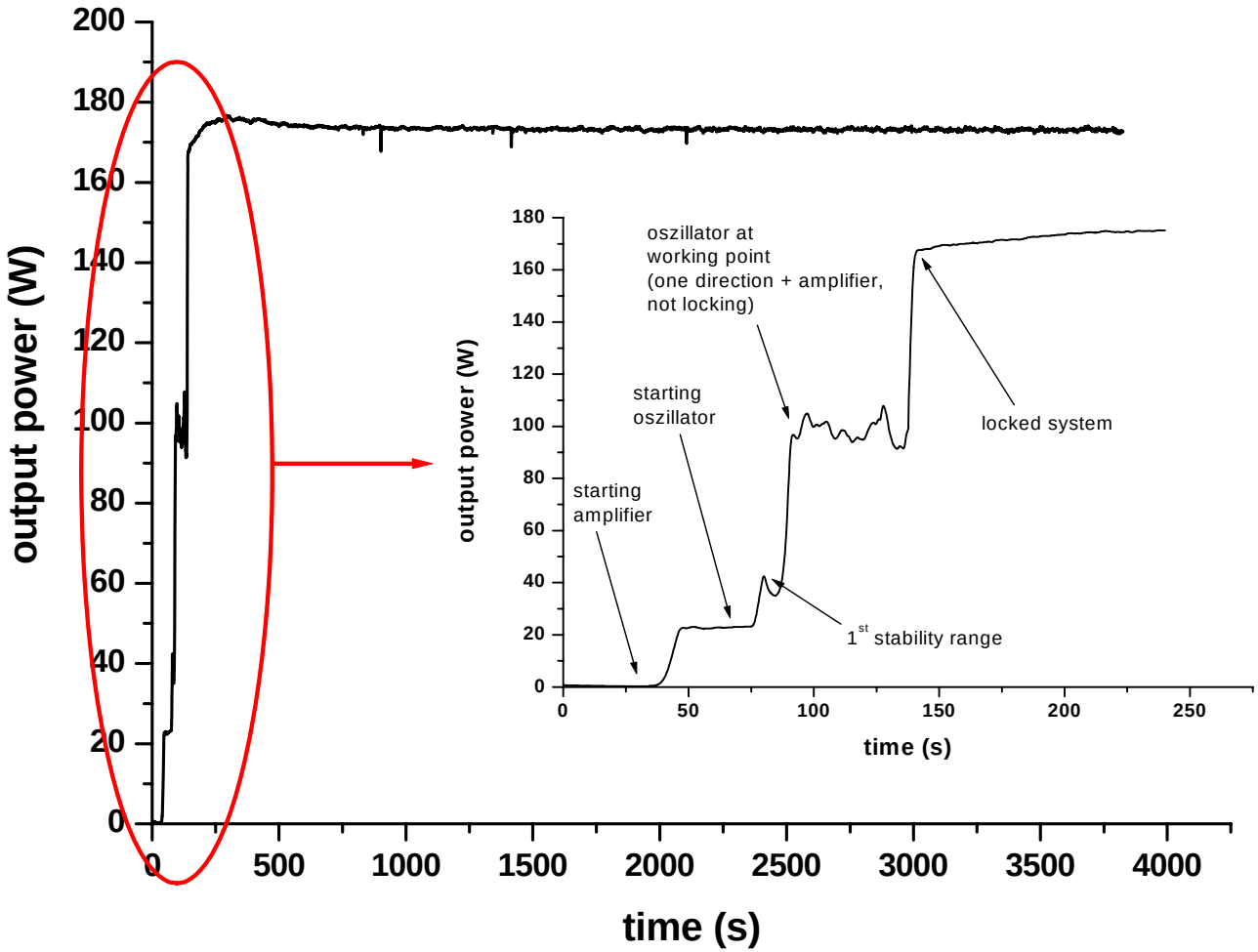
Control tower

Diode box



Visualization

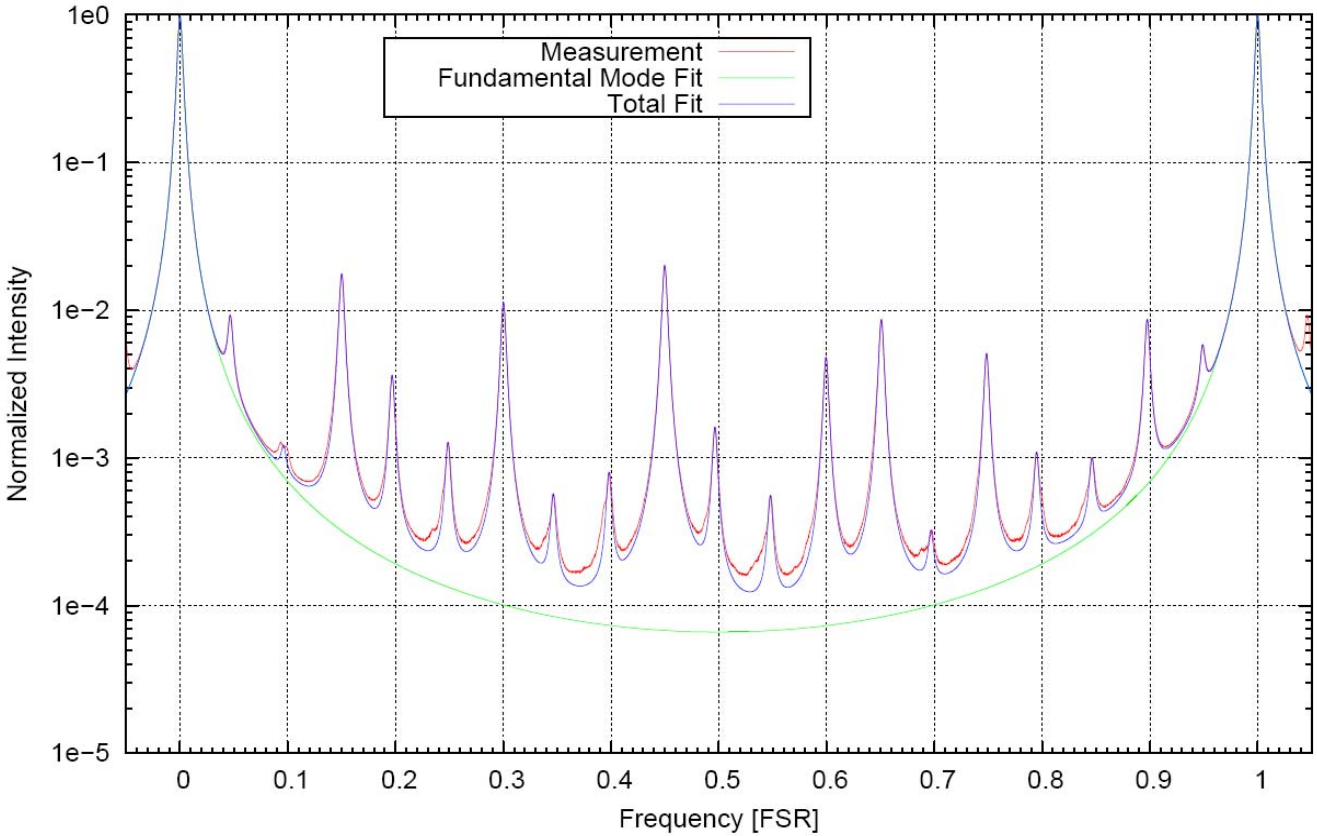
Start-up behavior

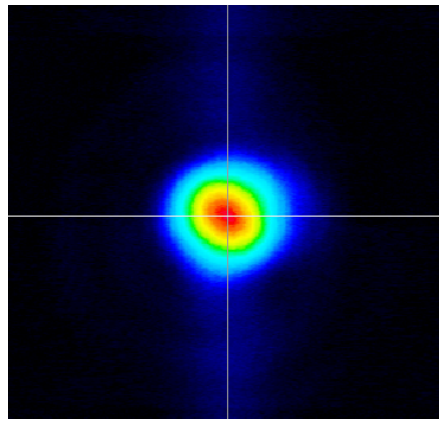


Complete system started and locked after 3 min !

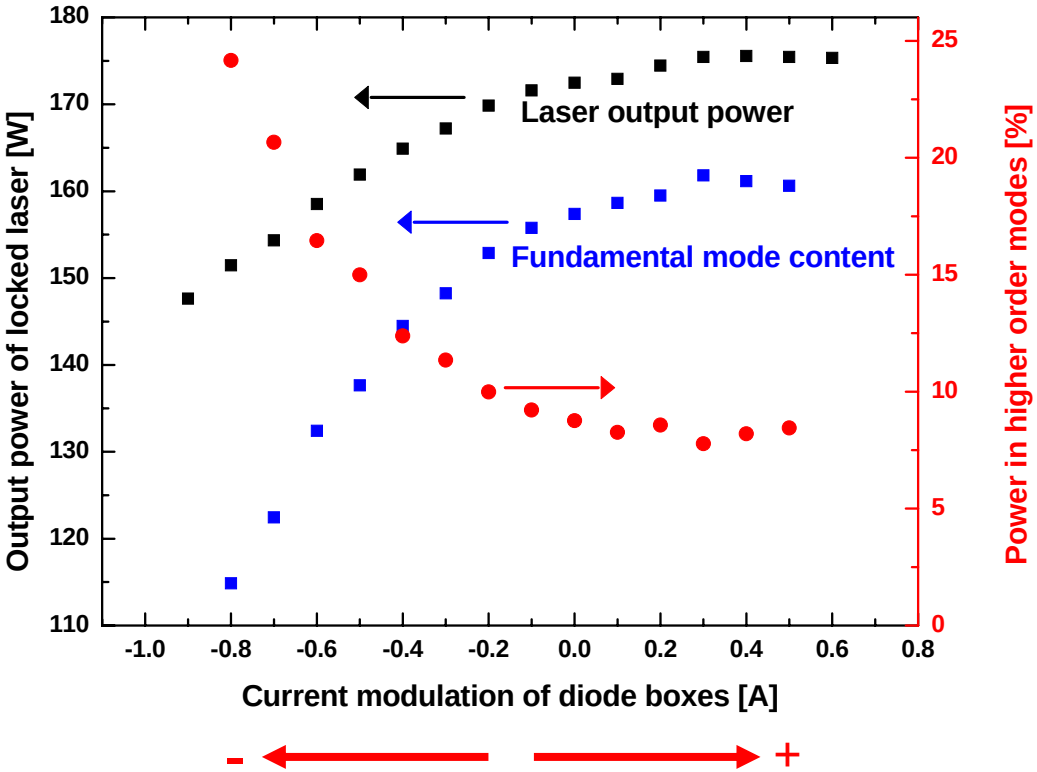
Beam quality (I)

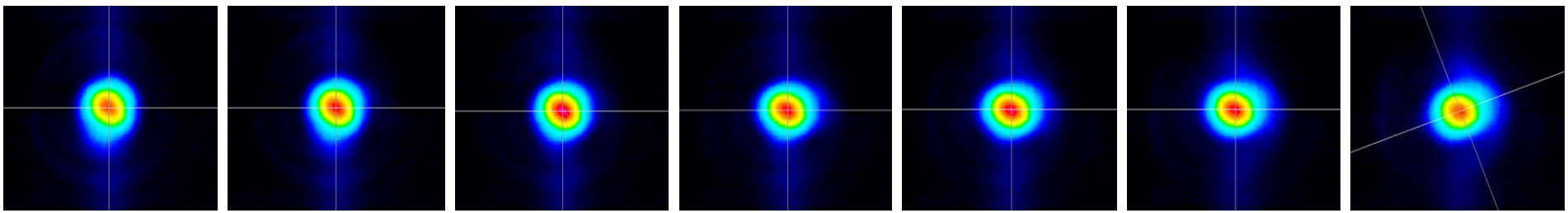
- Output power: 180.5 W
- 91.5% (~165 W) in $TEM_{0,0}$!
- Optical – optical efficiency: 23%



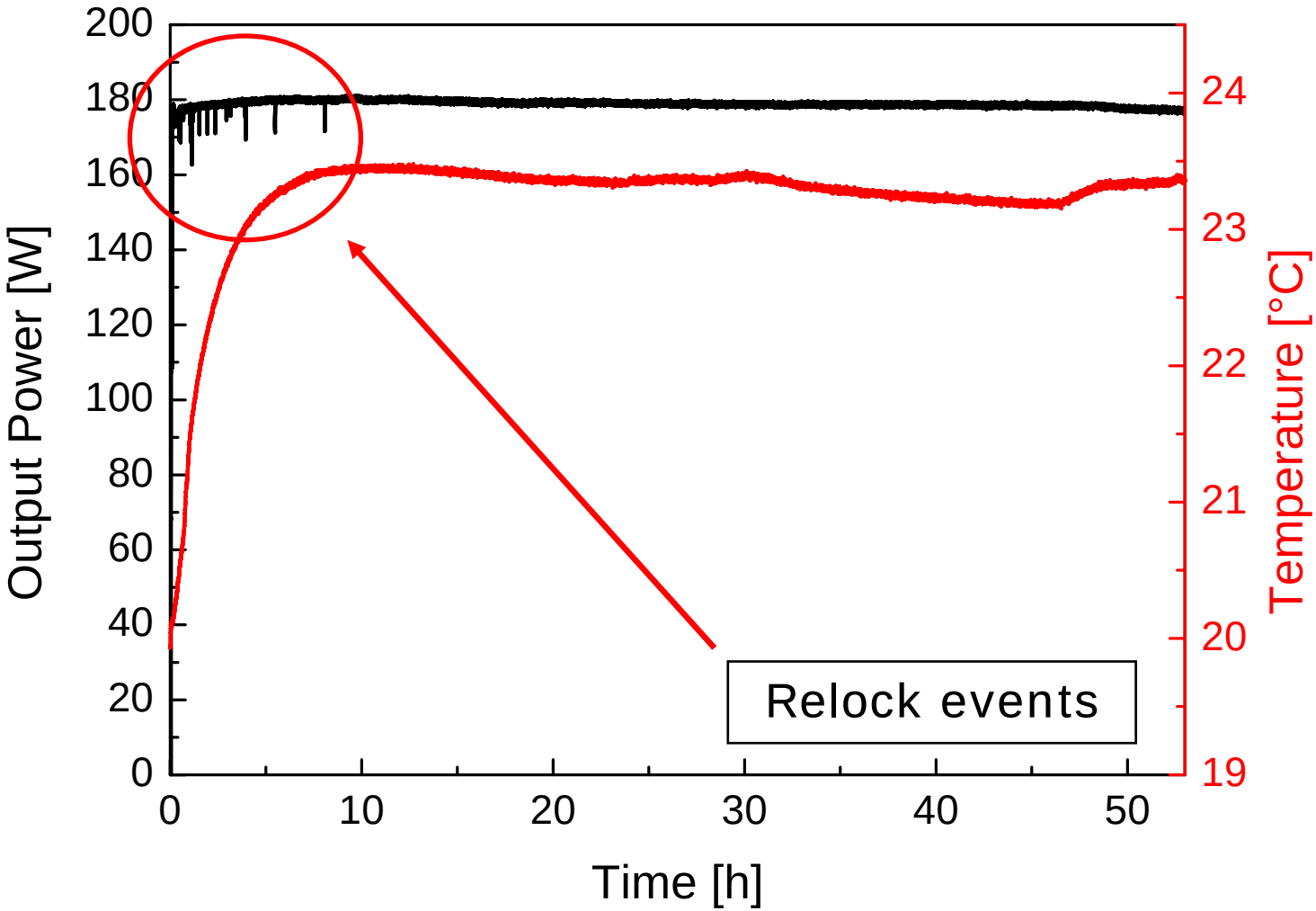


Beam quality (II)



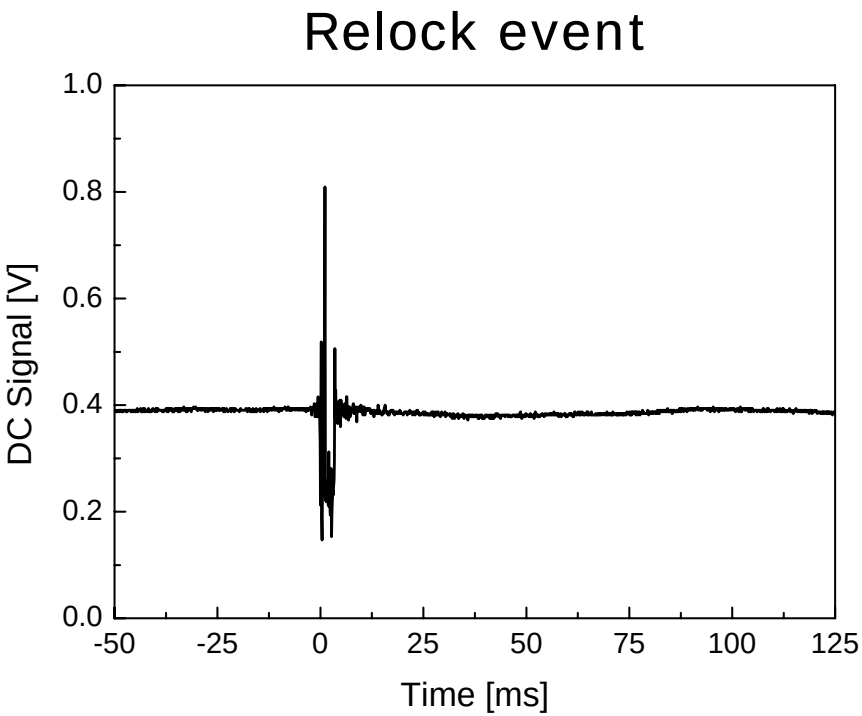


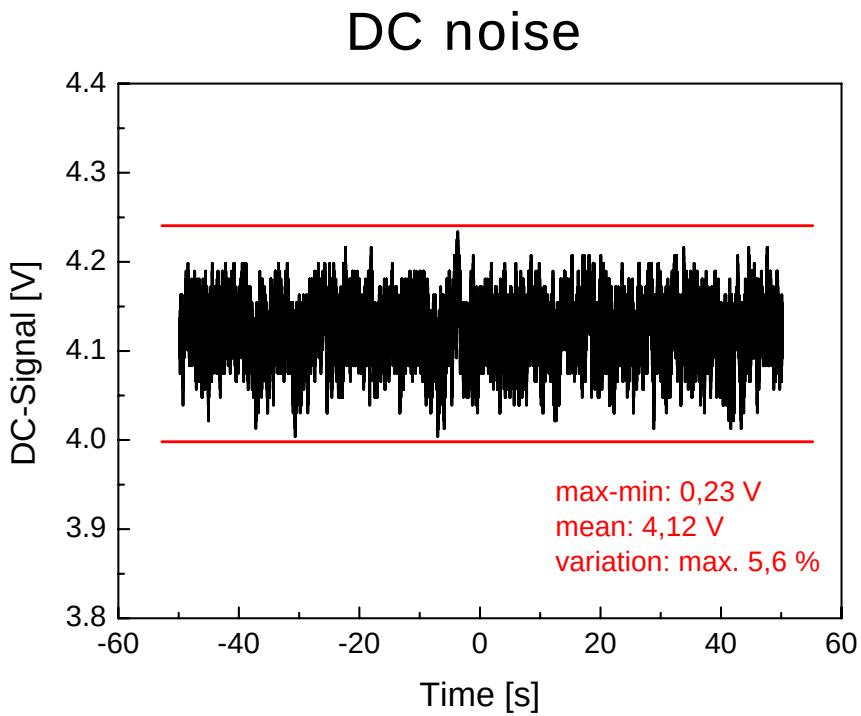
53h test run


Output Power [W]
Temperature [°C]
Time [h]
Relock events
0
20
40
60
80
100
120
140
160
180
200
19
20
21
22
23
24
0
10
20
30
40
50

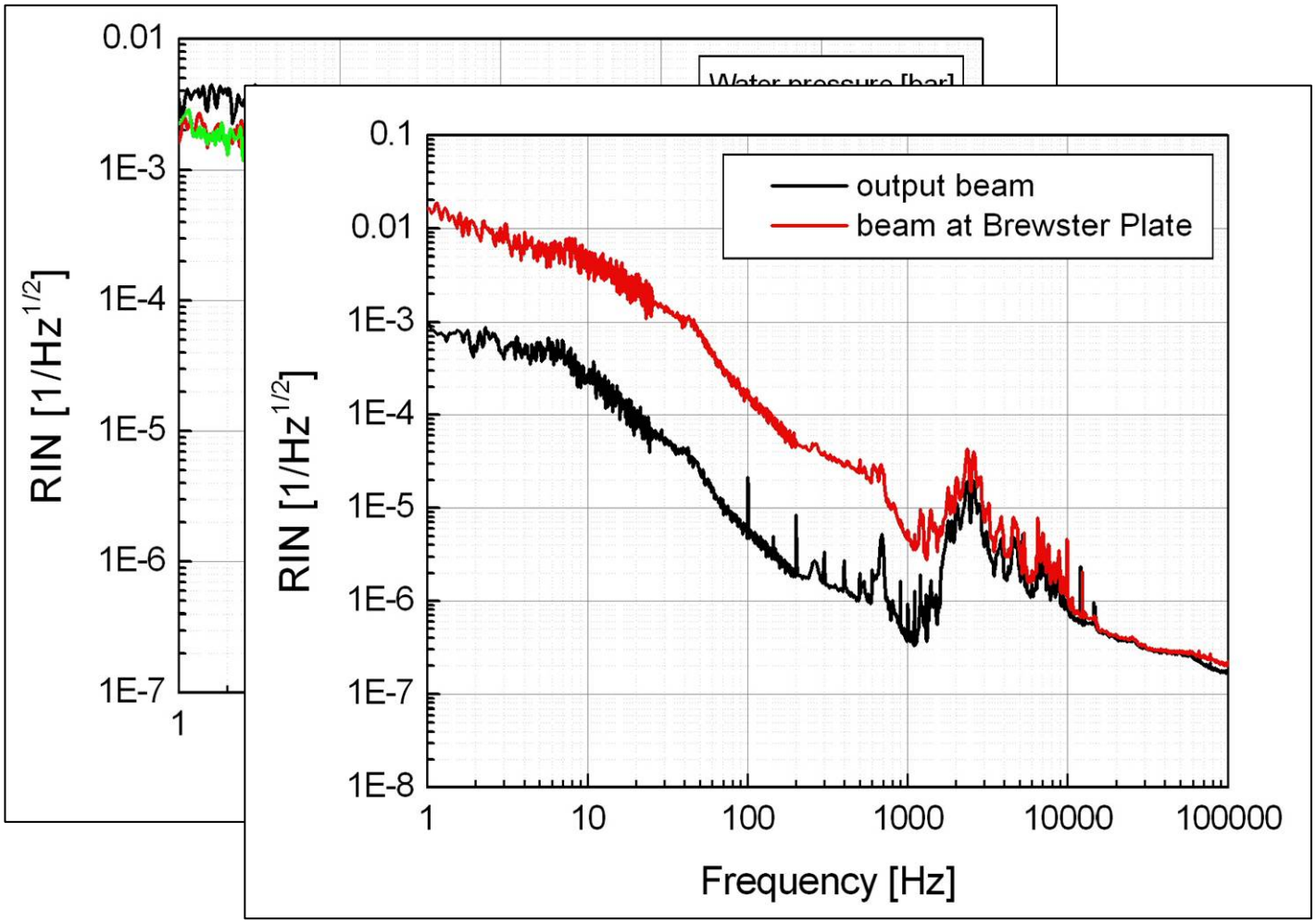
Reasons for the relocks

Relock behavior, DC noise





- Typical relock time < 50 ms
- DC noise ~ 5 %



→ Low frequency noise due to polarization dynamics ?

Polarization dynamics?

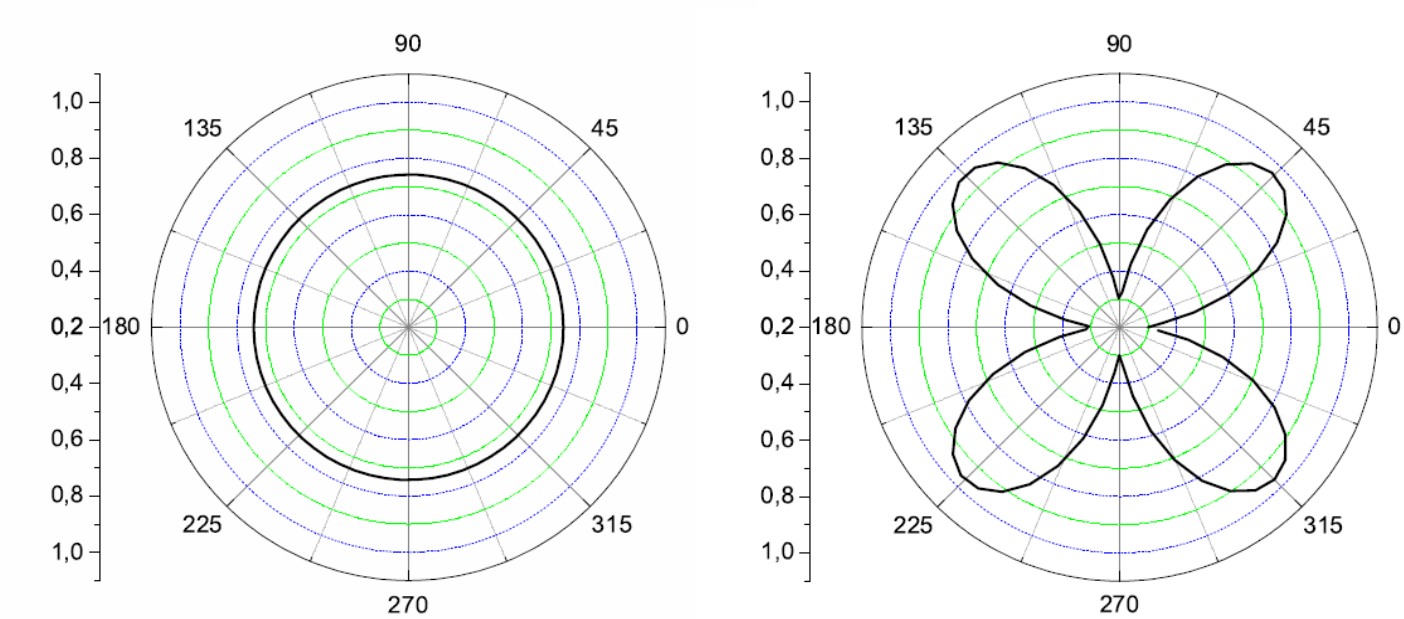
- Polarization dynamics due to depolarization in Nd:YAG crystals
- Compensation with quartz-rotator + 4f-imaging might depend on thermal lens shape (asymmetry)

Solutions:

- Less asymmetry of thermal lens
- Less depolarization

Nd:YAG crystal cut

Direct reduction of depolarization effects by different Nd:YAG crystal cut



Crystal cut: (111) (100)

→ Depolarization reduction up to 6x !

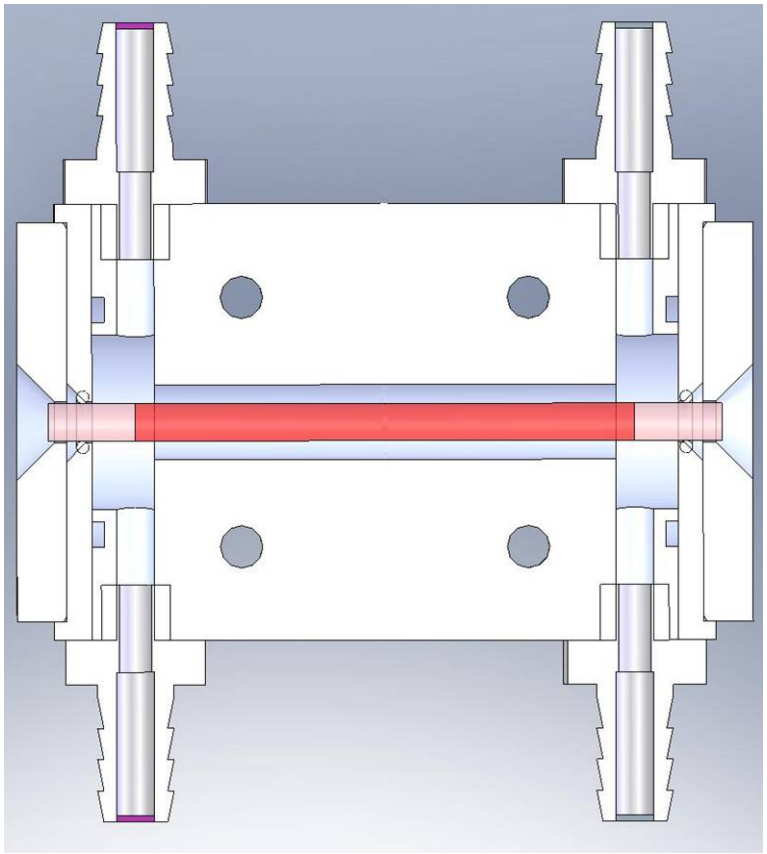
*Shoji, APL 80, 3048-3050 (2002)

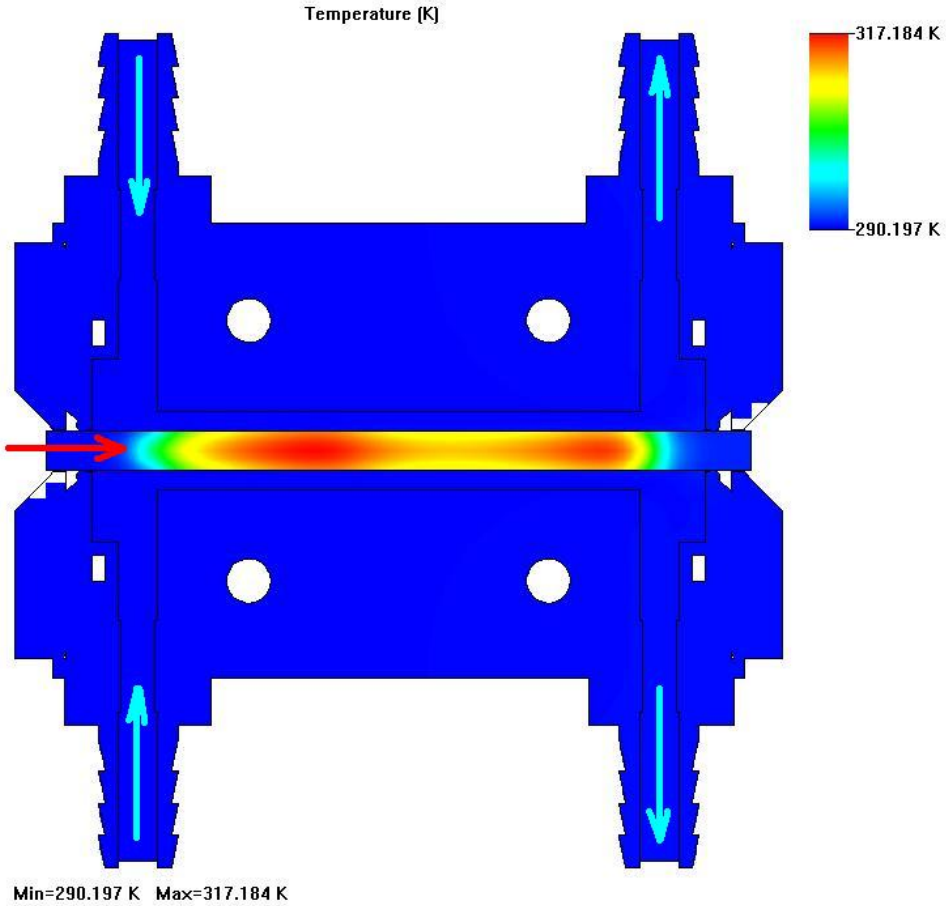
Pump chamber redesign

Redesign pump chamber for:

- Less acoustic noise
- Improved cooling efficiency
- Homogeneous crystal cooling

Pump chamber (current)

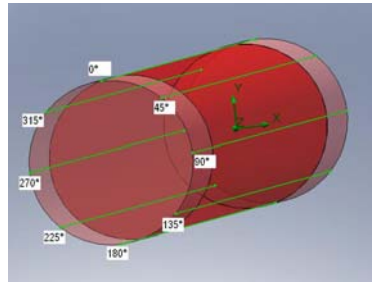


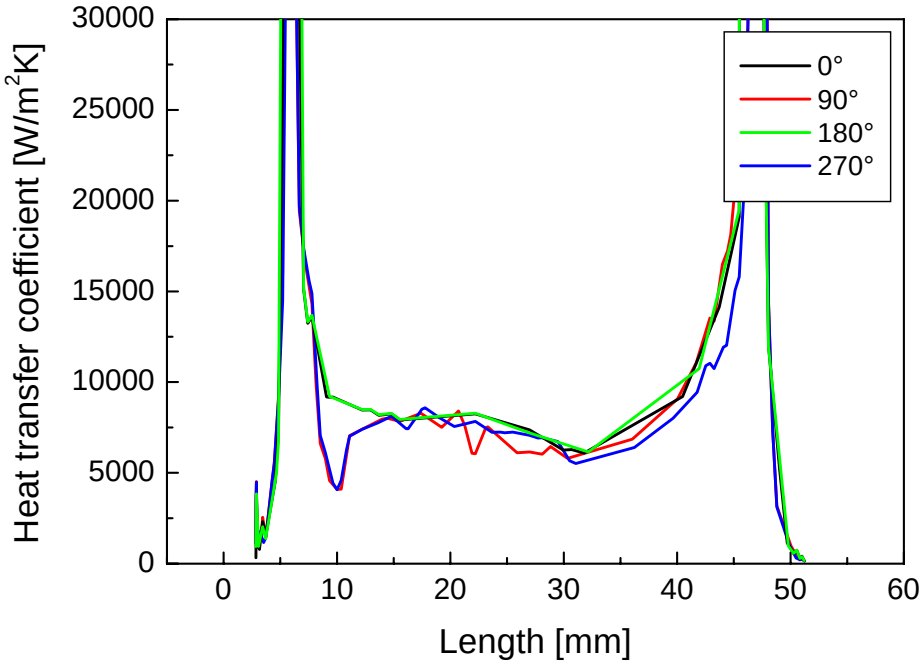


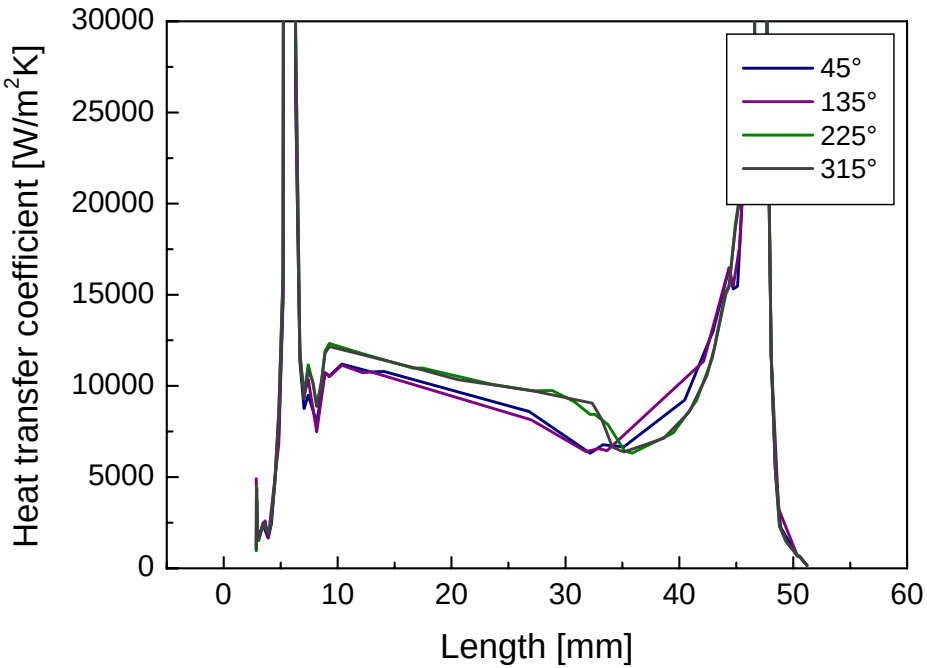
- Water-flow from the inlet directly onto the crystal
  → acoustic noise ?

Crystal cooling: current chamber

Heat transfer coefficient along crystal axis





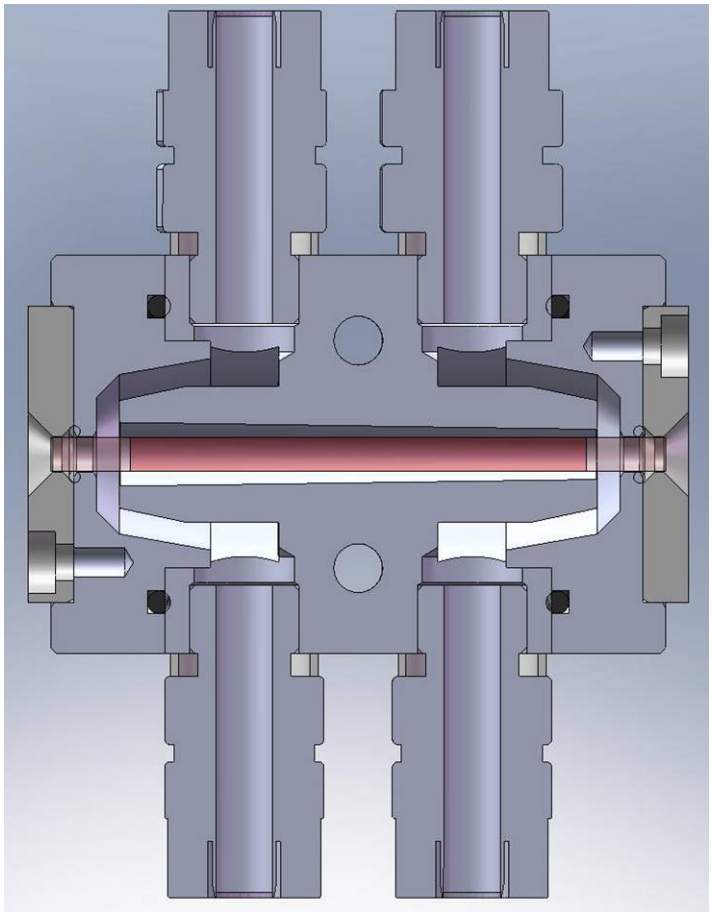


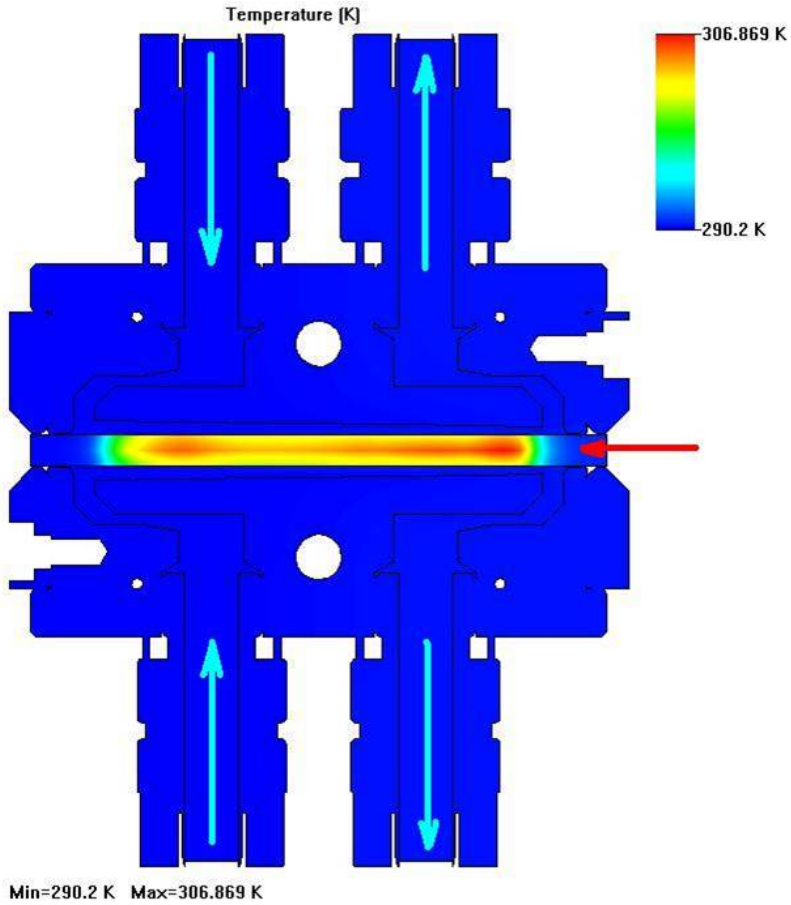
→ Inhomogeneous cooling of crystal

→ Asymmetry of thermal lens

→ No perfect depolarization compensation possible ?

Pump chamber – new design

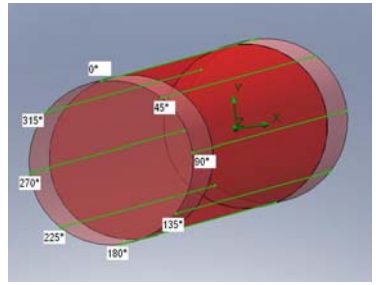


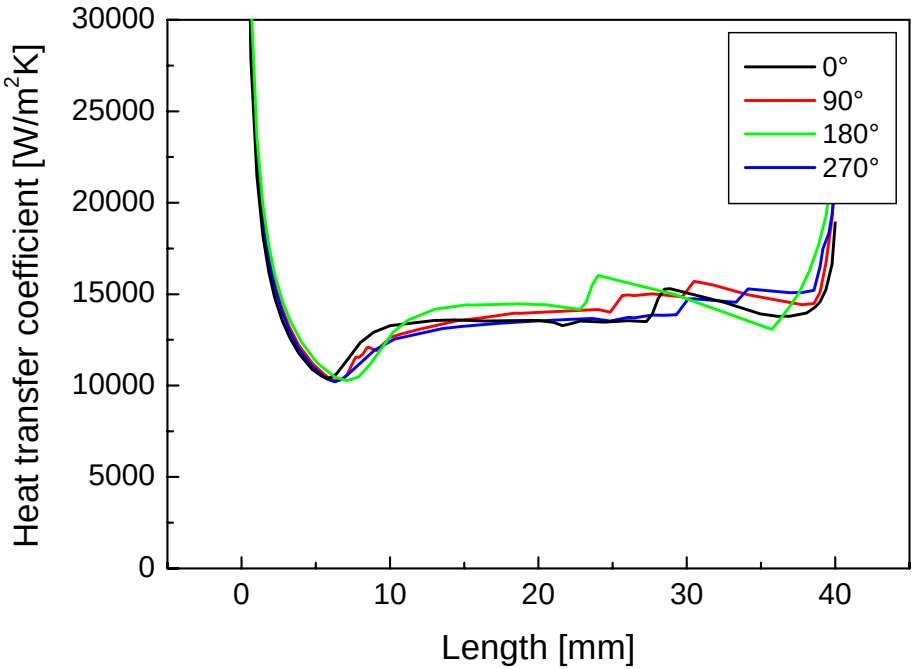


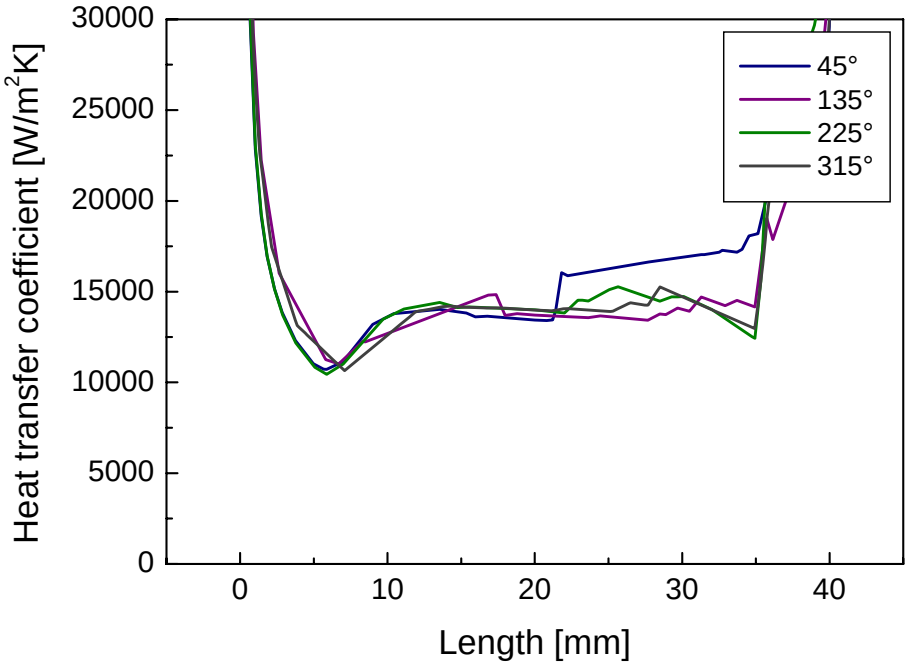
- Water-flow from the inlet **not** directly onto the crystal
  → less acoustic noise ?
- Increased water flow for better cooling efficiency

Crystal cooling: new chamber

Heat transfer coefficient along crystal axis







→ Homogeneous and improved cooling of crystal

→ Improved depolarization compensation and less polarization dynamics ?

What's next: advLIGO

- Implementation and test of power stabilization
  - Separate talk about advLIGO power stabilization by Peter King, Thursday, 09:40
- Test of high power pre-mode cleaner
- Investigation and reduction of low frequency intensity noise
- Demonstrate LIGO design specifications
- Preliminary Design Review: Jan. 2008
- Move on to advLIGO Engineering Prototype Design

Summary

- eLIGO
  - Eng. Prototype at Caltech
  - Reference System ready
    - 37 W / 93% in $TEM_{0,0}$
  - Ref. System now at AEI for stabilization
  - Observatory I/II ready by 12.07 / 02.08

- advLIGO
  - Functional Prototype ready
    - 180 W / 91.5% in $TEM_{0,0}$

LZH Lab tour

Not listed in the official program:

LZH Lab tour Thursday 14:00

Thank you for your attention!

Fiber amplifier results: PCF

- Photonic crystal fiber amplifier
- 148 W
- 92.6 % in $TEM_{0,0}$
- No sign of stimulated Brillouin scattering