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LASER ZENTRUM HANNOVER e.V.

# Status of the advanced LIGO laser

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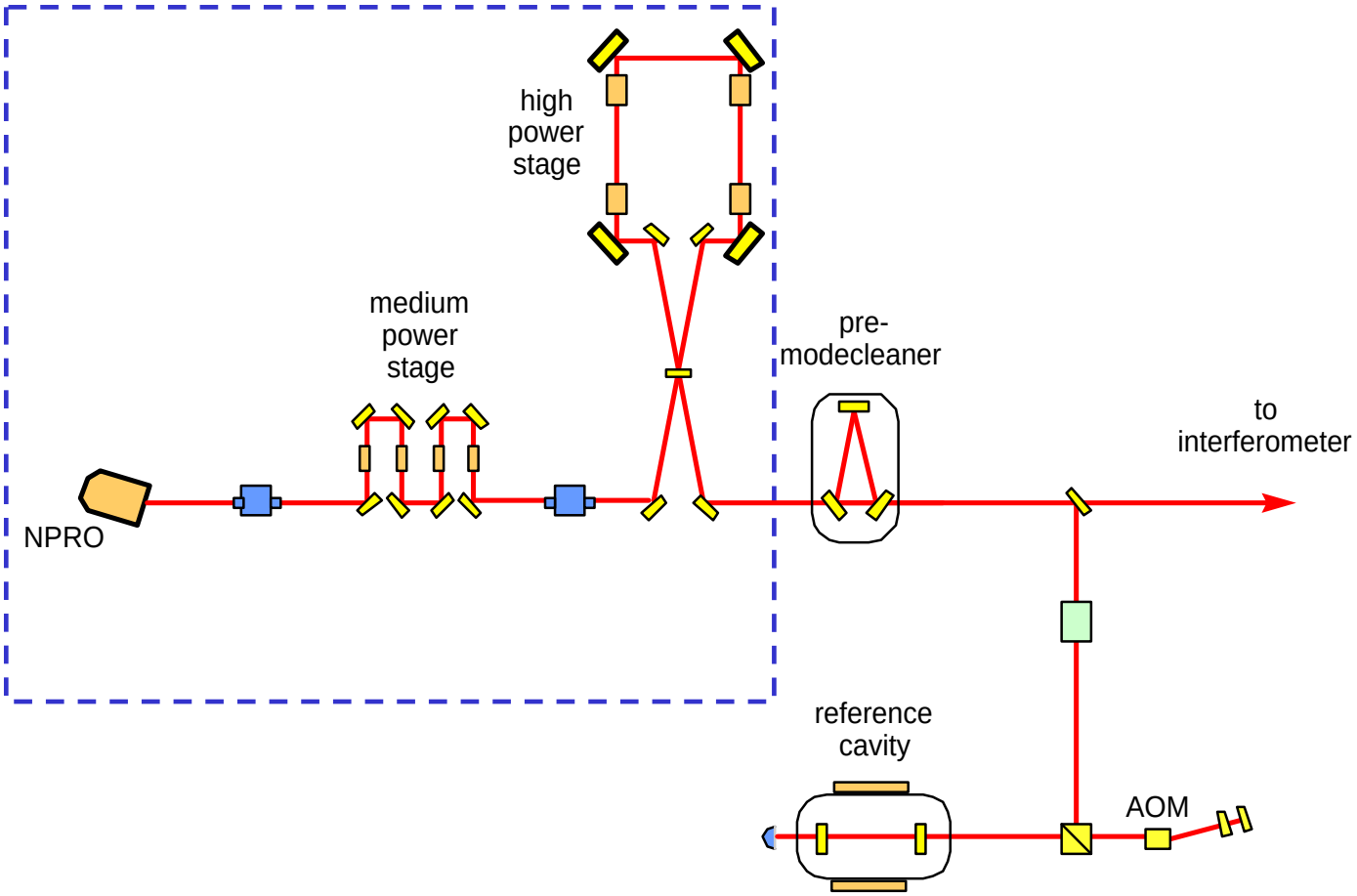
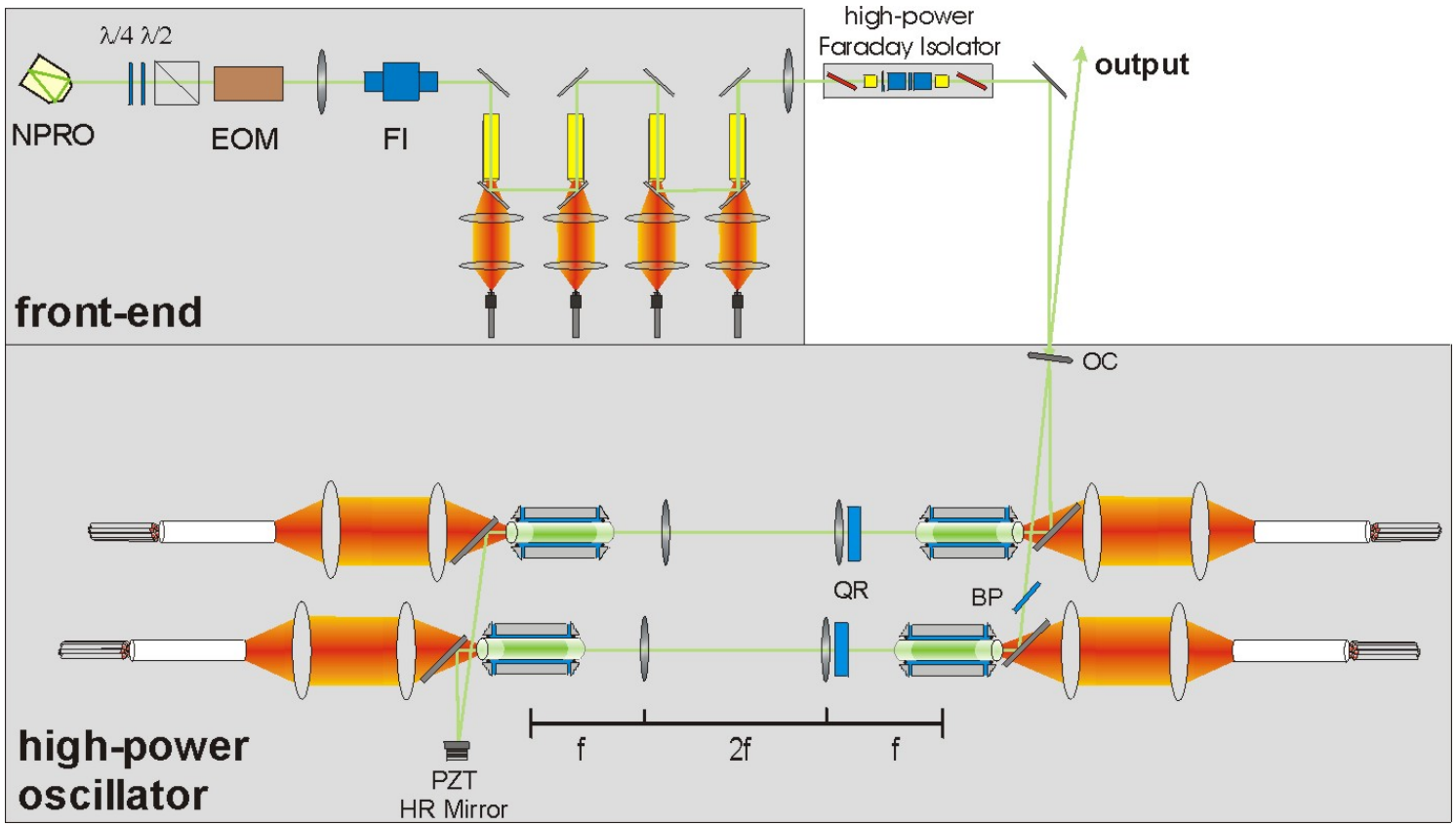
# Content

- Setup
- Status in October 2007
- Current status
- Characterization work
  - Crystals
  - Mirrors
  - Diodes
- System improvement / outlook
  - Crystal cooling

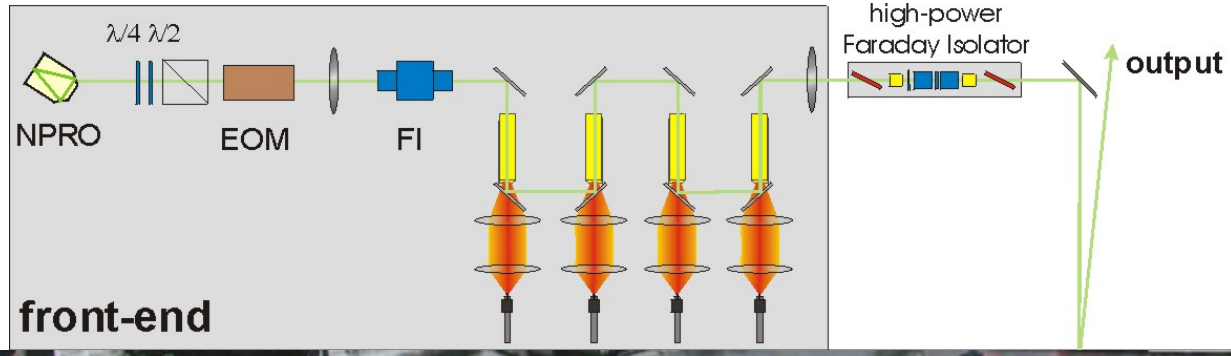
# Advanced LIGO PSL: high power laser



# Setup


λ/4 λ/2
NPRO
EOM
FI
high-power
Faraday Isolator
output
front-end
OC
QR
BP
high-power
oscillator
PZT
HR Mirror
f
2f
f

# Setup


λ/4 λ/2
NPRO
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output
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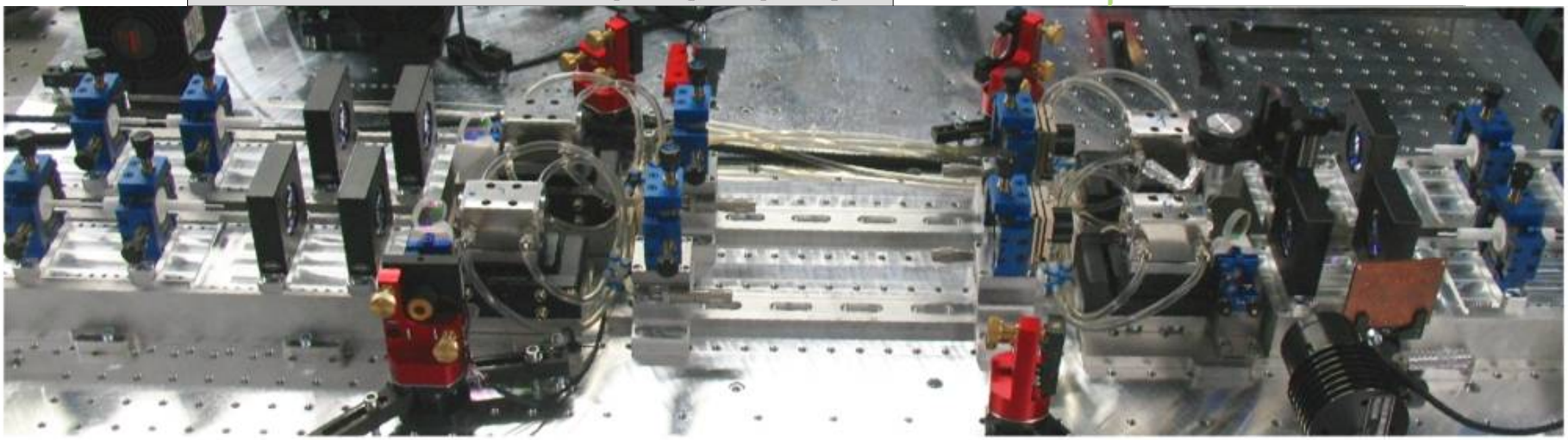
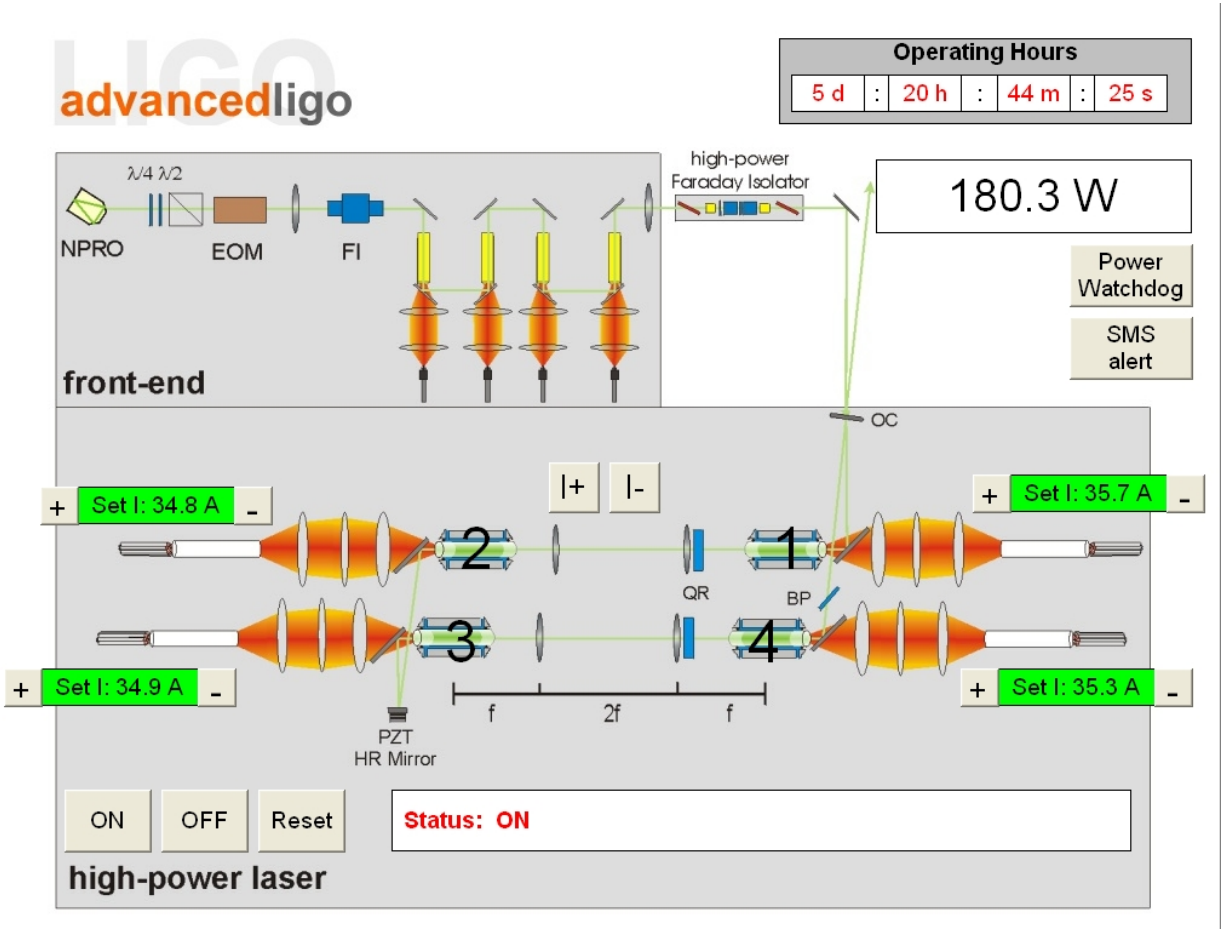
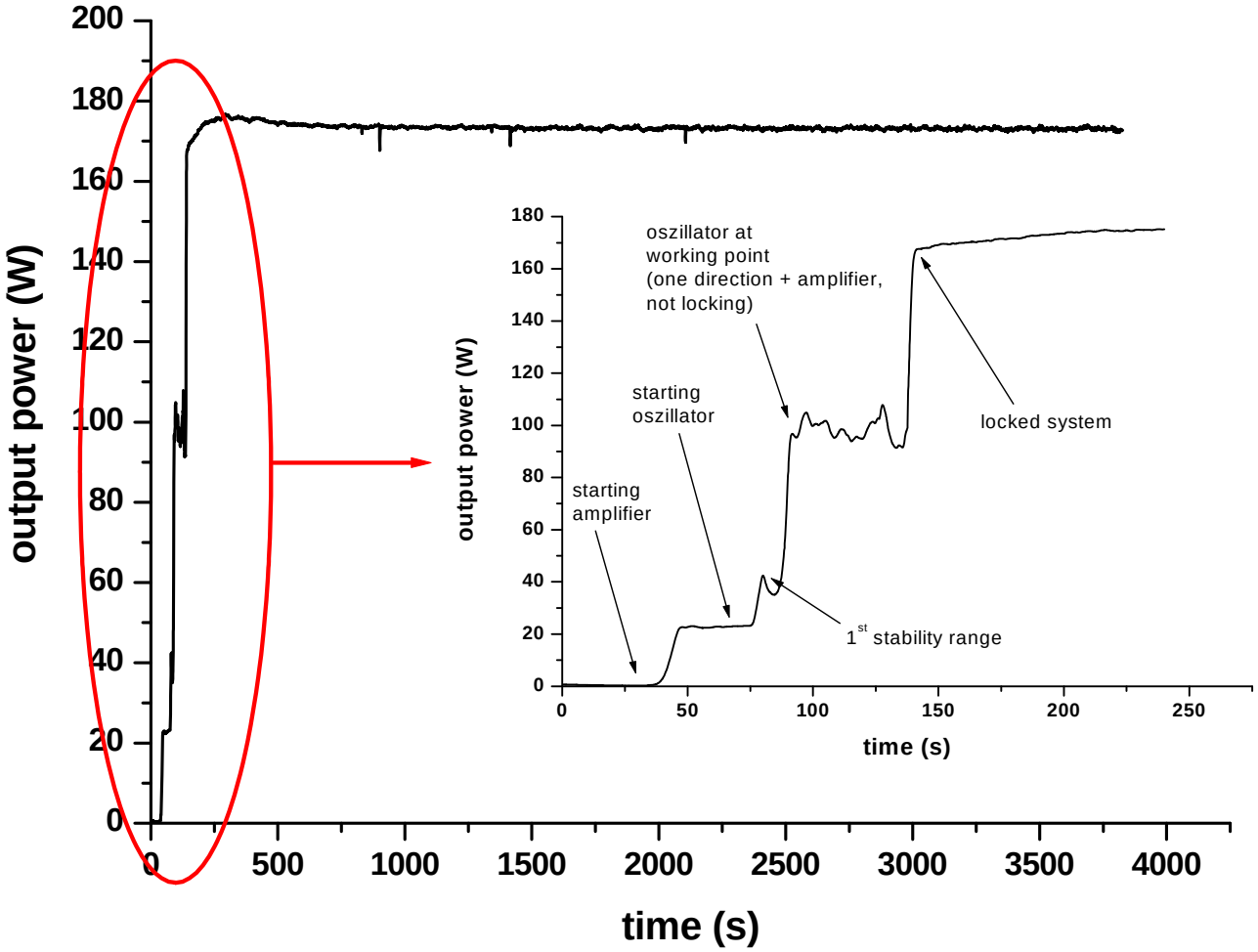


# Adv. LIGO electronics



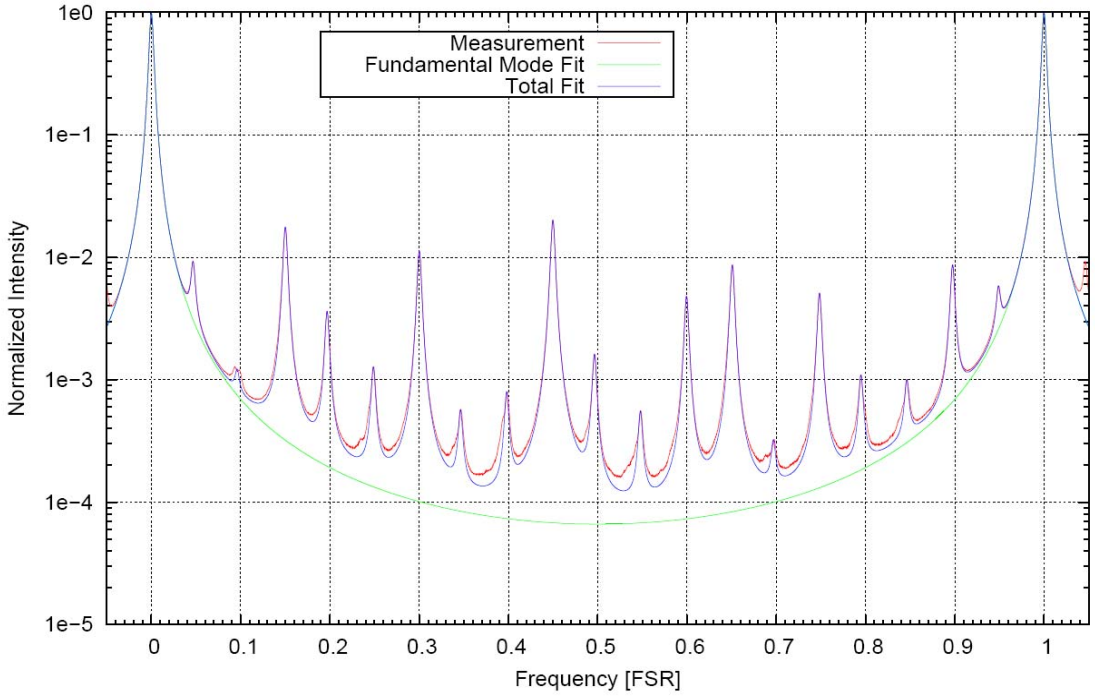
# Start-up behavior

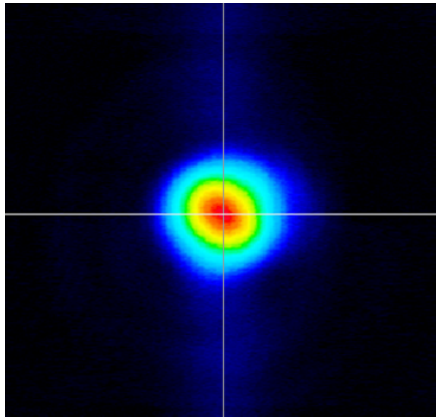



Complete system started and locked after 3 min !

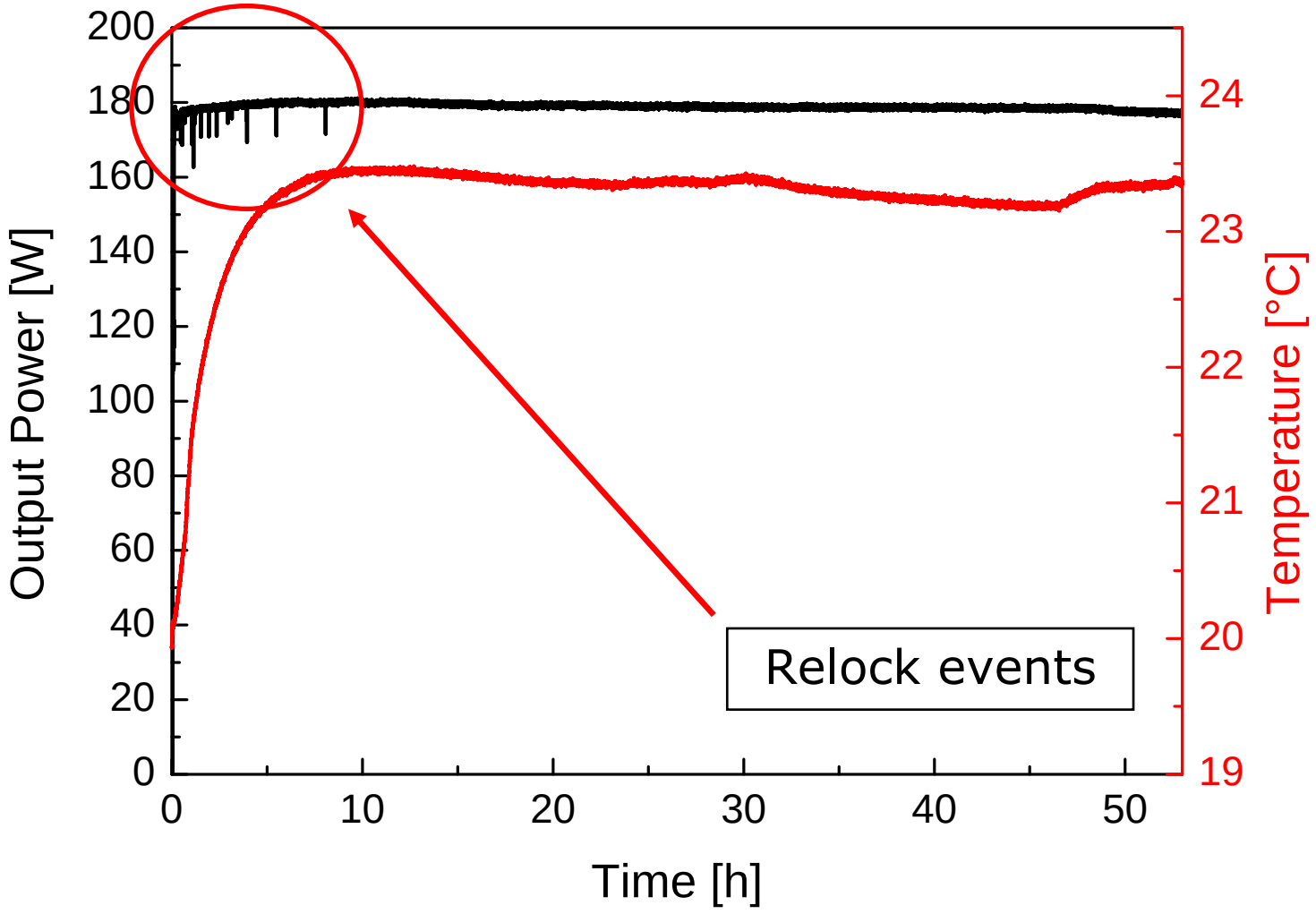
# Beam quality

- Output power: 180.5 W
- 91.5% (~165 W) in $TEM_{00}$



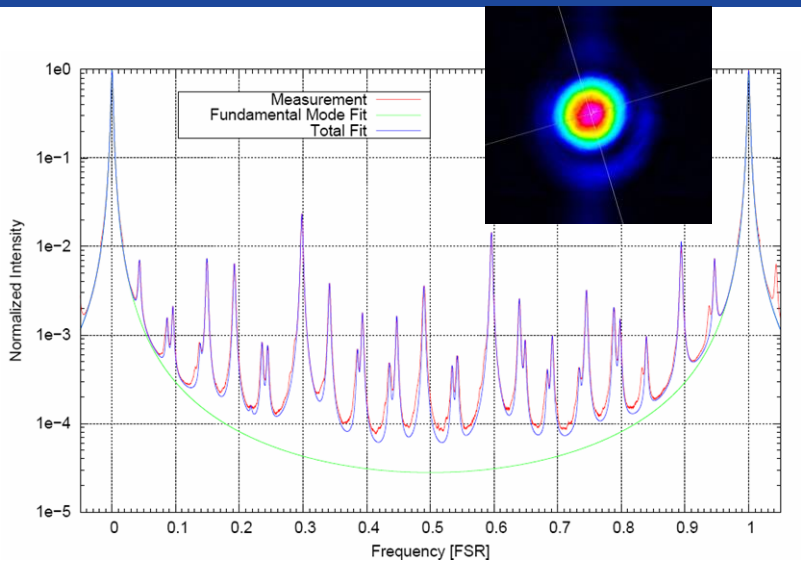



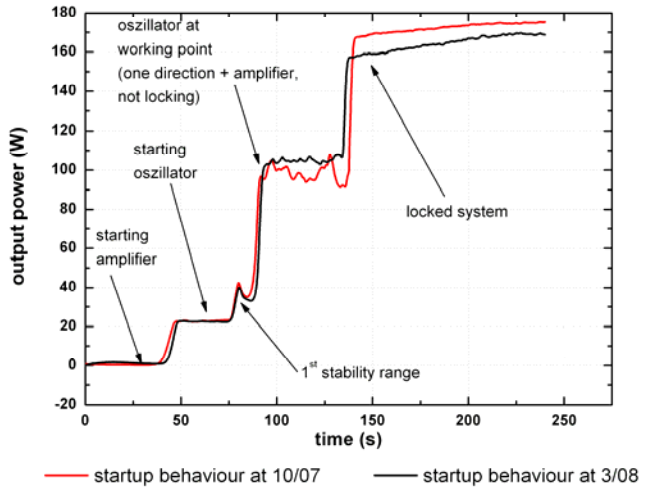
# 53h test run


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

# Current status

- ≈ 174 W at 4 x 185 W pump power
- 91 % in $TEM_{00}$
- DC noise ≈ 5% (not changed)
- Typical relock time < 50 ms (not changed)
- Startup: complete system started after 3 min

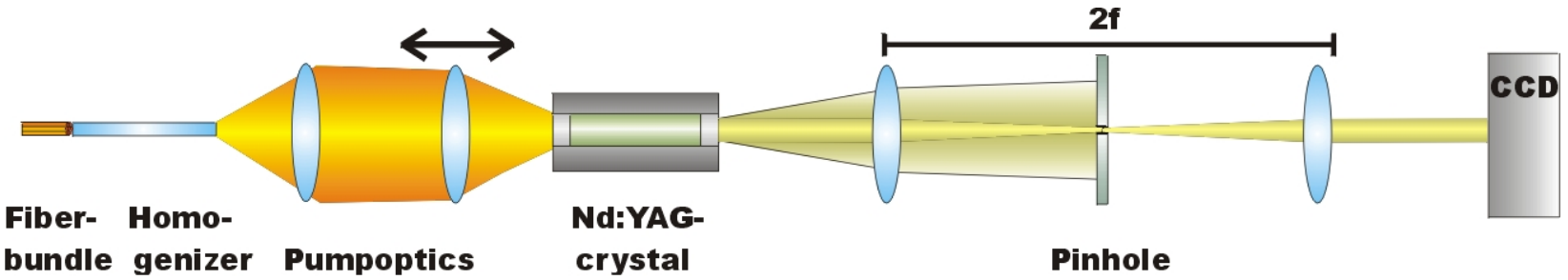


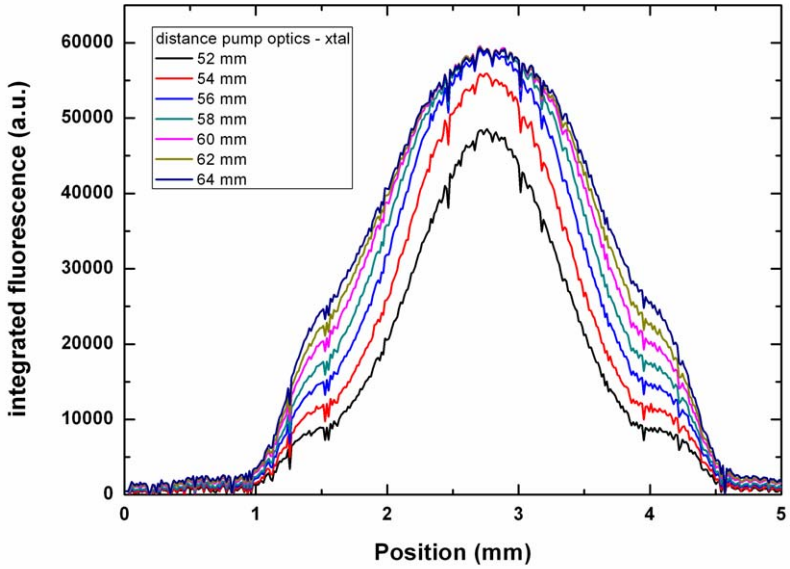
# Doping of the crystals

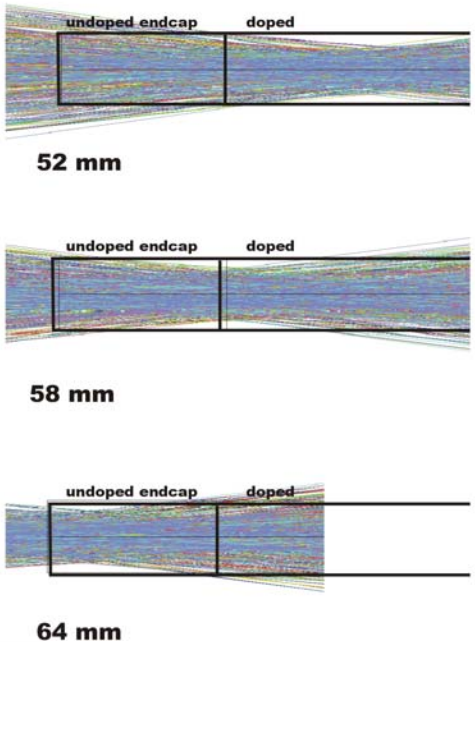
- Nd:YAG crystals, 40mm 0.1 at % doped region / 7mm undoped endcap
  - Doping specifications 0.1 at. % +/- 0.01 at. %
- Actual incoming from different vendors:
  - ~ 0.1 – 0.13 at %
  - Doping gradient over crystal length
- → different thermal optical effects !

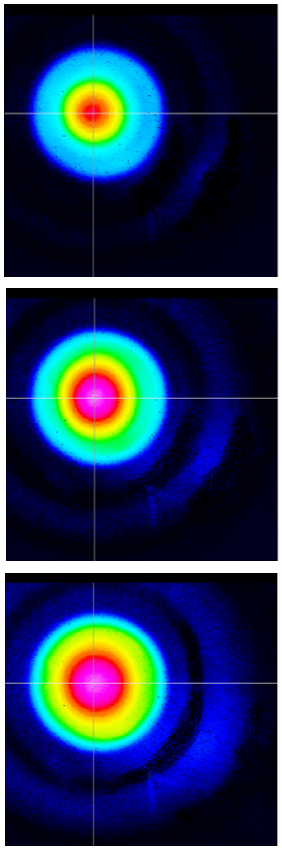
# Integrated fluorescence



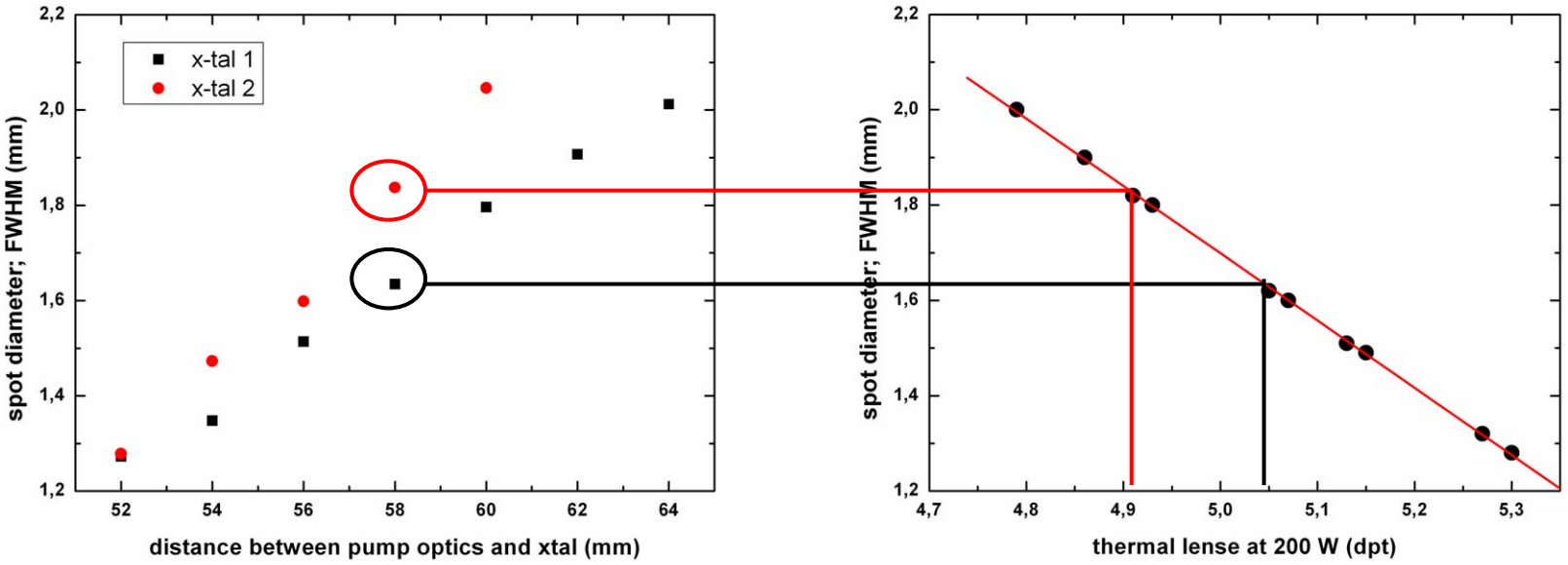
# Integrated fluorescence



# Spot diameters from integrated fluorescence



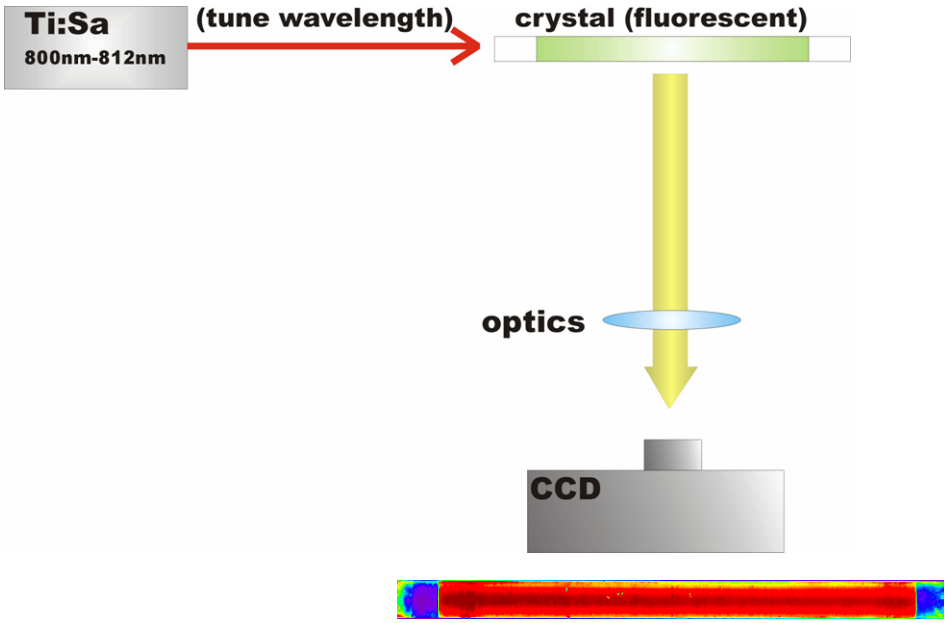

→ Crystals are slightly different doped
→ Characterization of the incoming crystals

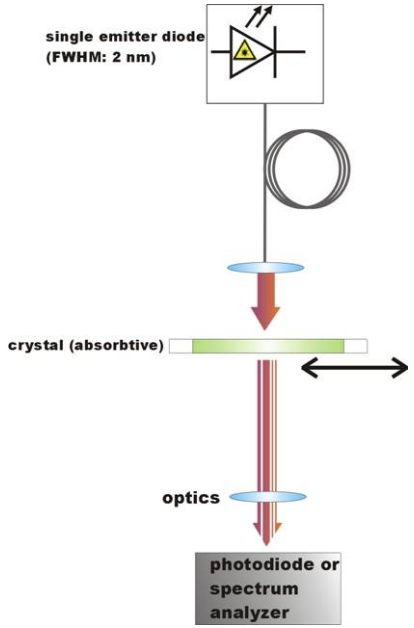
# Incoming inspection of the components

- Since small qualitative differences seem to have a big effect, this is the only way to guarantee the reproducibility of the system !

- Development of characterization facilities for
  - Crystals
  - Mirrors and lenses
  - Pump diodes

# Crystal characterization



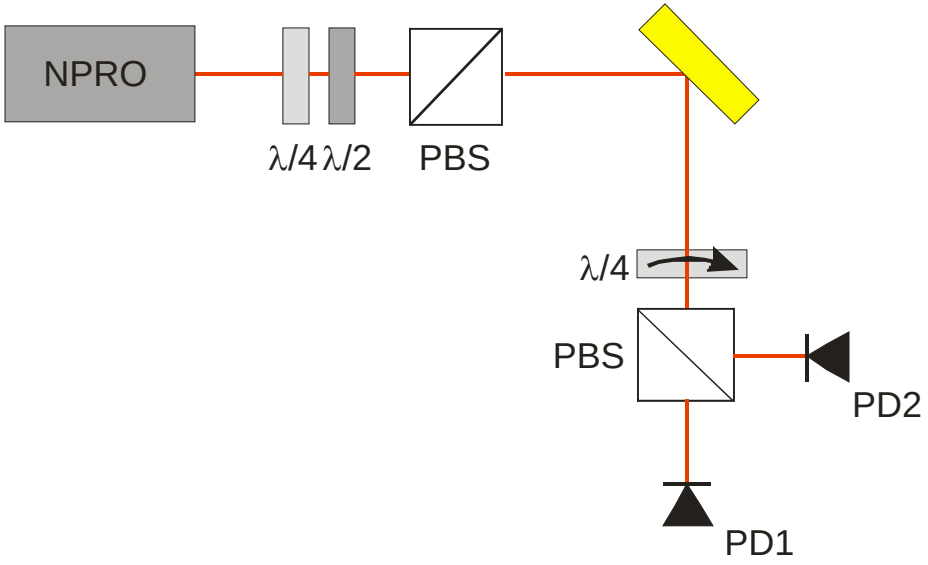

- so far: longitudinal measurement of the fluorescence
- upcoming: transversal measurement of the absorption

→ Direct measurement of the doping concentration

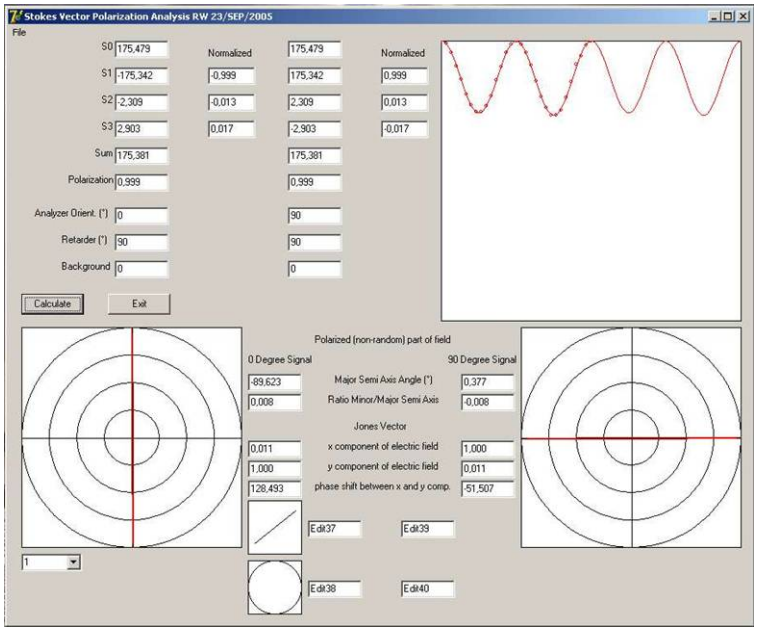
→ Possibility of „scanning" the crystal to find doping gradients

# Mirror characterisation

automated polarimeter

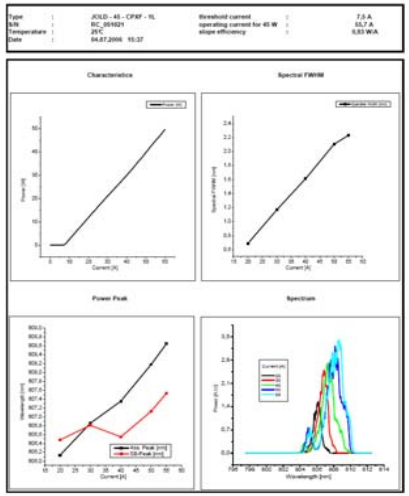



polarization analysis software



# Diode characterisation

- Automated test facility for measuring
  - Slope
  - Spectral FWHM at different currents
  - Spectrum at different currents
  - Peak wavelength
  - Threshold
  - Operating current for 45 W optical output



# Content

- Setup
- Status in October 2007
- Status now
- Characterization work
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  - Mirrors
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- System improvement / outlook
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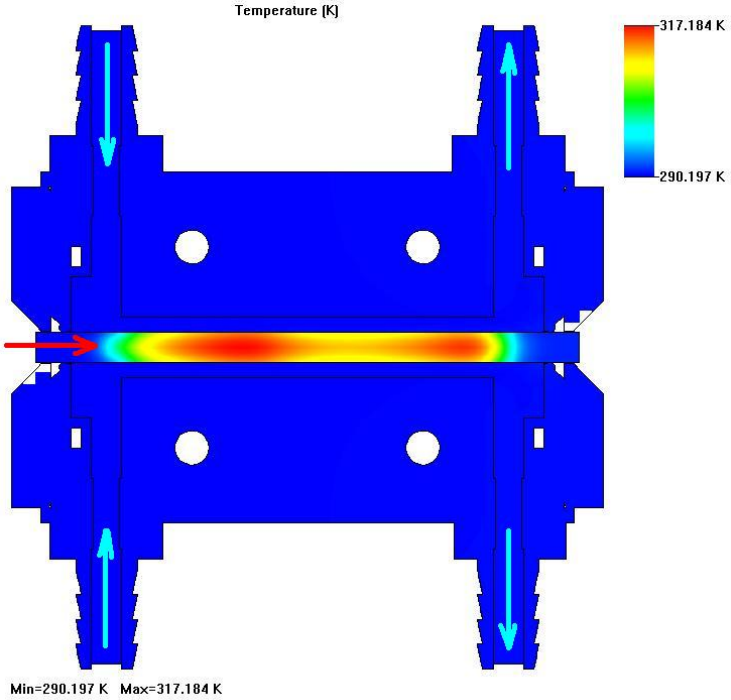
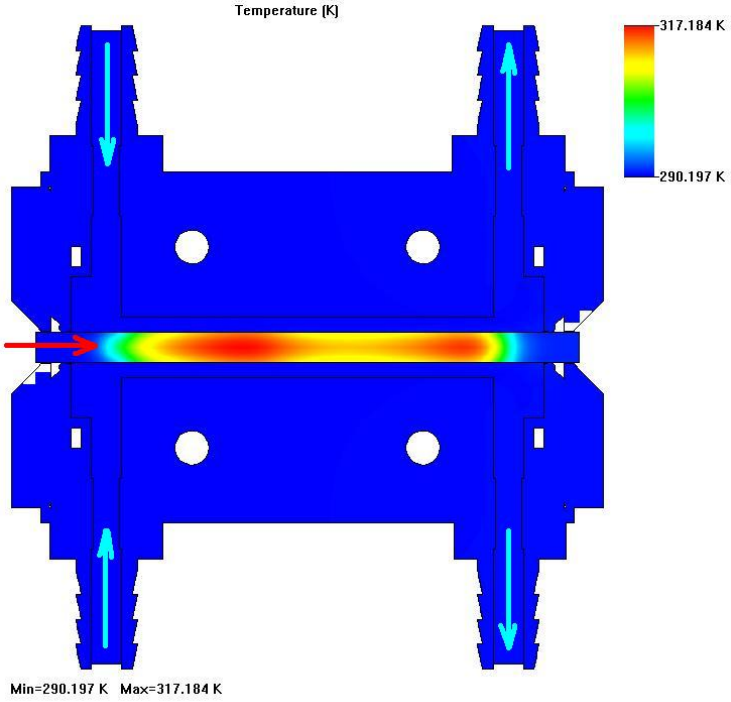
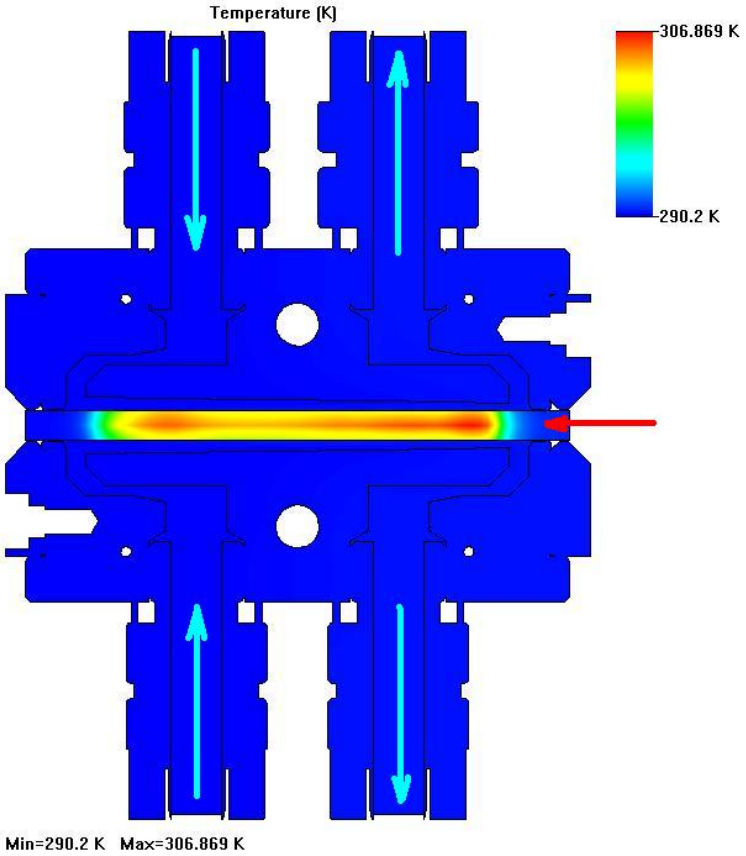
# Improvements: new pump chambers



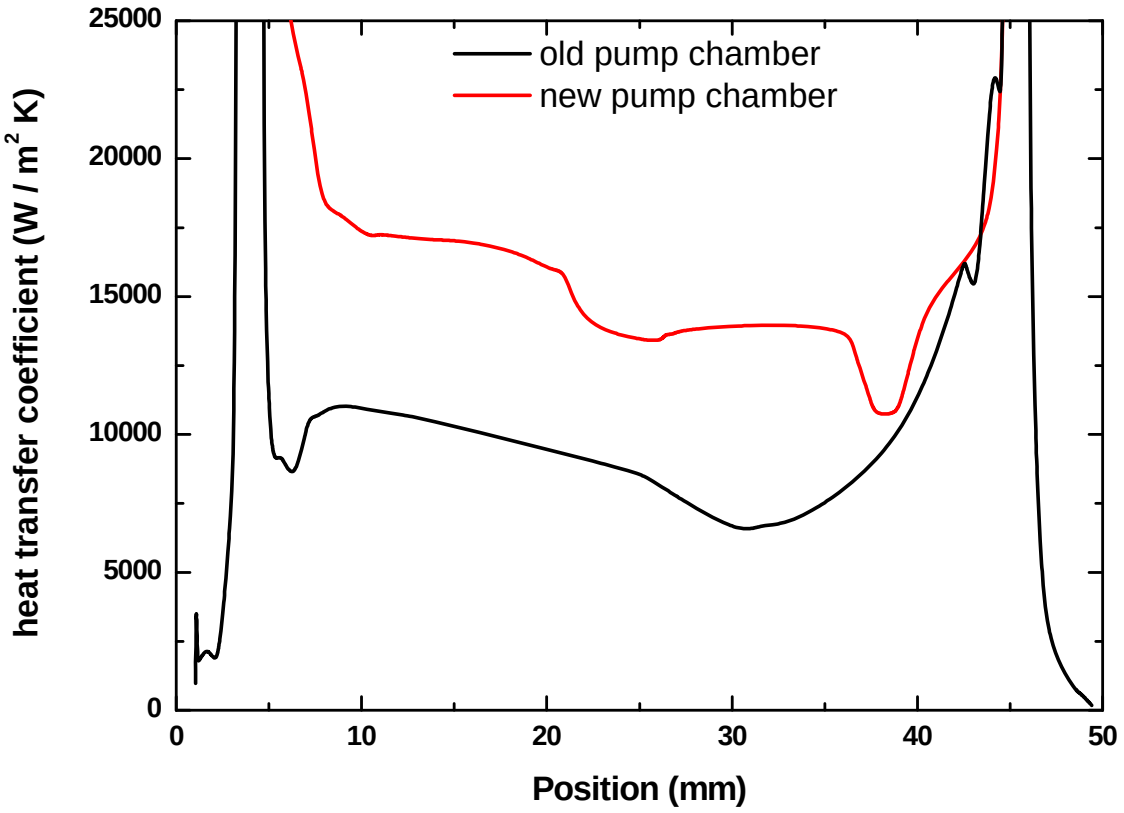

- More homogeneous cooling at the crystal surface ?
- Higher cooling efficiency ?
- Less acoustic noise ?

# Improvements: new pump chambers



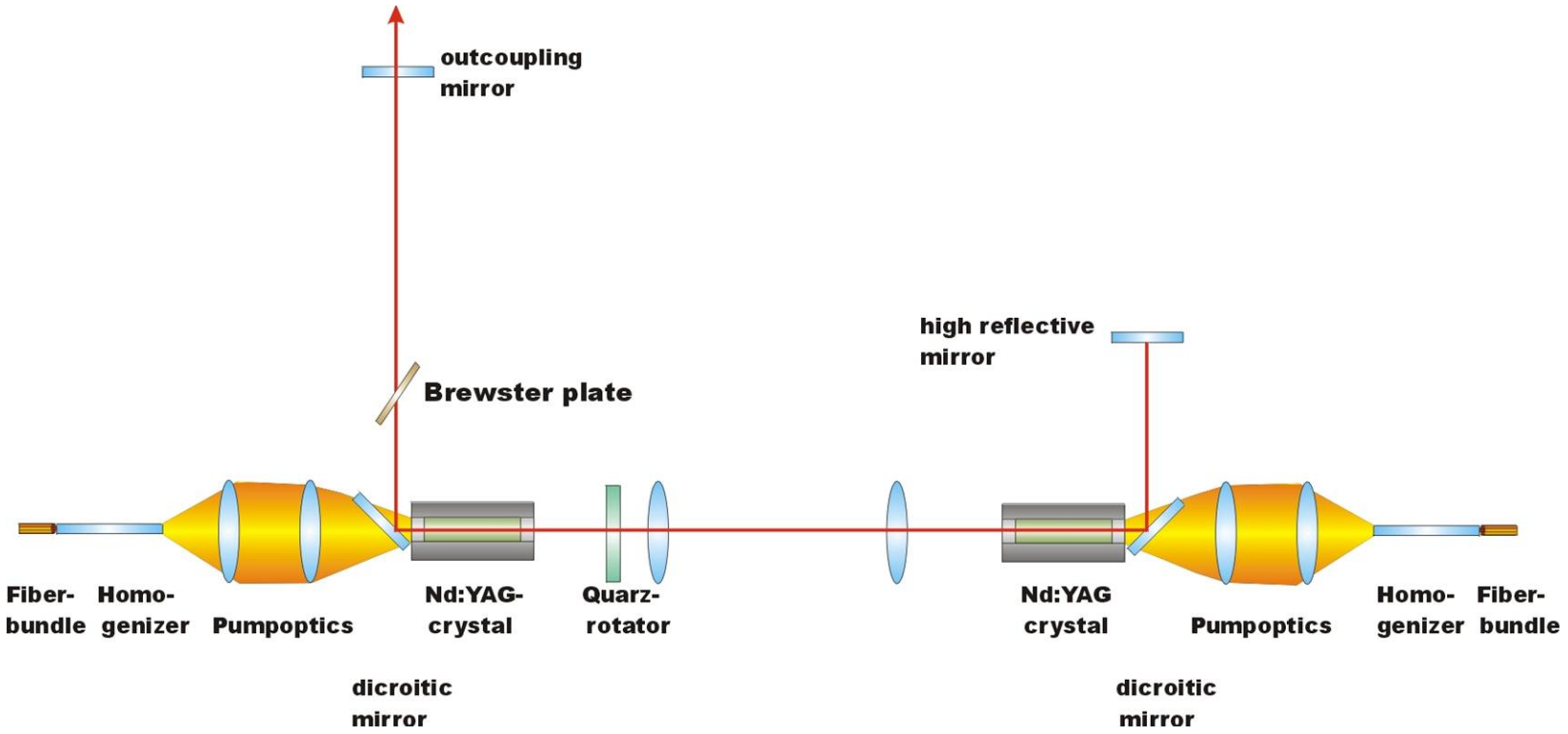



# Improvements: new pump chambers

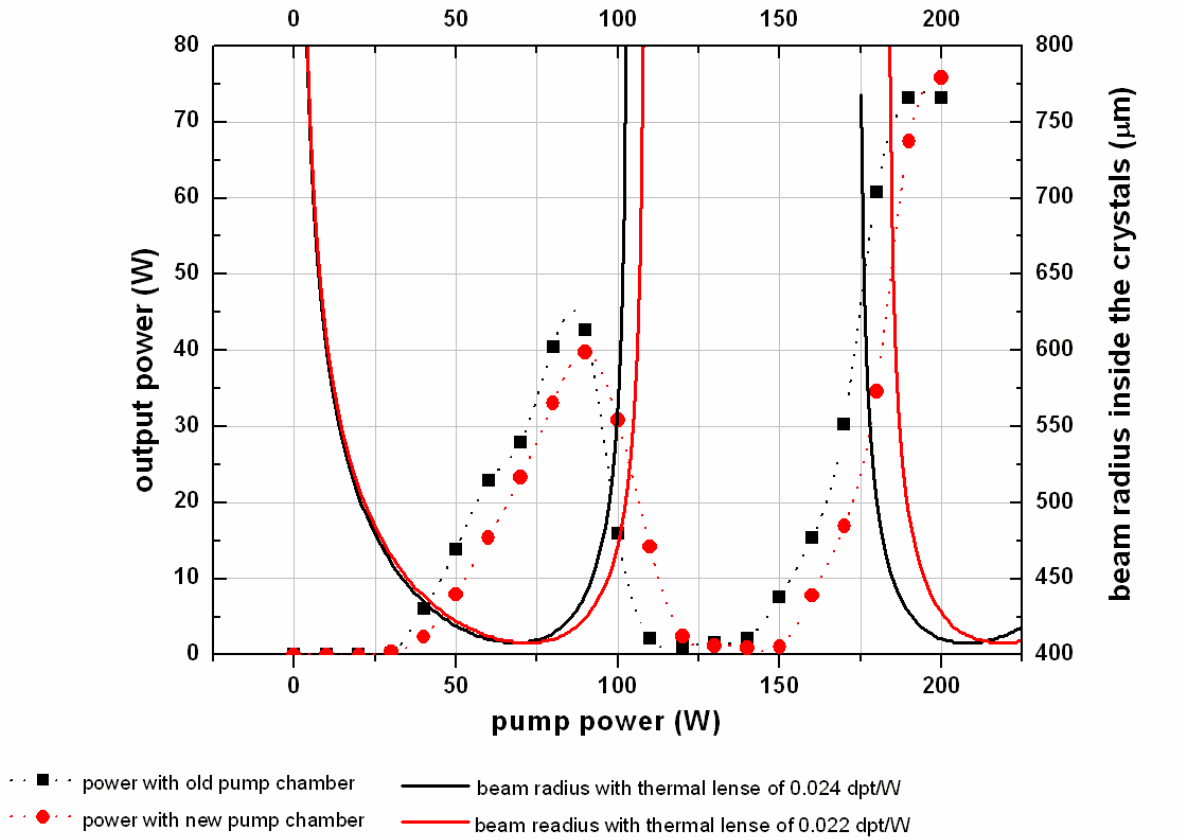



- Calculated thermal lens for old chamber: 0.027 dpt/W
- Calculated thermal lens for new chamber: 0.025 dpt/W

# Test setup


outcoupling mirror
Brewster plate
high reflective mirror
Fiber-bundle
Homo-genizer
Pumpoptics
Nd:YAG-crystal
Quarz-rotator
Nd:YAG crystal
Pumpoptics
Homo-genizer
Fiber-bundle
dicroitic mirror
dicroitic mirror

# Improvements: new pump chambers



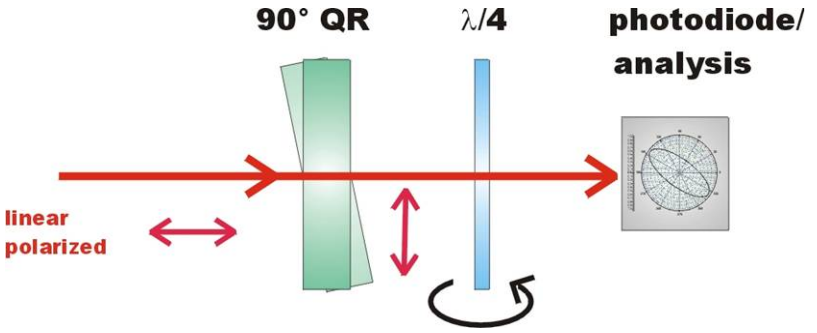
# Summary

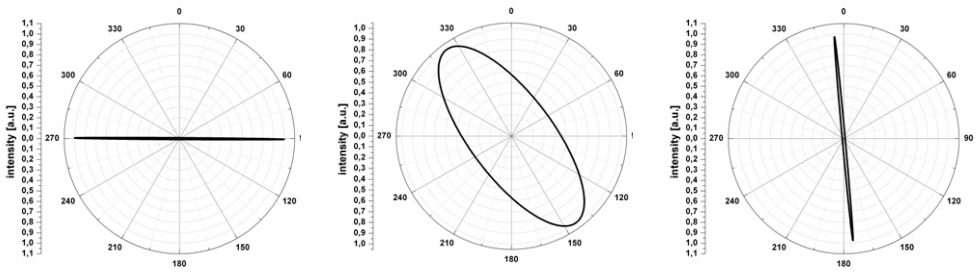
- System runs with lower output power and more pump power than 6 month before
- Reason: probably lower doped crystals
- We have to take care that all incoming components are well characterized and of the same high quality
- Ideas on system improvement (pump chambers) are going to be checked


Thank you for your attention !

# Improvements: non-conventional cut crystals

+ good birefringence compensation with quarz rotators
  (adv. LIGO laser: output power: ≈ 170 W cw, linear polarized; depolarized power: ≈1W)
- Additional components inside the resonator
  (Absorption/thermal effects/losses, spots)
- Sensitive adjustment

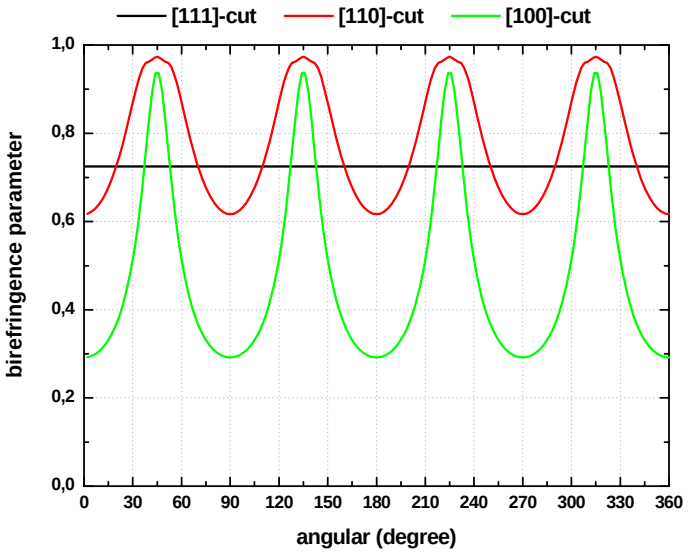


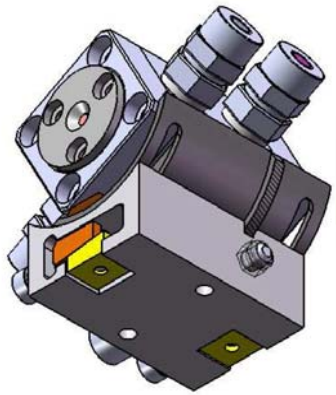
0° 5° 7°

# Improvement: non-conventional cut crystals

- Reduction of birefringence is possible by use of crystals, which are cut in [100]- or [110]-direction instead of [111]-direction[1)]




- Birefringence depends on the angle between crystal-axis and polarization-axis

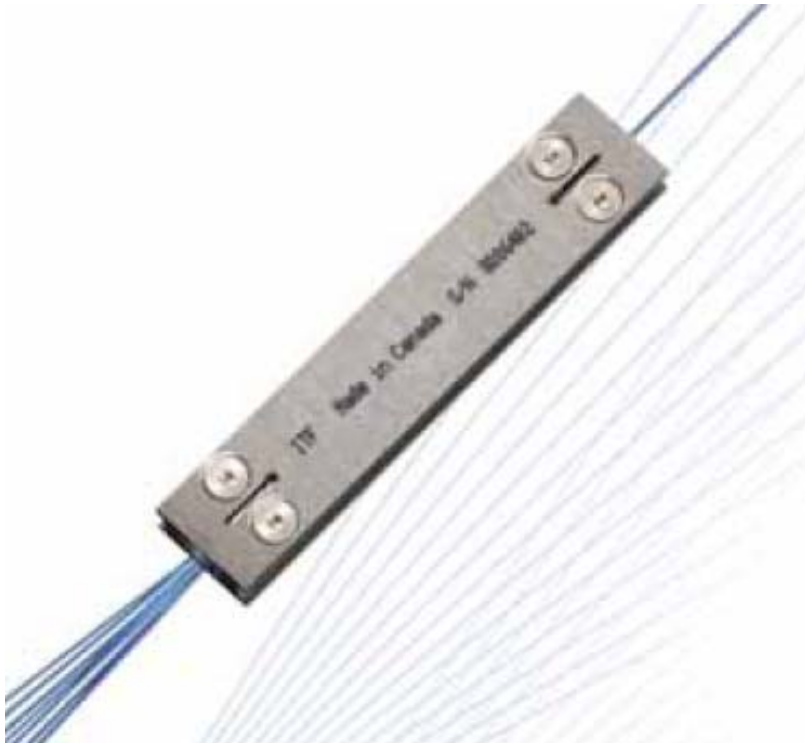




[1)] I. Shoji et al: Appl. Phys. Lett., Vol. 80, No. 17, 29 April 2002

# Improvements: pump combiners

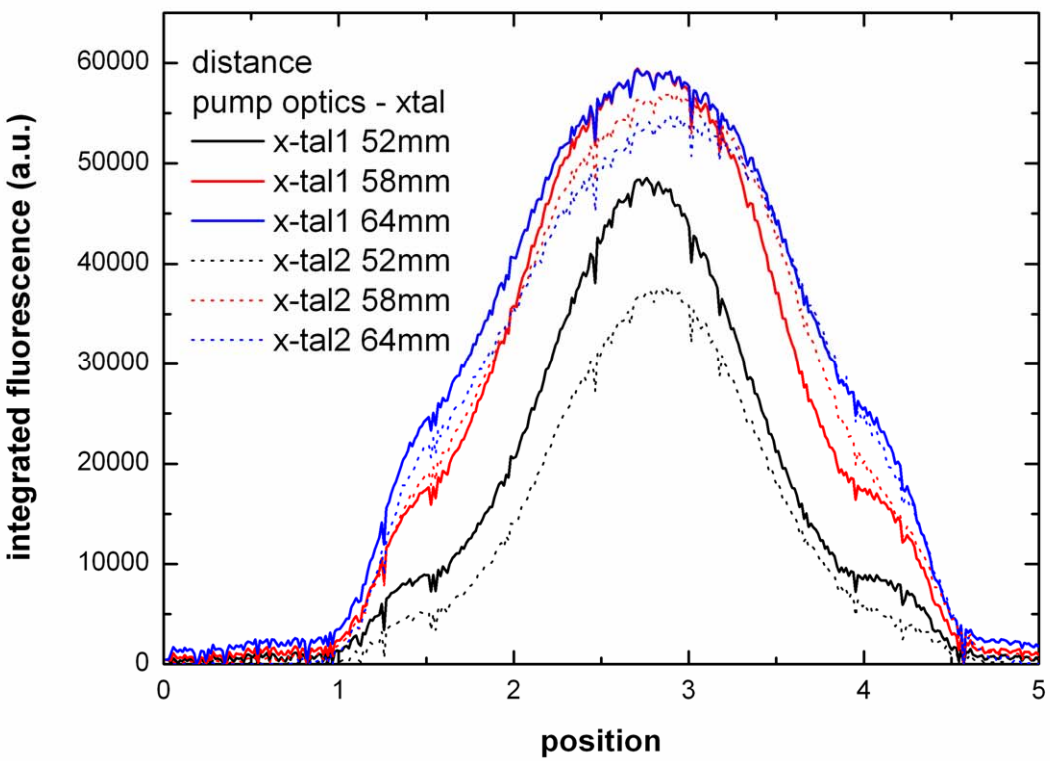
- 7x200µm input : 1
- up to 700 W input power
- transfer efficiency > 93%

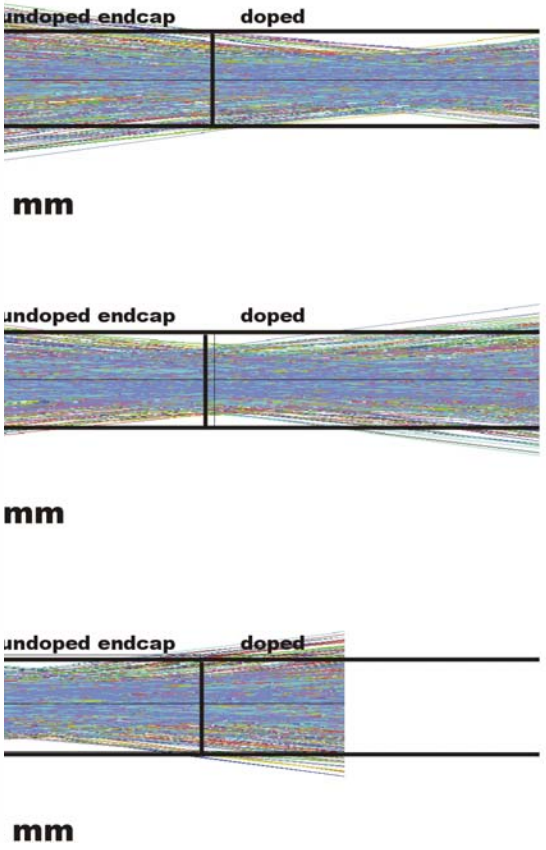




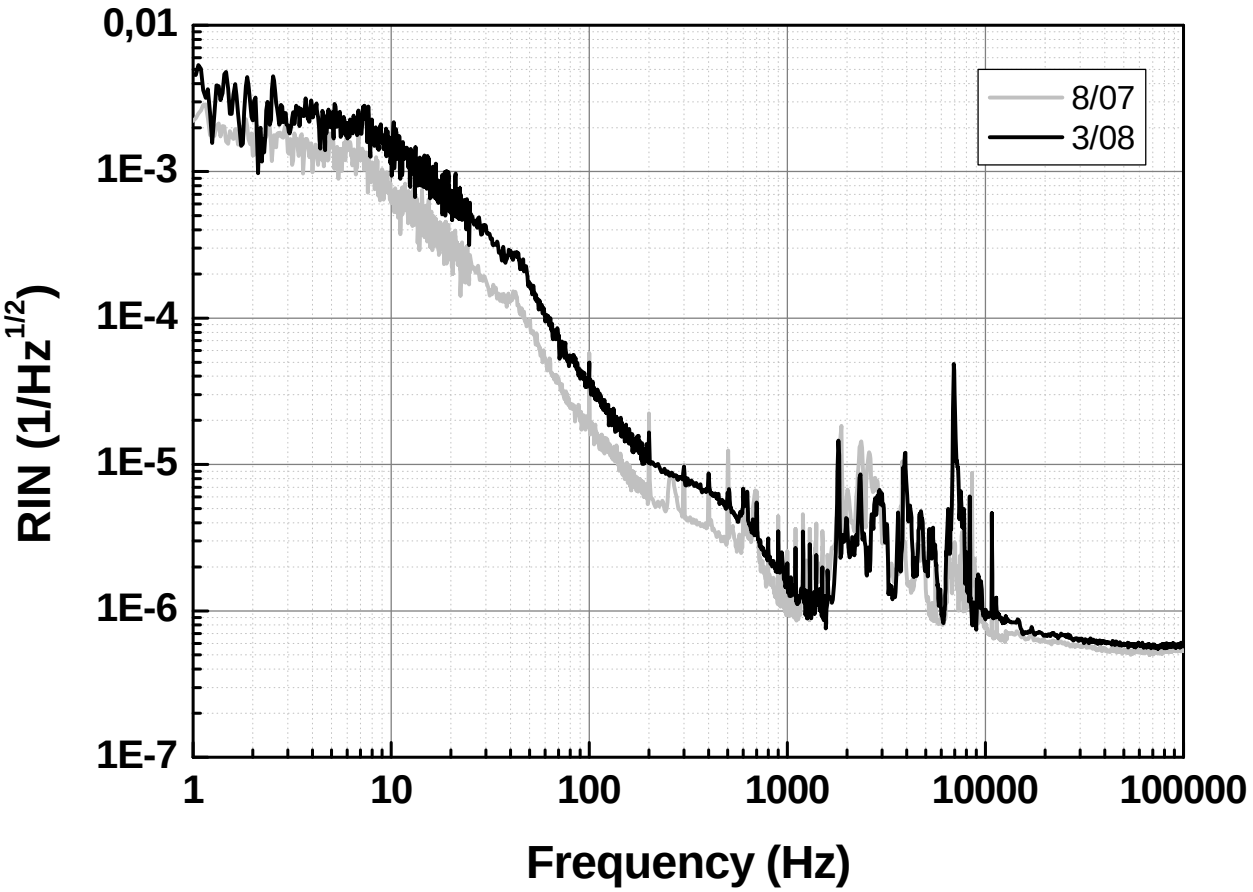
Source: ITF

# Integrated fluorescence



# RIN (unstabilized, locked laser)



# Spots on surfaces and coatings

- Spots on coatings and optical components knocked out the system several times

→ Bring as few dust as possible to the laser table

→ Check quality of incoming components