Multipass amplifiers of POLARIS

from daily operation to development

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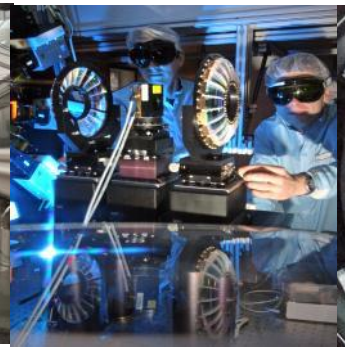
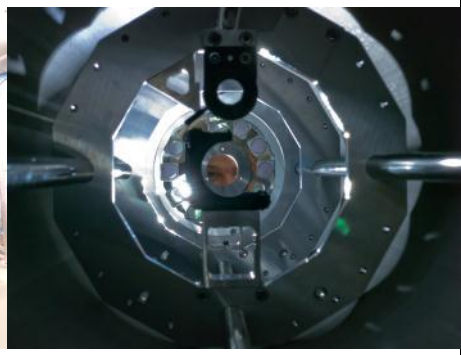
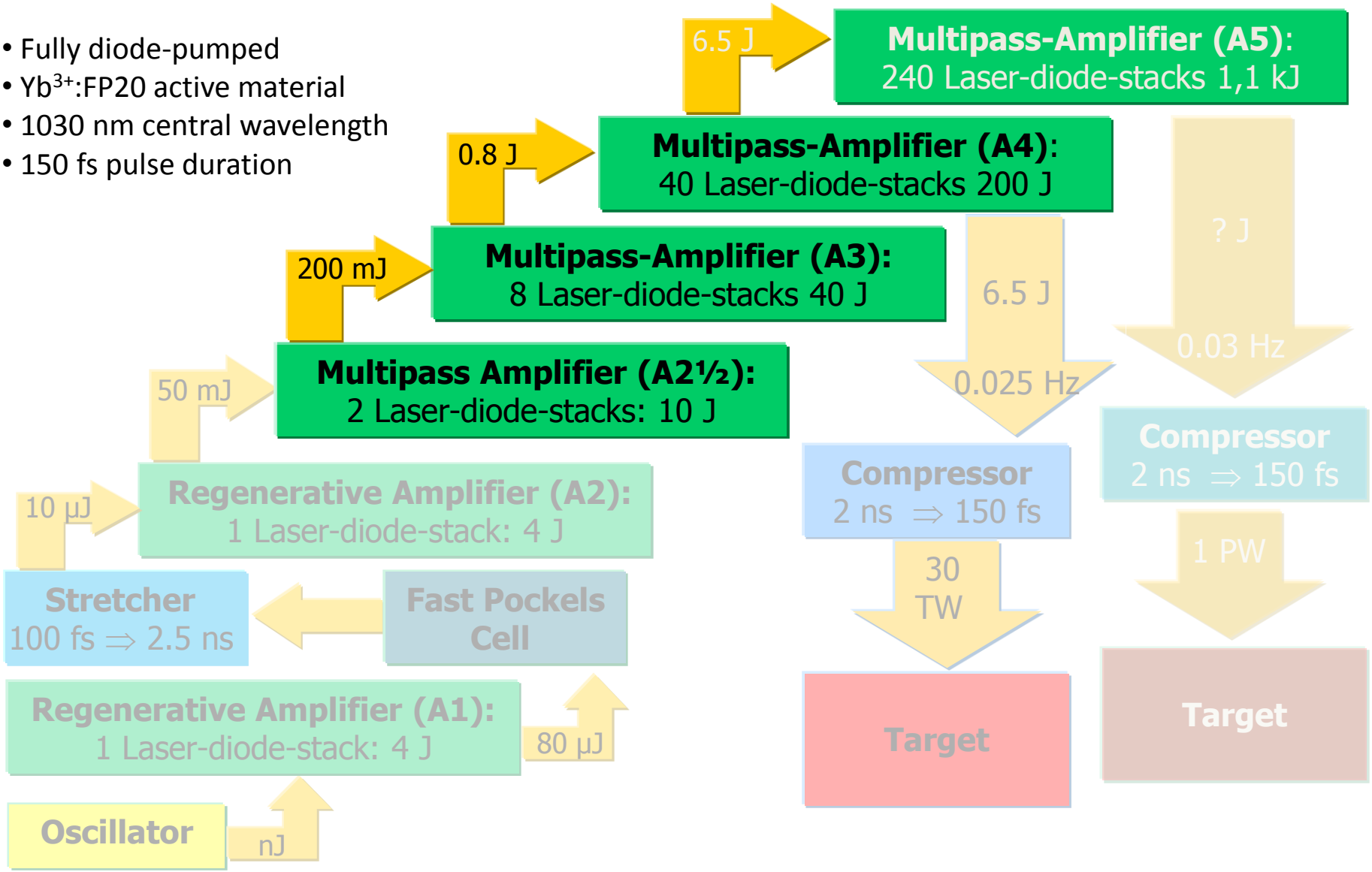


HEC-DPSSL 13-Sep-2012

Outline

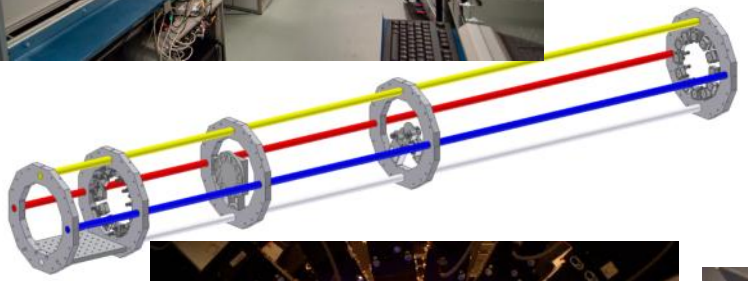
- Fully diode-pumped
- Yb^{3+}:FP20 active material
- 1030 nm central wavelength
- 150 fs pulse duration



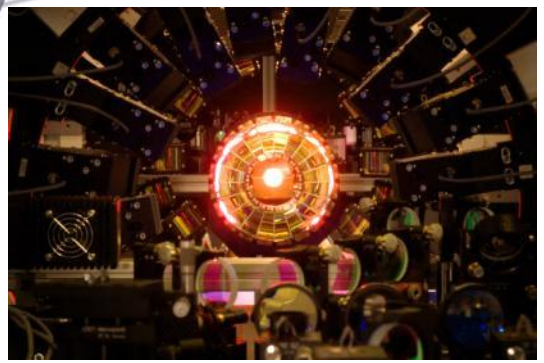
outline

- current setup and performance
  - A2.5 & A3

- a new joule-level amplifier A3
  - motivation and current status

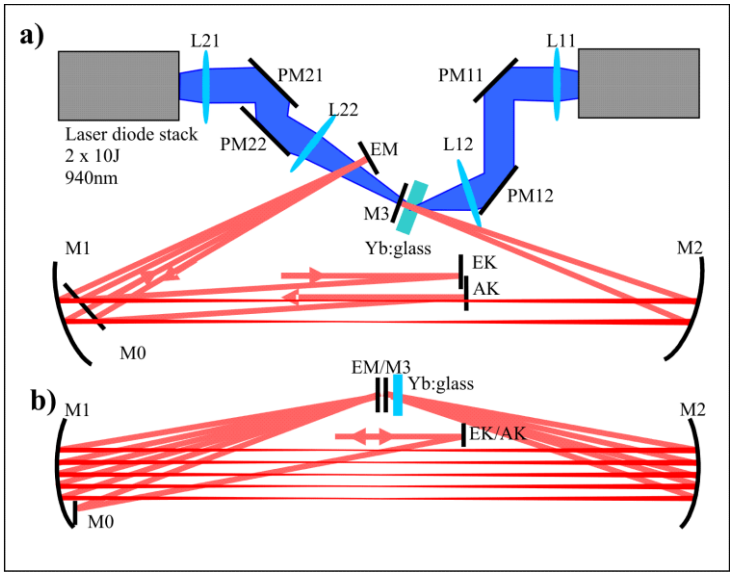


- multi-joule amplifier A4
  - pump alignment and future prospects



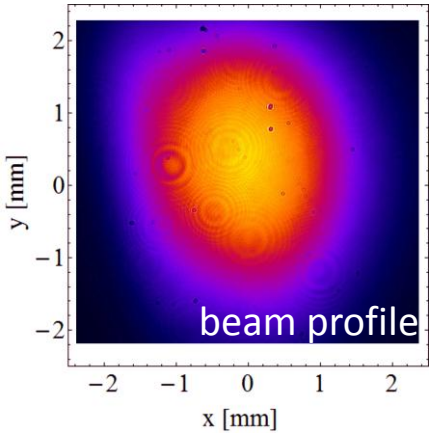
- final amplifier A5
  - pump engine
  - safety- and remote-control system

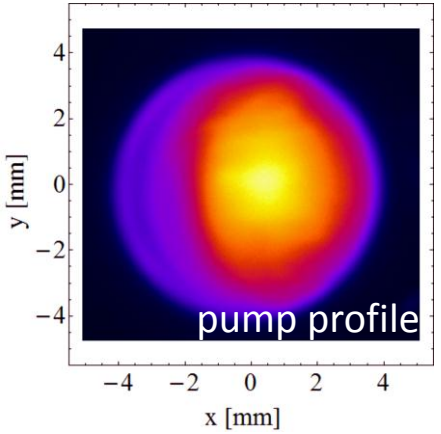
current setup – A2.5

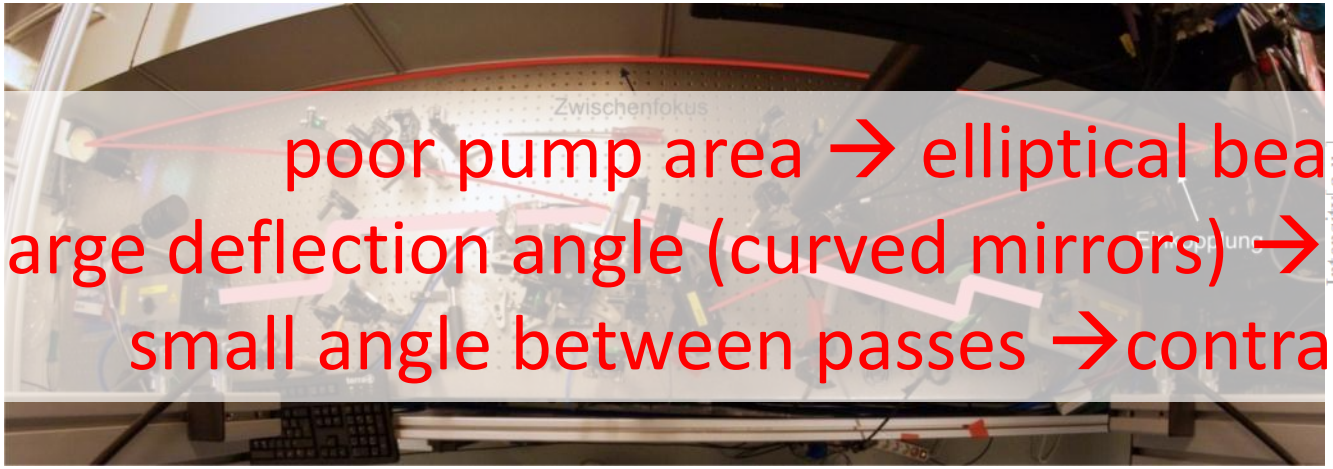


(J. Körner HEC-DPSSL 2010)

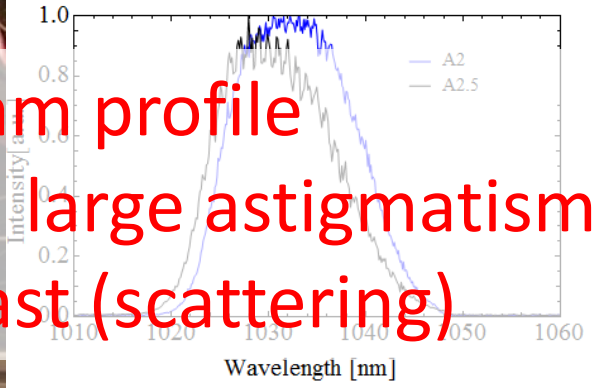
10 Passes
10mJ to 80mJ (gain factor 8) @1/5Hz
bandwidth of 13nm (15nm Seed)
2x4,5kW @2,7ms





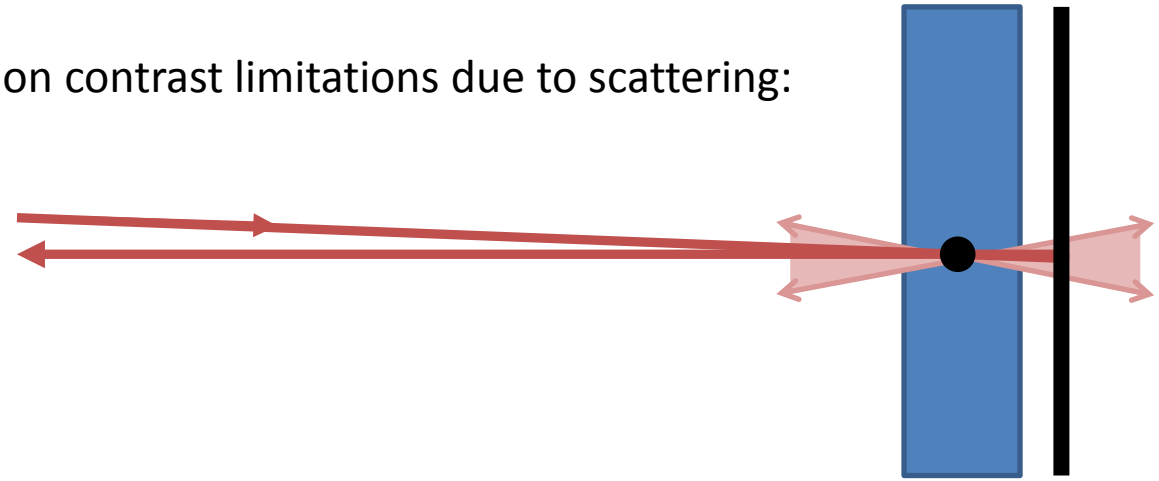


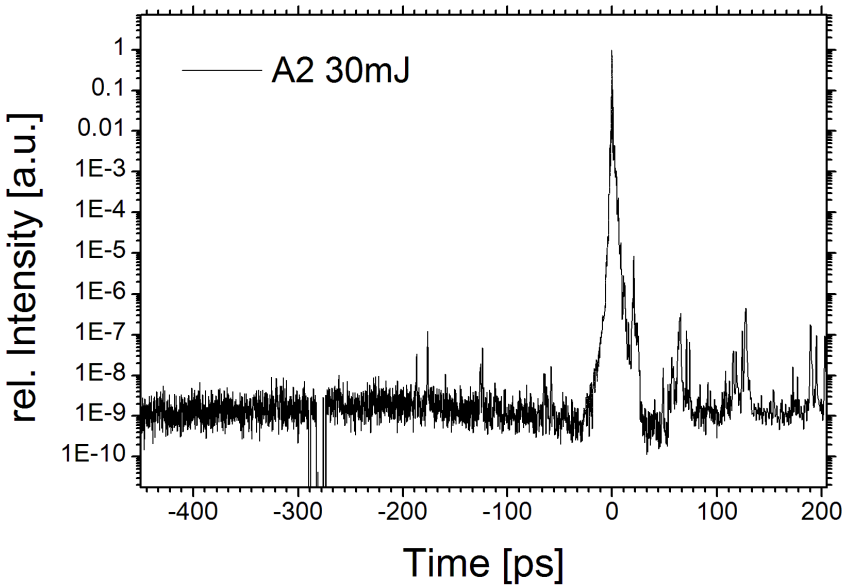
poor pump area → elliptical beam profile
large deflection angle (curved mirrors) → large astigmatism
small angle between passes →contrast (scattering)



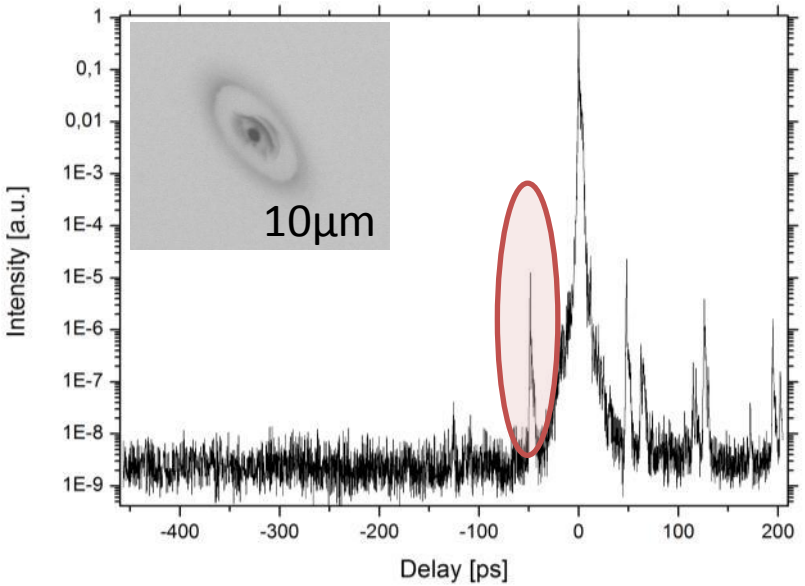
current setup A2.5 & A3

Remark on contrast limitations due to scattering:



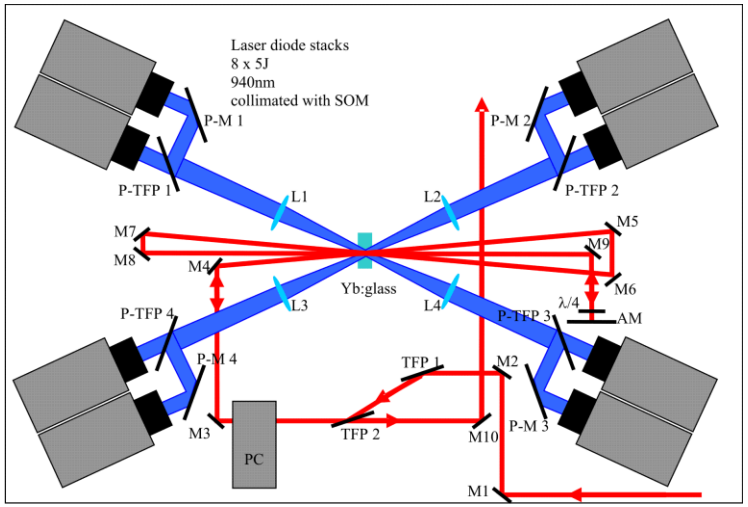


front-end contrast Jan 2012 (after prepuls suppression)

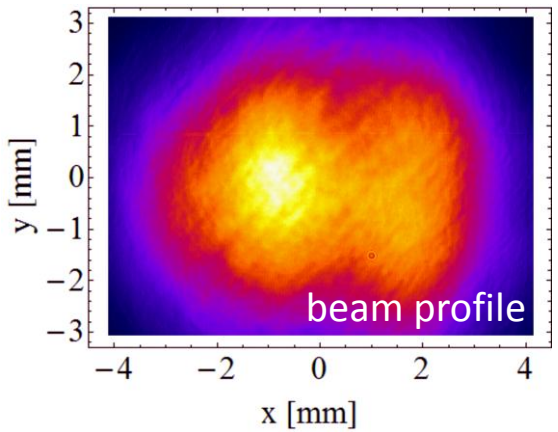


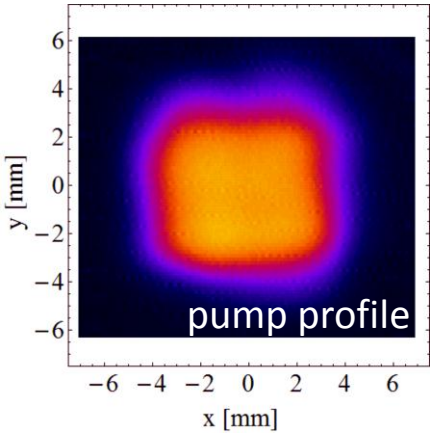
Aug 2012 (7000 high-power-shots)

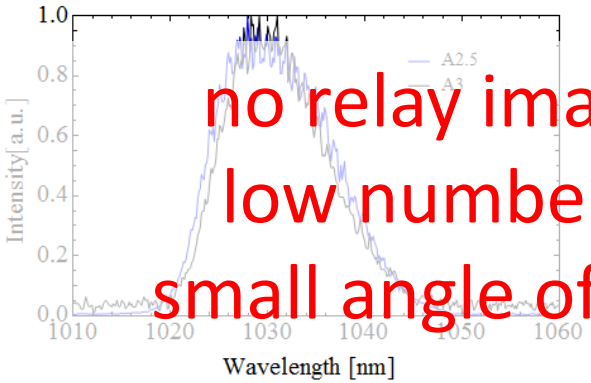
current setup – A3



6 Passes
60mJ to 550mJ (gain factor 9) 1/10Hz
bandwidth of 12nm (13nm Seed)
8x2,5kW @2,7ms







no relay imaging → poor pointing stability
low number of passes → poor efficiency
small angle of passes → contrast (scattering)

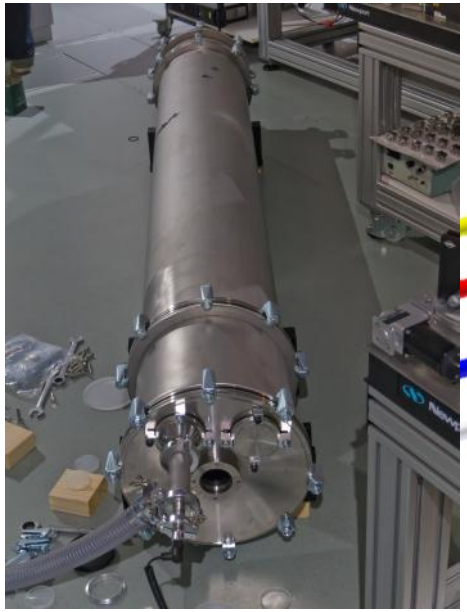
new joule-level amplifier A3

main properties of the new A3

factor 100 ✓
20 passes ✓
yes ✓

main requirements of a new amplifier:

- gain factor >80 to replace both amplifiers
- high number of passes → better efficiency
- relay imaging design → better pointing stability and smoother beam profile
- flat-top pump profile → smoother beam profile
- larger angle between different passes → better contrast ratio



new joule-level amplifier A3

HELMHOLTZ ASSOCIATION | IOQ Jena

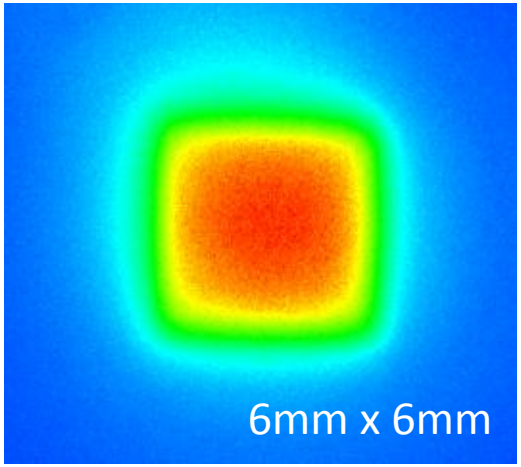
main properties of the new A3

factor 100 ✓
20 passes ✓
yes ✓

Lastronics pump module ✓

main requirements of a new amplifier:

- gain factor >80 to replace both amplifiers
- high number of passes → better efficiency
- relay imaging design → better pointing stability and smoother beam profile
- flat-top pump profile → smoother beam profile
- angle between different passes >7° → better contrast ratio



- squared flat top profile
- ripple <1% pv
- super gaussian profile order 7
- energy content in wings <5%
- size can be adapted by relay imaging

19 kW Lastronics pump source

new joule-level amplifier A3

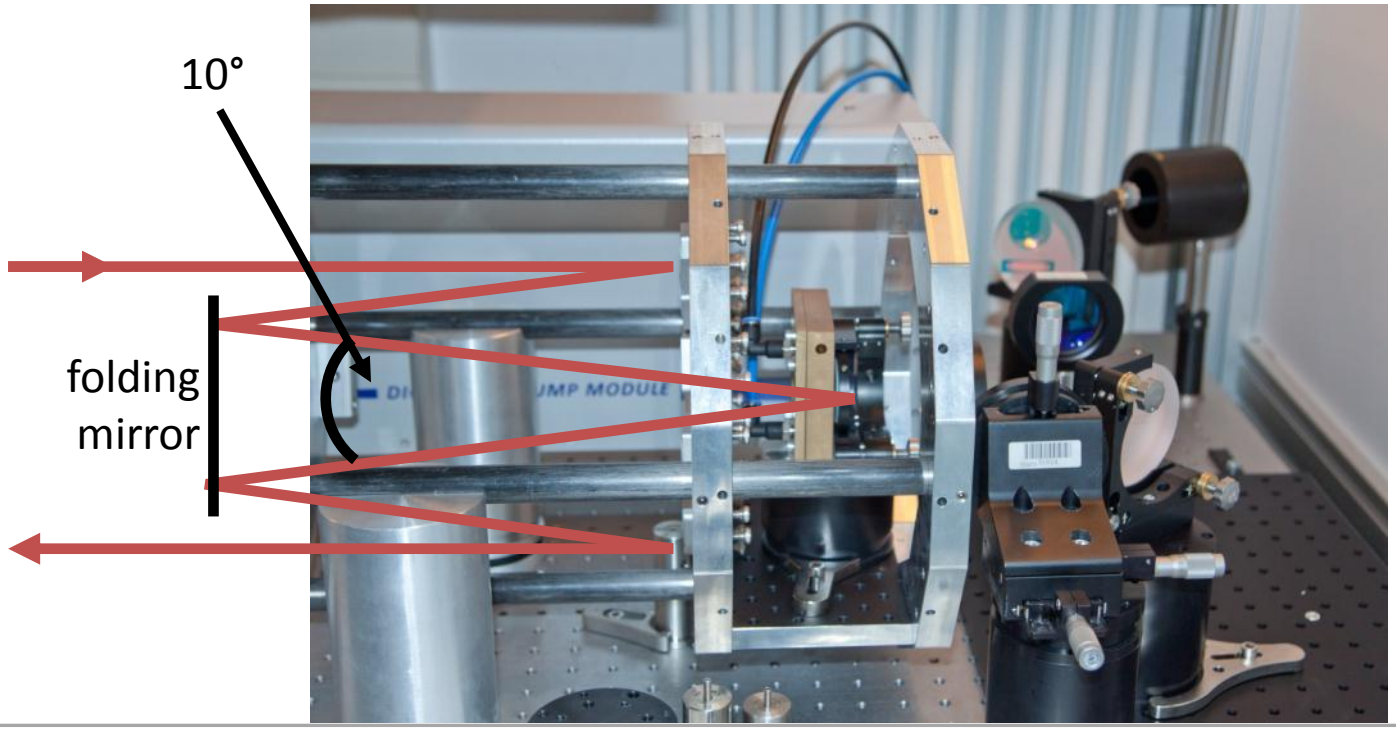
main properties of the new A3

factor 100 ✓
20 passes ✓
yes ✓

Lastronics pump module ✓
radial symmetric angle of 10° ✓

main requirements of a new amplifier:

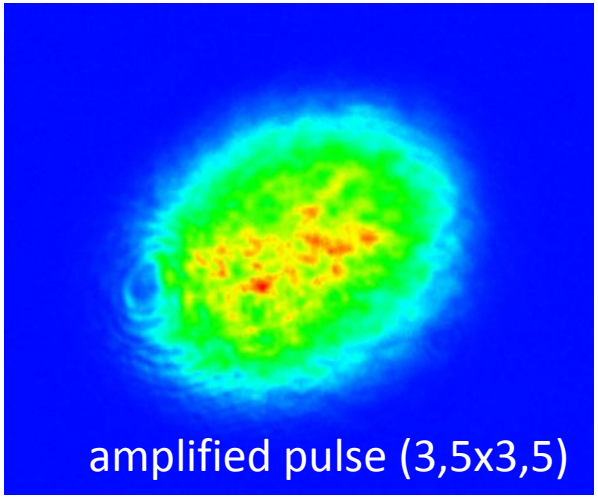
- gain factor >80 to replace both amplifiers
- high number of passes → better efficiency
- relay imaging design → better pointing stability and smoother beam profile
- flat-top pump profile → smoother beam profile
- angle between different passes >7° → better contrast ratio

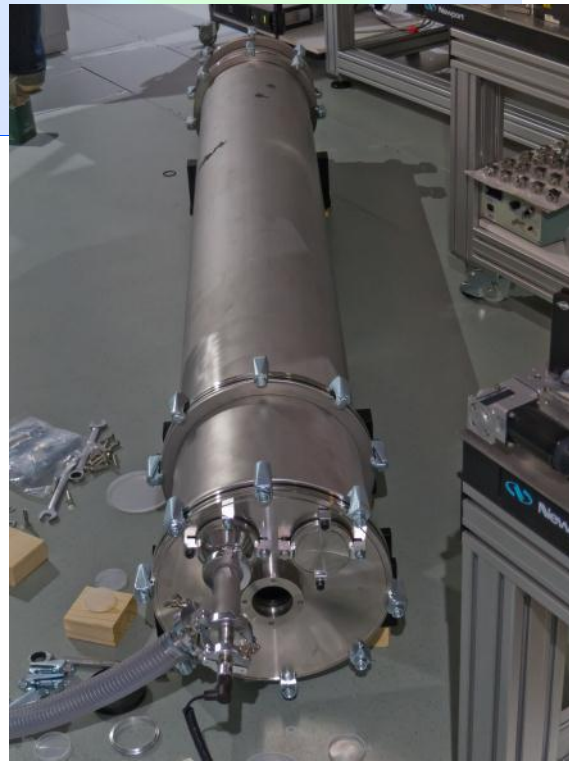


new joule-level amplifier A3

first successful amplification test:

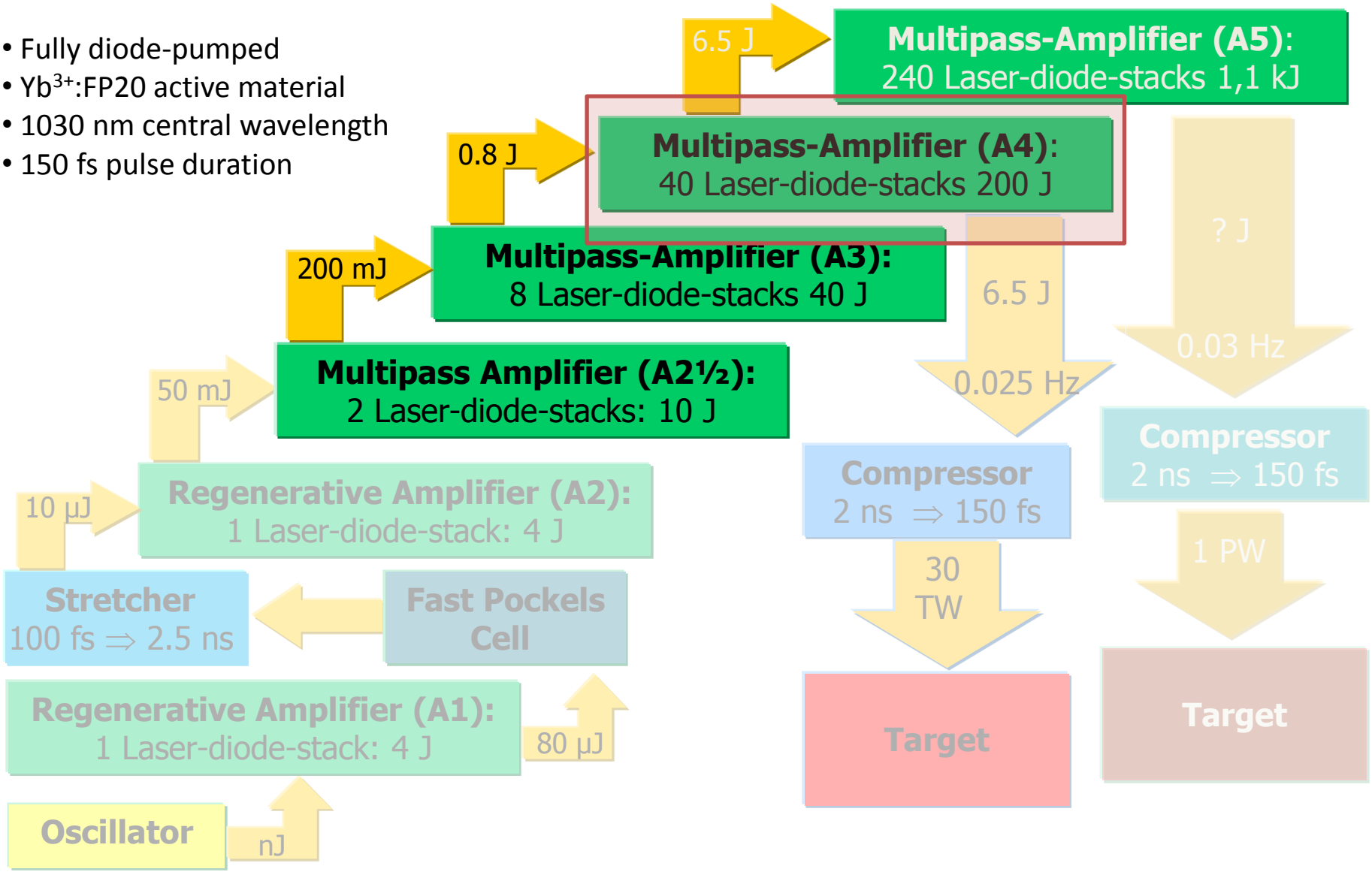
- gain factor 100 (1,5mJ to 150mJ)
- beam size 3,5x3,5mm (distance glass – end mirror)
- very smooth beam profile
- very good pointing stability
- very good energy stability (3% RMS)
- successful test of the vacuum condition



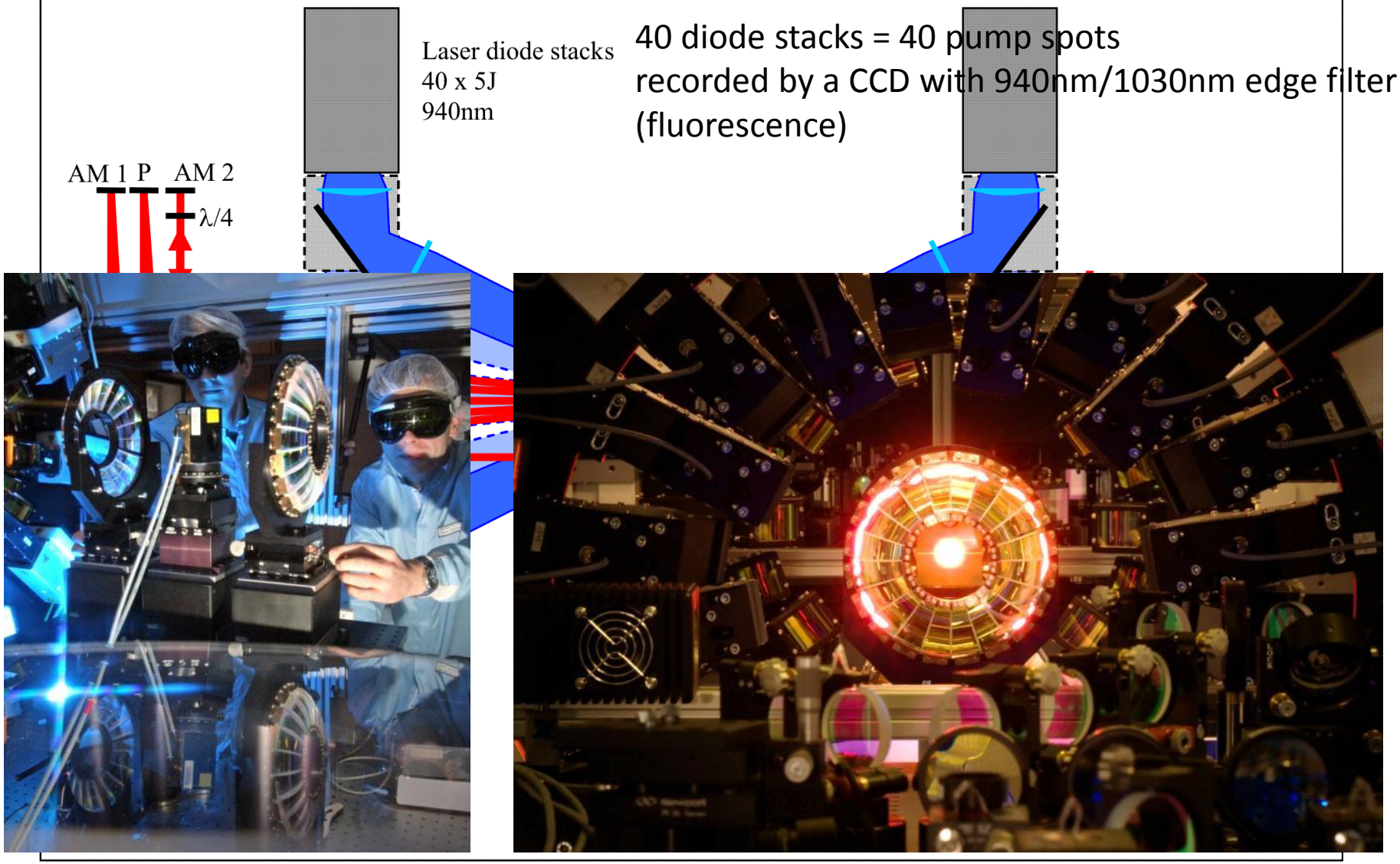


multi-joule amplifier A4

- Fully diode-pumped
- Yb^{3+}:FP20 active material
- 1030 nm central wavelength
- 150 fs pulse duration

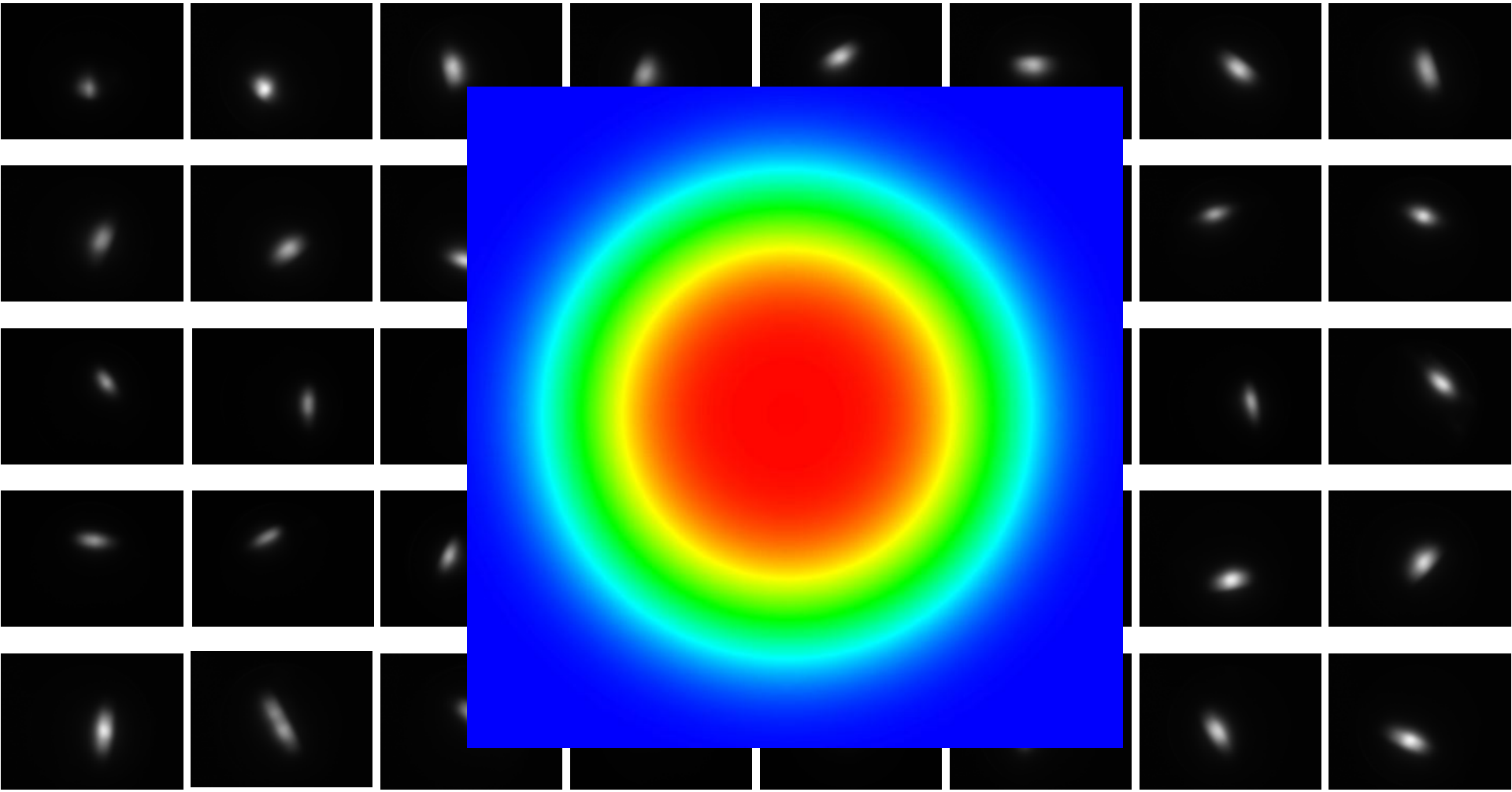


multi-joule amplifier A4



40 diode stacks = 40 pump spots recorded by a CCD with 940nm/1030nm edge filter (fluorescence)

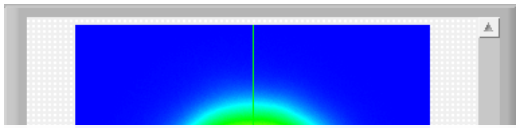
multi-joule amplifier A4



multi-joule amplifier A4

generic algorithm[1]

random variation of the spot position inside the allowed area (mutation)
evaluation (quadratic difference to the target function)
best attempts (elites) → next generation
new positions can be extracted and be set
next iteration

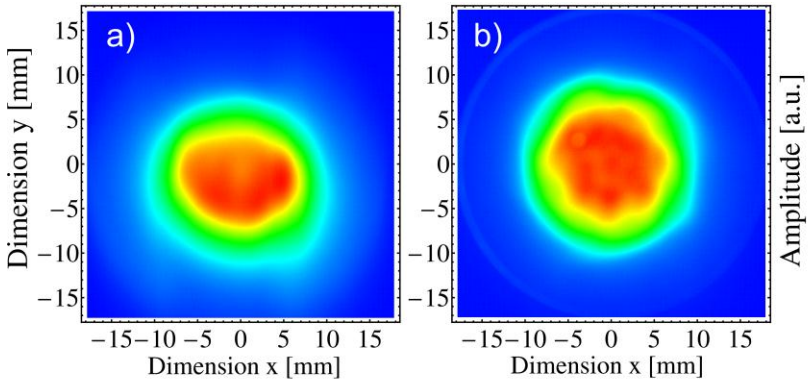


advantages:

- not every iteration has to be set
- number of alignment procedures decreases drastically
- highest possible accuracy (±2% PV) is reached with pure computing power
- applicable for complete automated systems (A5) & high number of spots

[1]B. Schmidt *et. al.* LAB2 – a virtual fs laser lab – http://www.lab2.de

multi-joule amplifier A4

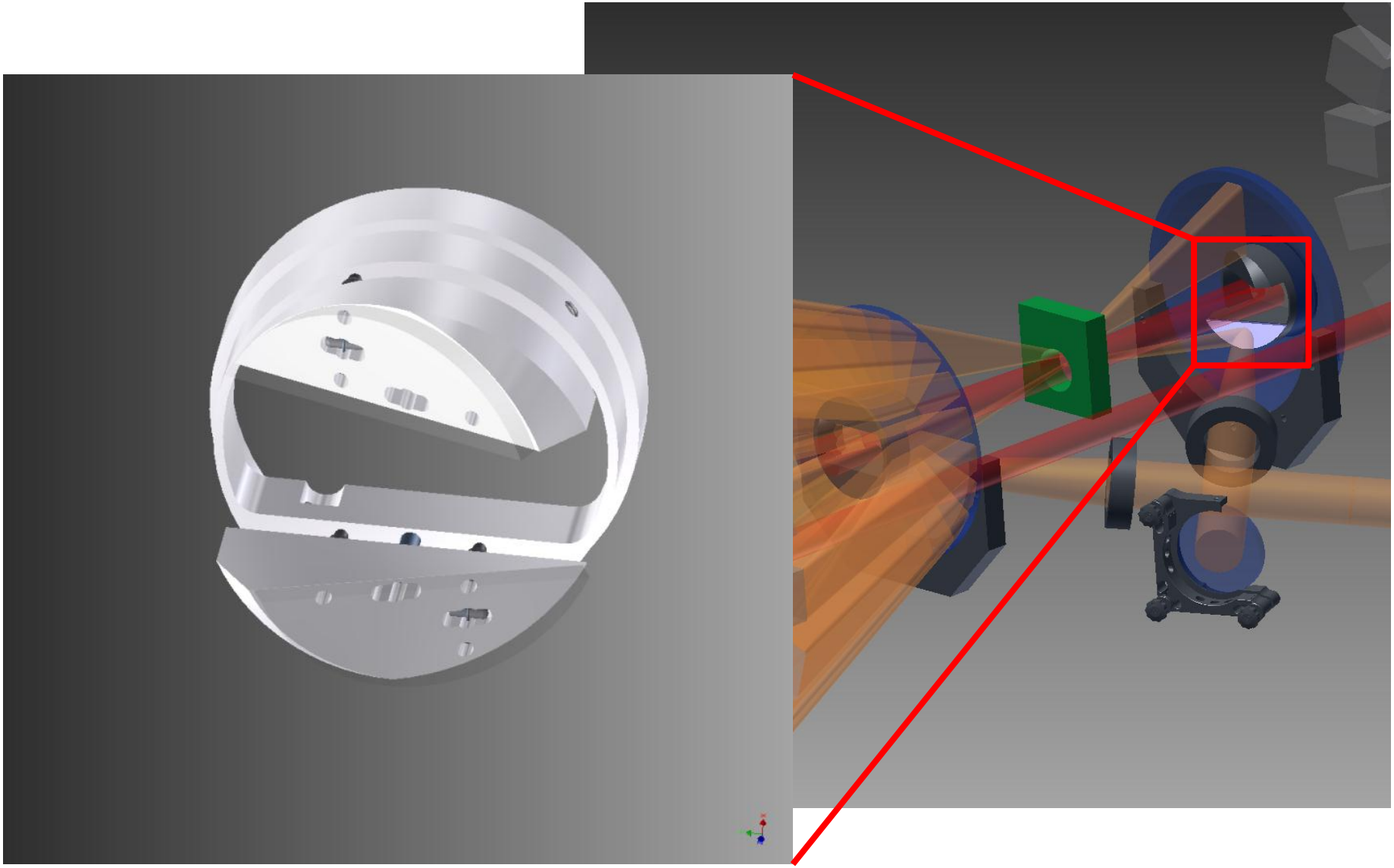


for pulse energy >10J

→larger beam diameter

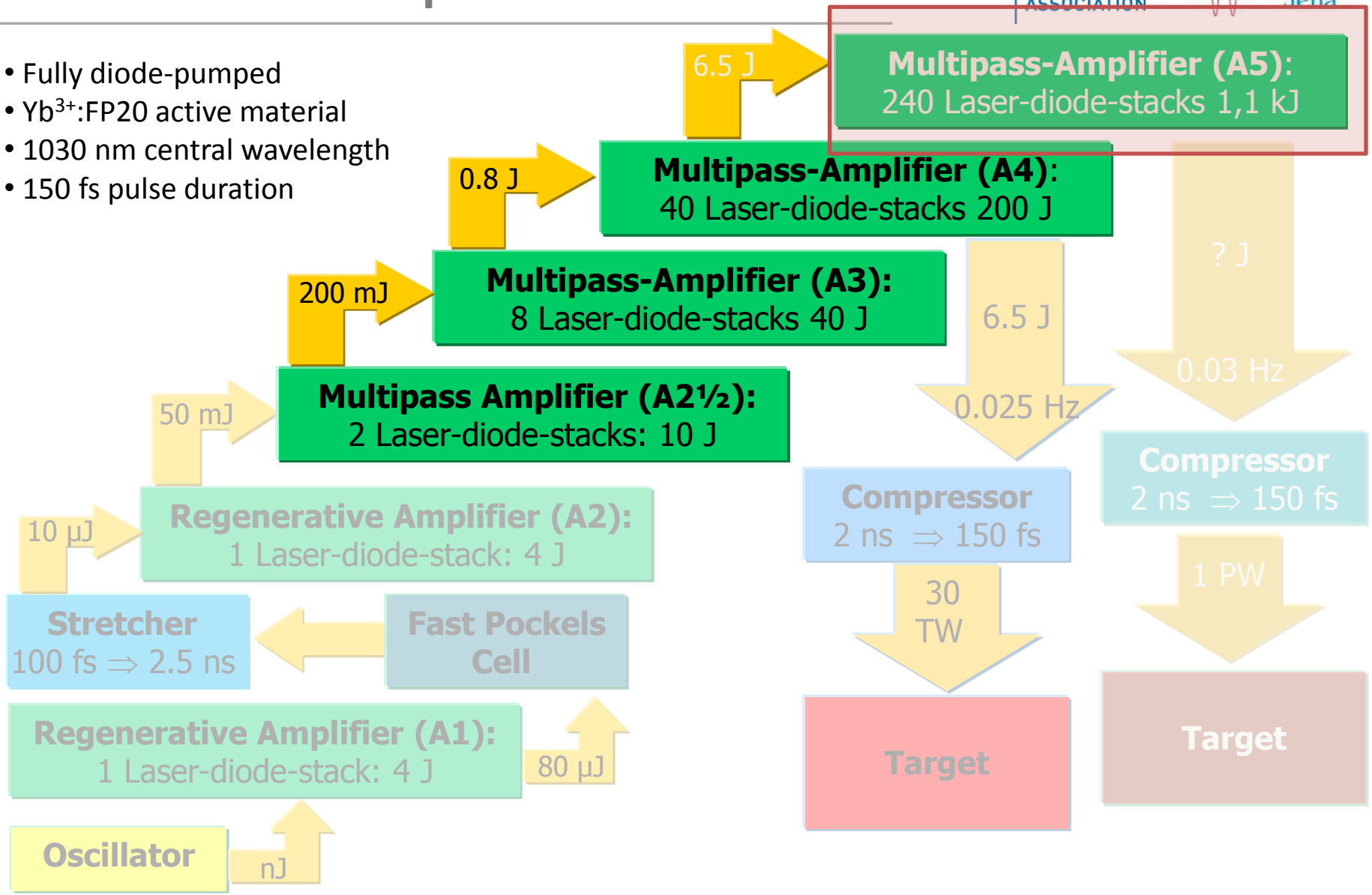
→ more spots are needed

multi-joule amplifier A4

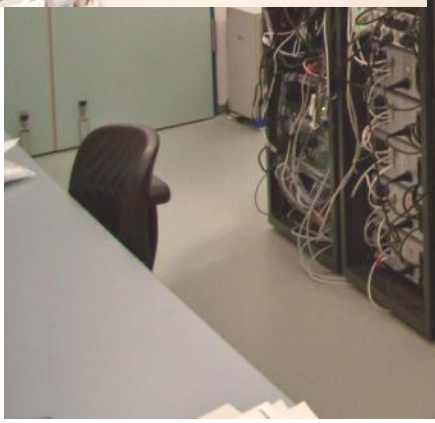


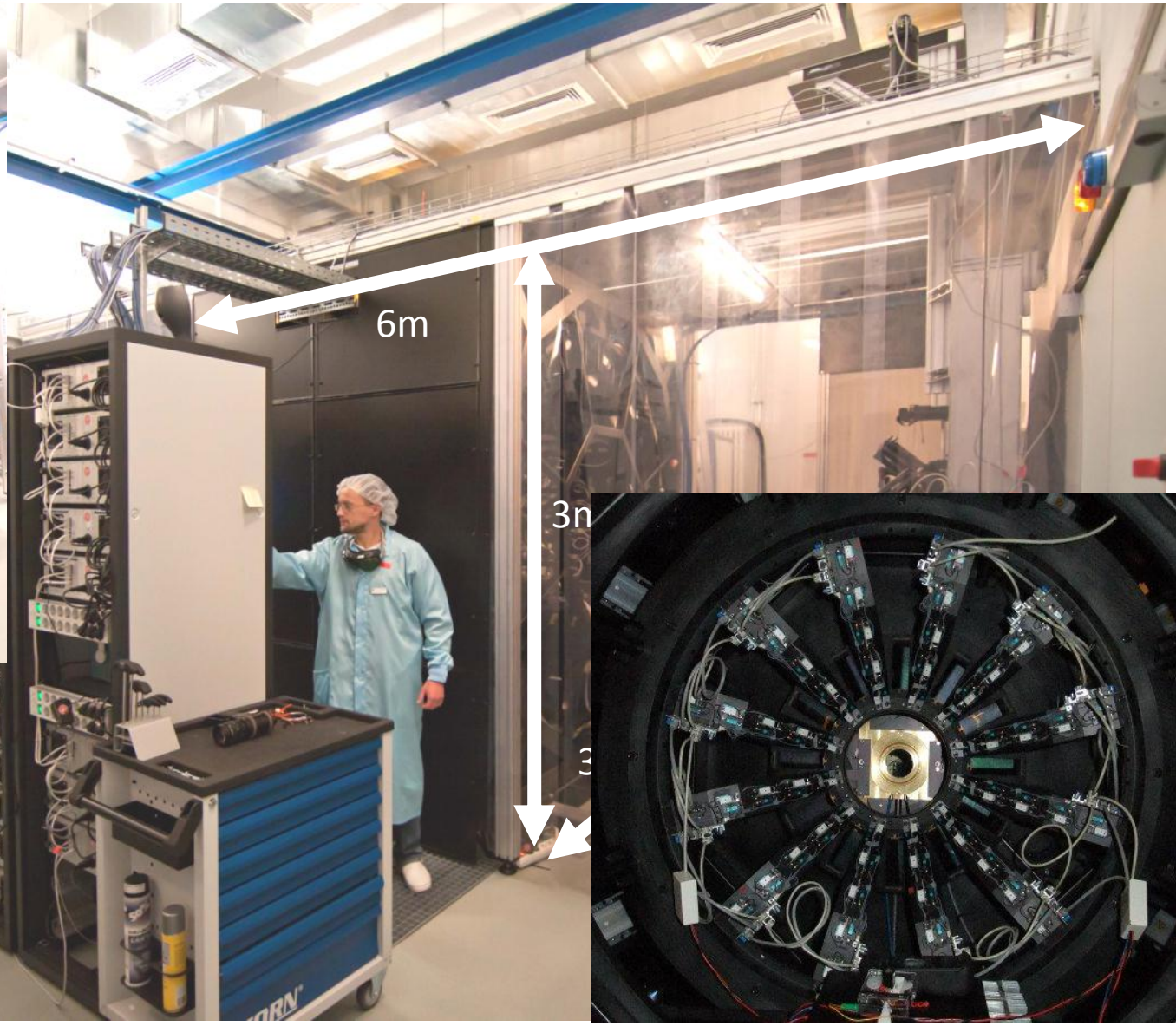
final amplifier A5

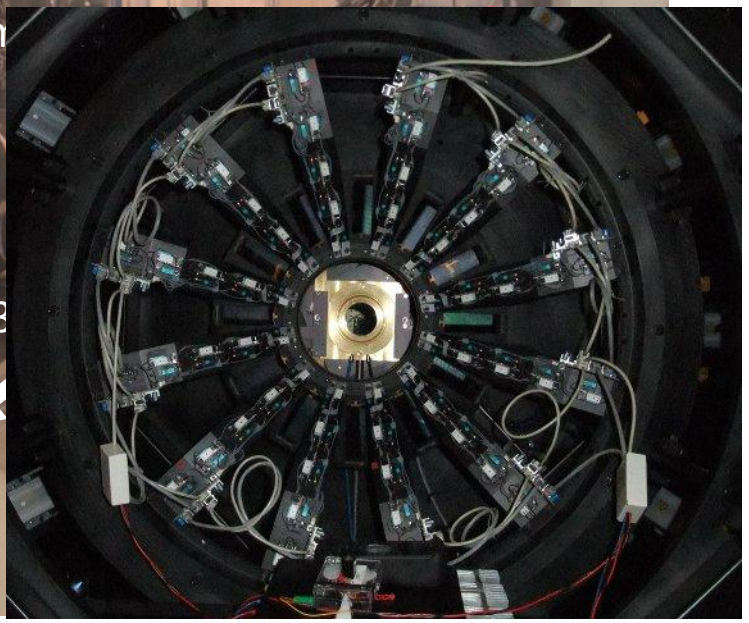
- Fully diode-pumped
- Yb^{3+}:FP20 active material
- 1030 nm central wavelength
- 150 fs pulse duration



final amplifier A5 - impressions

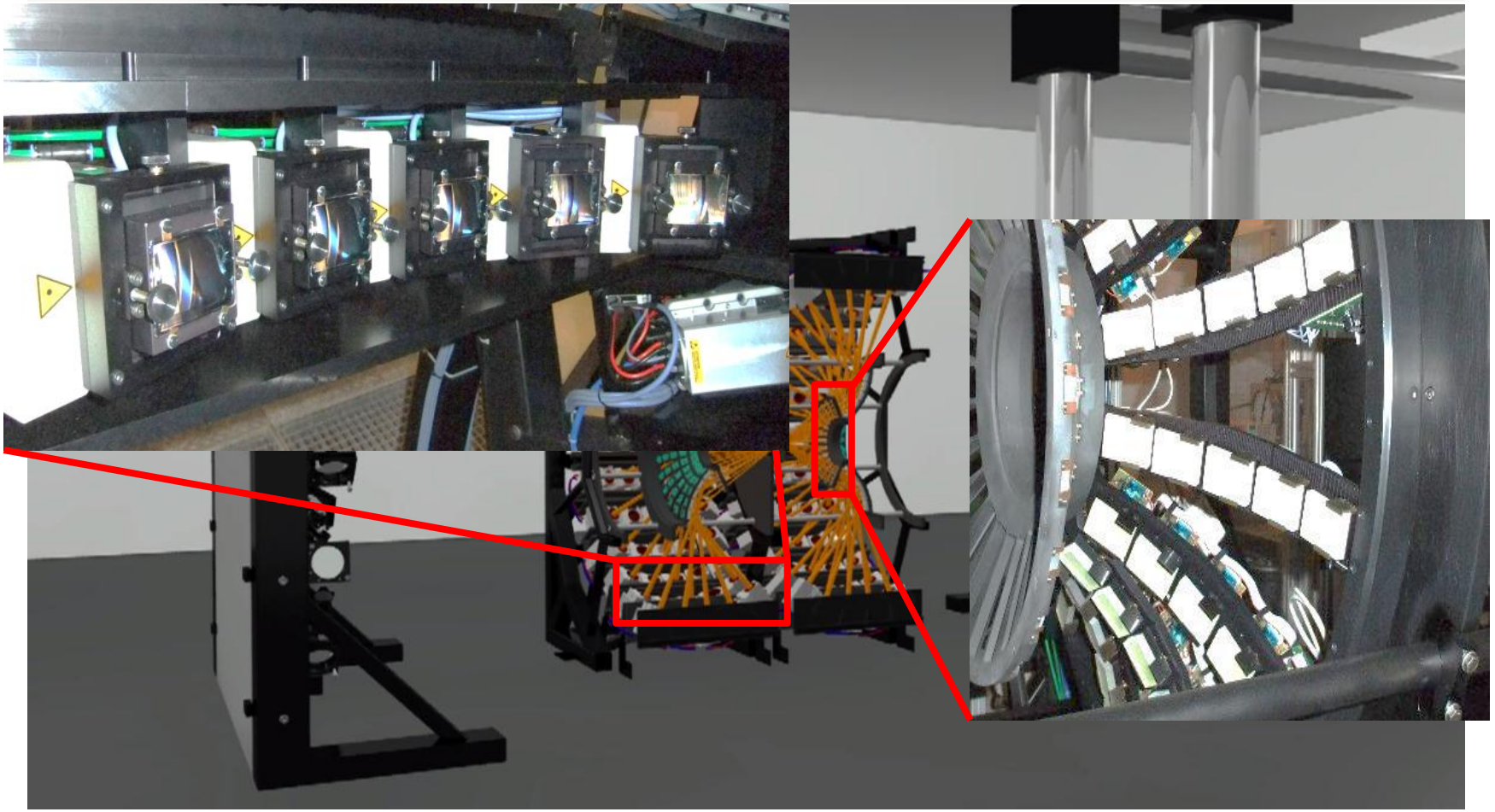




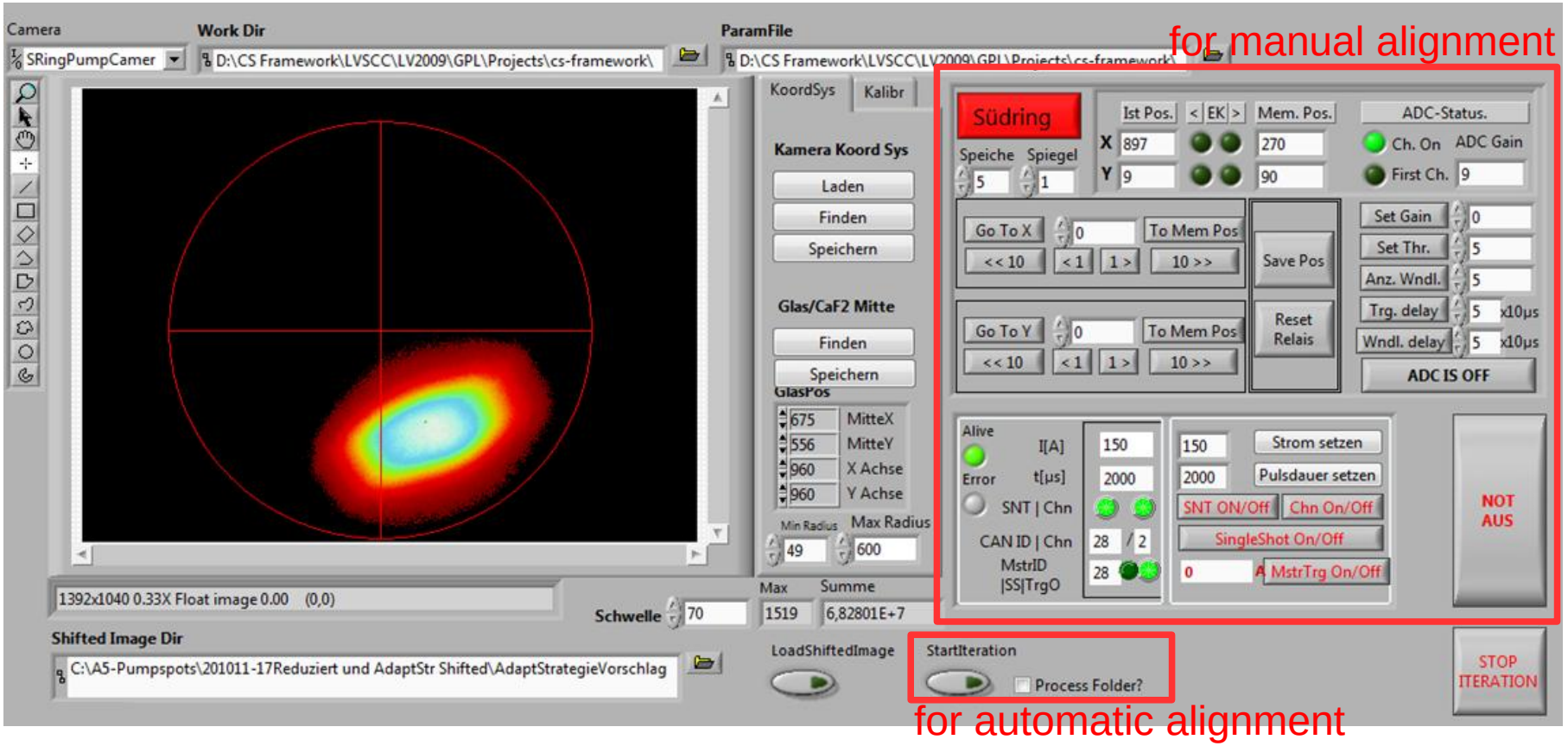


final amplifier A5 – pump engine

- Currently 120 laser diode stacks λ=940 nm, P=2.5kW
- Upgrade to 240 stacks is possible
- Yb^{3+} doped CaF_2 crystal, or FP20-Glass with 35mm pump diameter



final amplifier A5 – pump engine



final amplifier A5

~ 30 mirror motors
motorized pinholes
12 CCD cameras
spectrometer
powermeter
fluence control
humidity control
interlock control
120 x 3 parameters for pump alignment
…

complete alignment under full power operation

a powerful remote control system is indispensible

A5 safety- and remote-control system

POLARIS control system

= CS-framework[1] + add-ons

back-end (graphic user interface)

application layer (sequencer, ...)

front-end (devices, drivers, ...)

GSI, Germany; Mainz, Germany; Jena, Germany

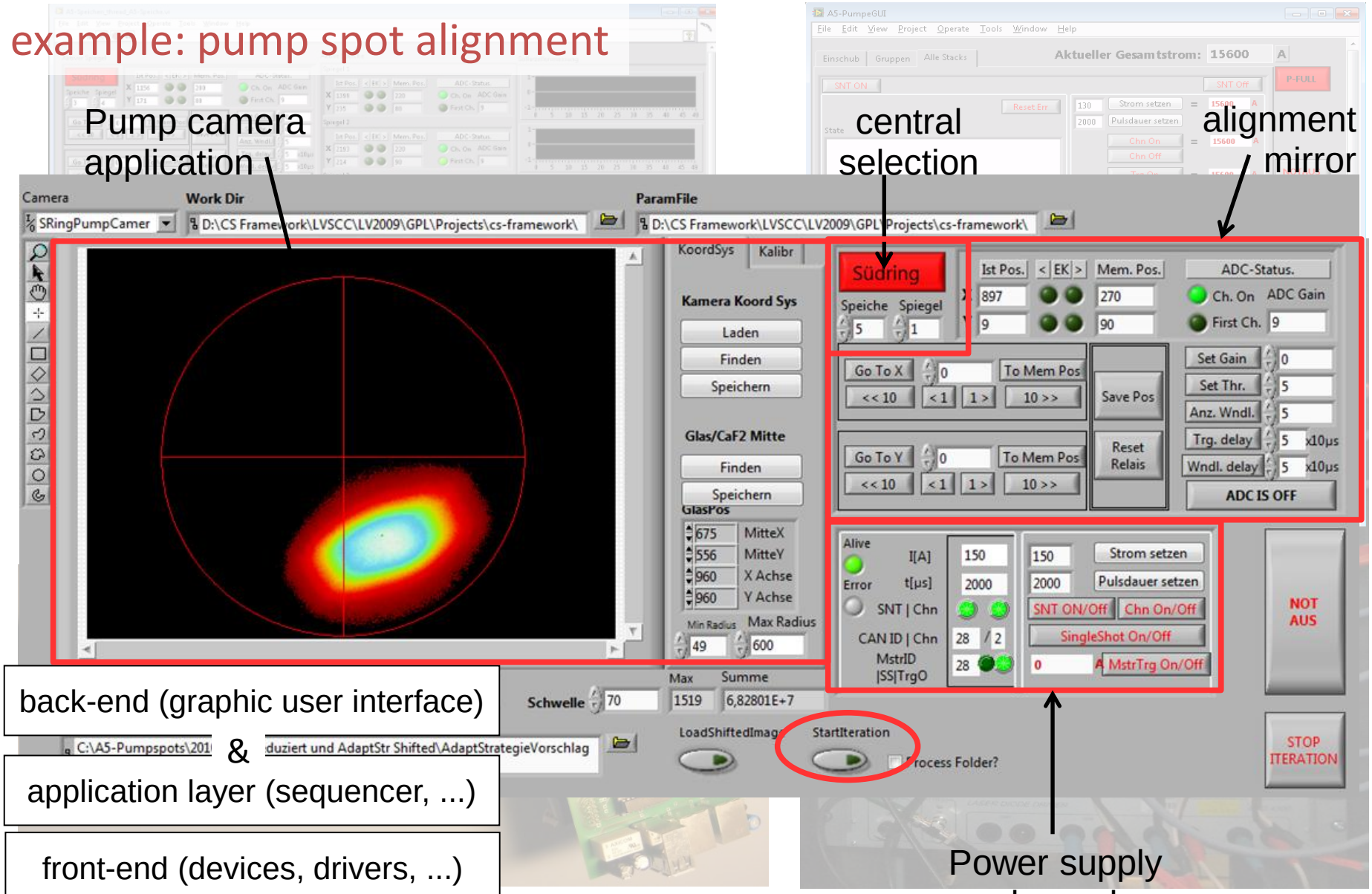
Greifswald, Germany; CERN, Switzerland; MSU, USA; Lanzhou, China

[1]Control System for Experiments

http://wiki.gsi.de/cgi-bin/view/CSframework/WebHome

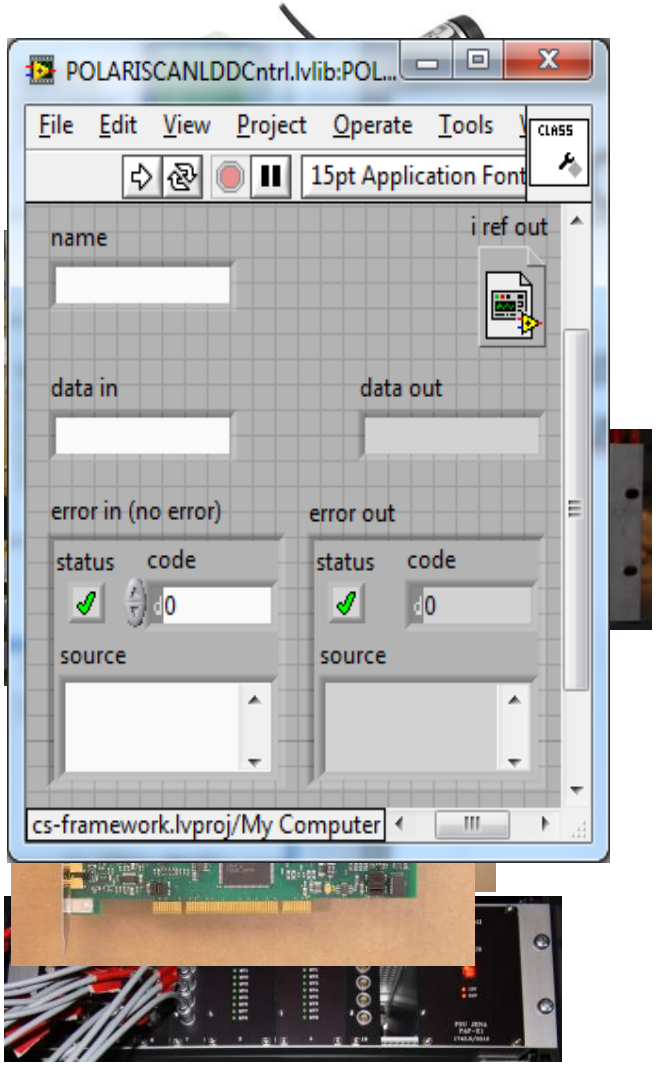
A5 safety- and remote-control system

example: pump spot alignment



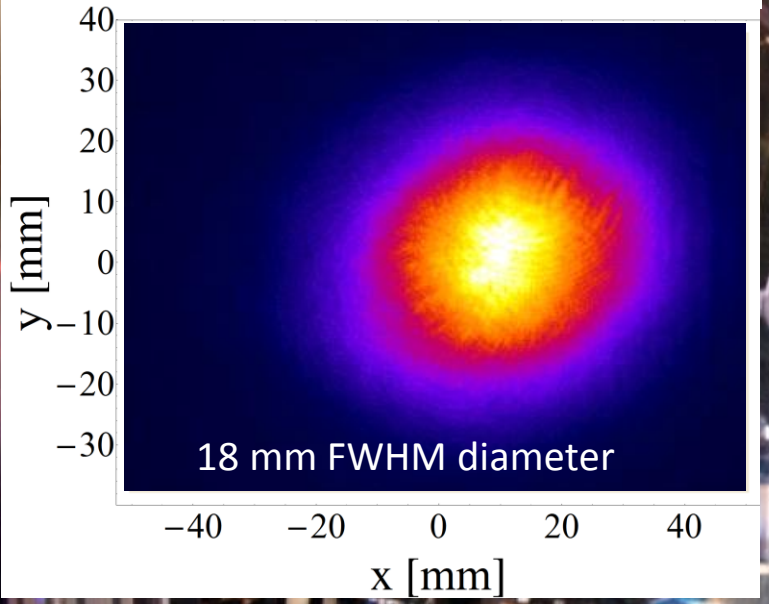
POLARIS add-ons

- POLARIS interlock controller
- Newport step motor controller
- Newport piezo motor controller
- FSU step motor controller
- FSU/ Lastronics LDD + CAN
- pump alignment mirrors + CAN
- FSU magnetic valves
- TC3000 Coolers
- Bergmann delay generators

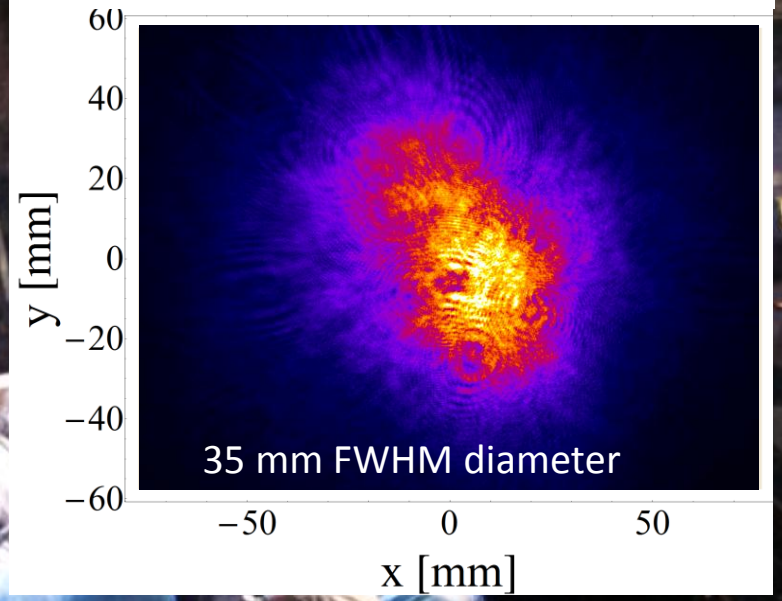


A5 low-energy amplification

Seed-Pulse:



Amplified pulse:



- In 7-pass configuration a pulse energy of 40 mJ was achieved
- currently 9 passes are installed
- Gain = 3.2
- Active material: two 9 mm thick, 69 mm diameter, Yb:CaF_2-disks
- Repetition-rate = 1/80 Hz

Conclusion

new amplifier design based on experiences of the daily operation

very stable, good beam quality, better efficiency

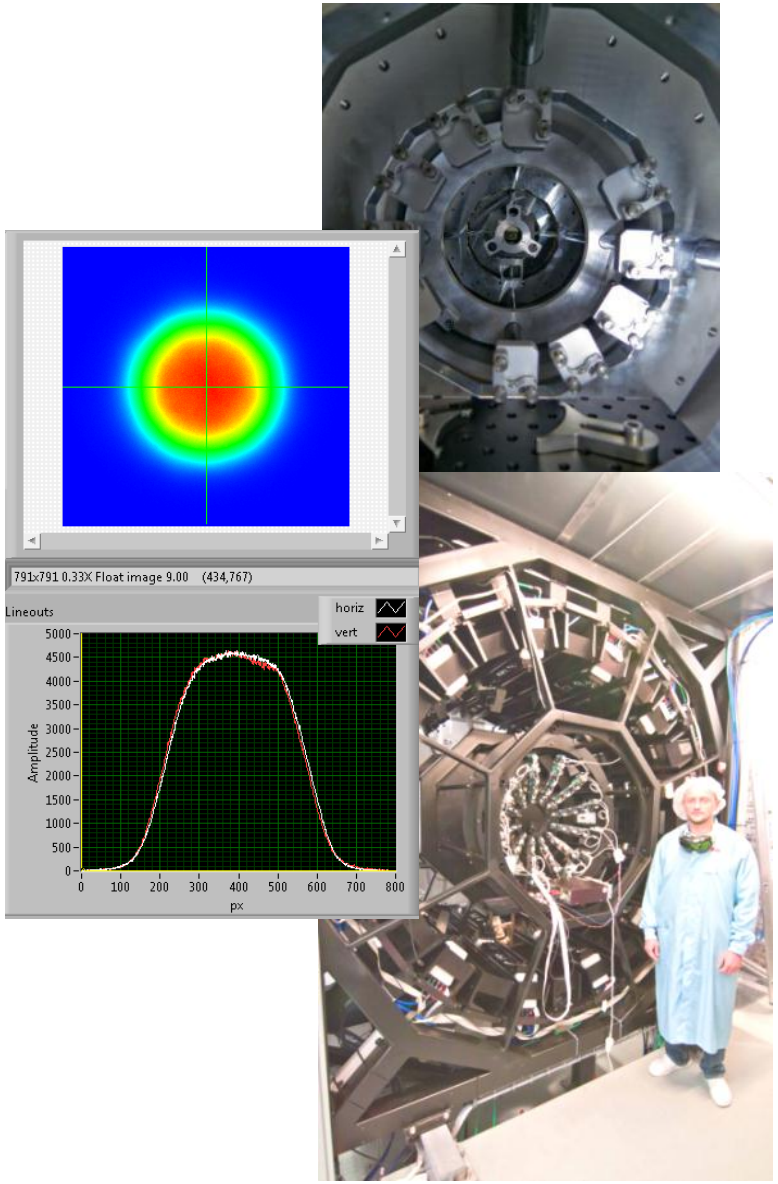
new homogenization algorithm of multi-spot composed pump areas

best possible accuracy, complete automated, for large number of spots

current progress of A5

complex safety- and remote control-system with CS-framework

low-energy amplification with CaF_2



Thank you for your attention