Amplifier development at POLARIS

from daily operation to development

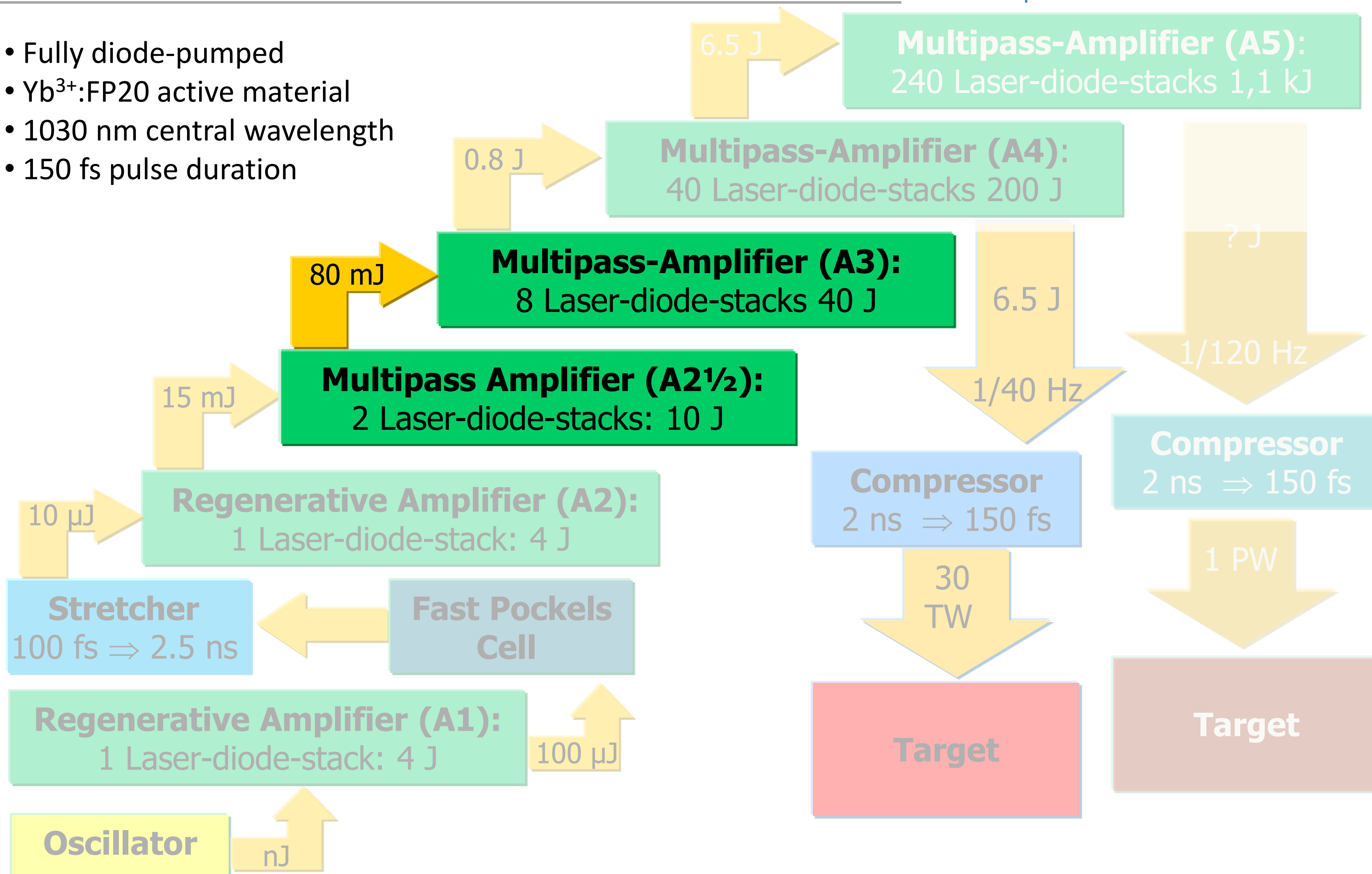
S. Keppler, Chr. Wandt*, M. Hornung, A. Kessler, H. Liebetrau,
A. Sävert, J. Polz, M. Hellwing, F. Schorcht,
J. Hein and M.C. Kaluza

*MPQ, Garching

HEC-DPSSL – 27.03.2014

outline

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



outline

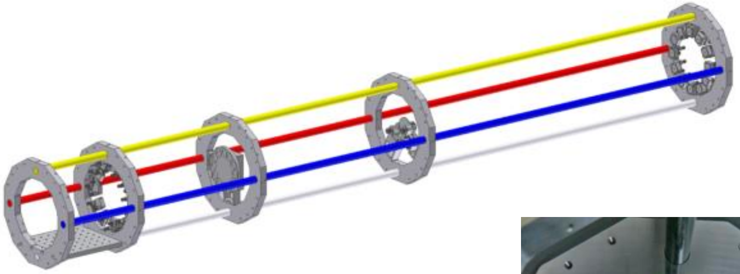
- current setup and performance
  - A2.5 & A3
  - →basic requirements for new developments

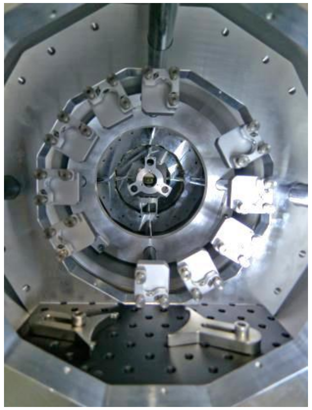
- a new joule-level amplifier A3
  - basic architecture
    - wavefront aberrations
    - beam profile modulations

  - pump arrangement
  - thermal effects and compensation

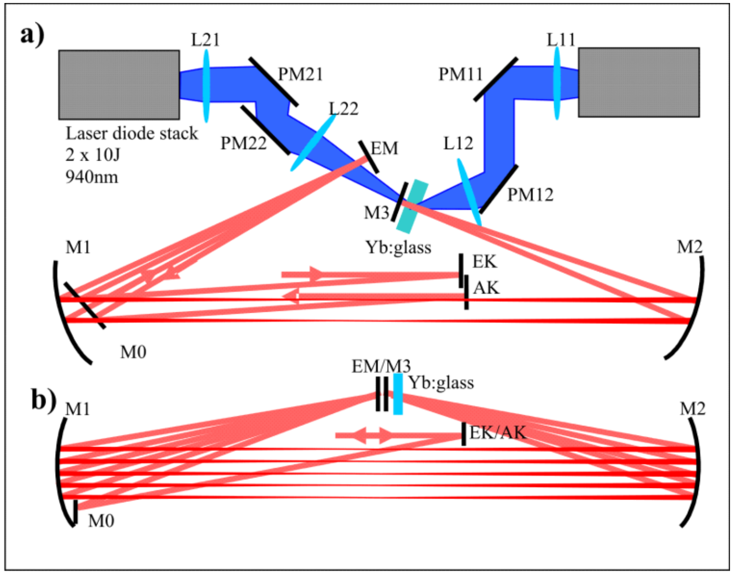
  - current results

- conclusion

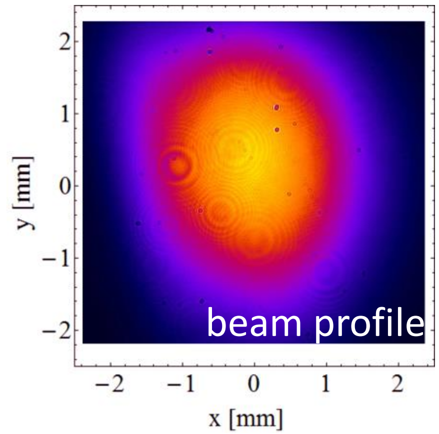


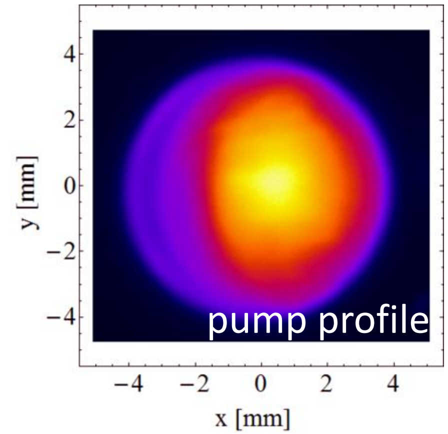


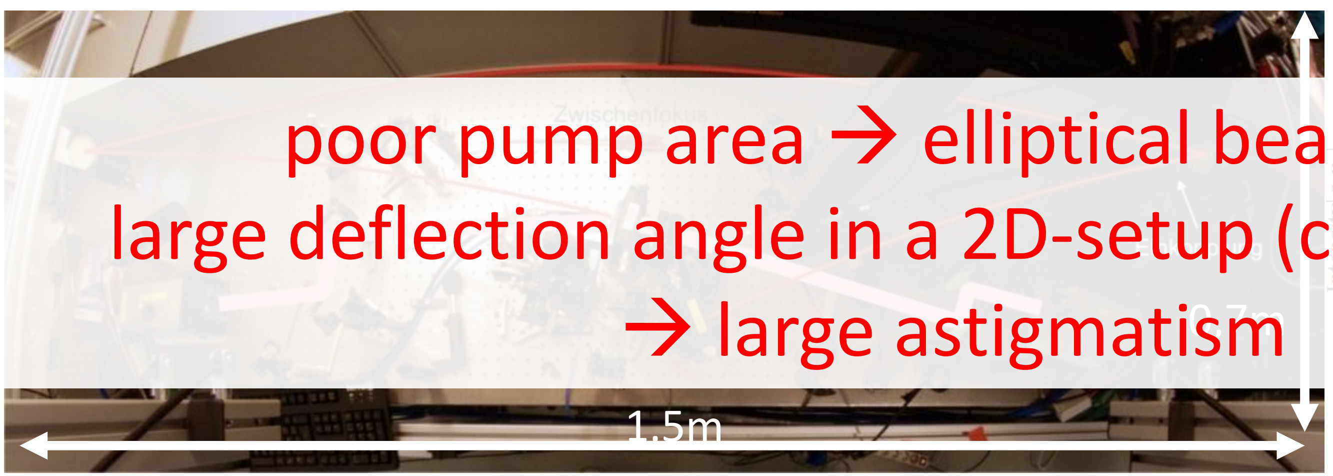
current setup – A2.5

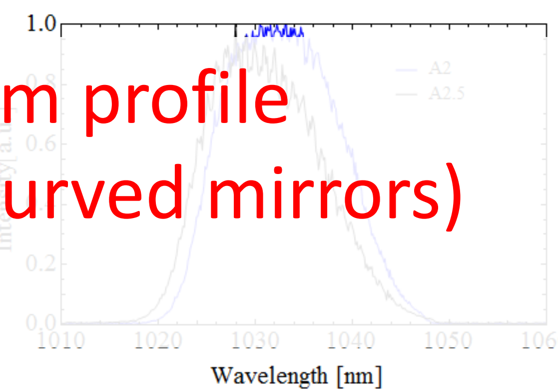


10 Passes
10mJ to 80mJ (gain factor 8) @1/5Hz
bandwidth of 13nm (15nm Seed)
2x4,5kW @2,7ms



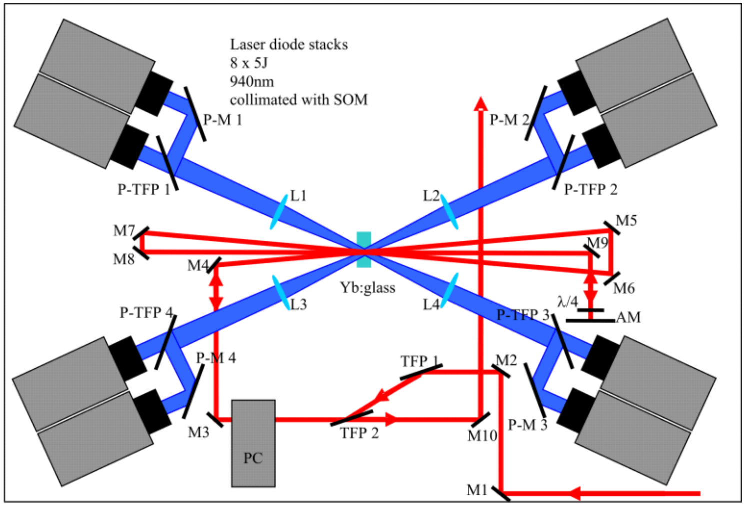




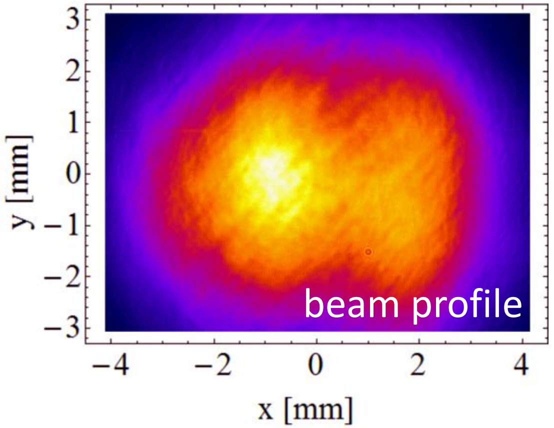


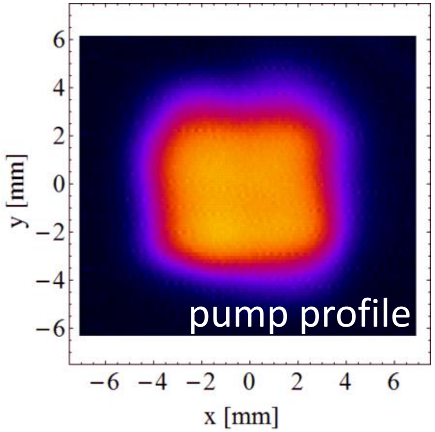
poor pump area → elliptical beam profile
large deflection angle in a 2D-setup (curved mirrors)
→ large astigmatism

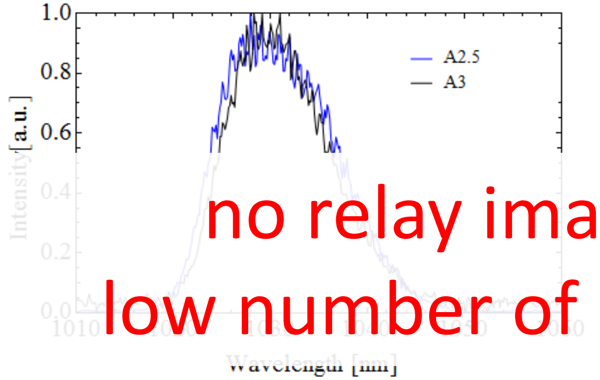
current setup – A3

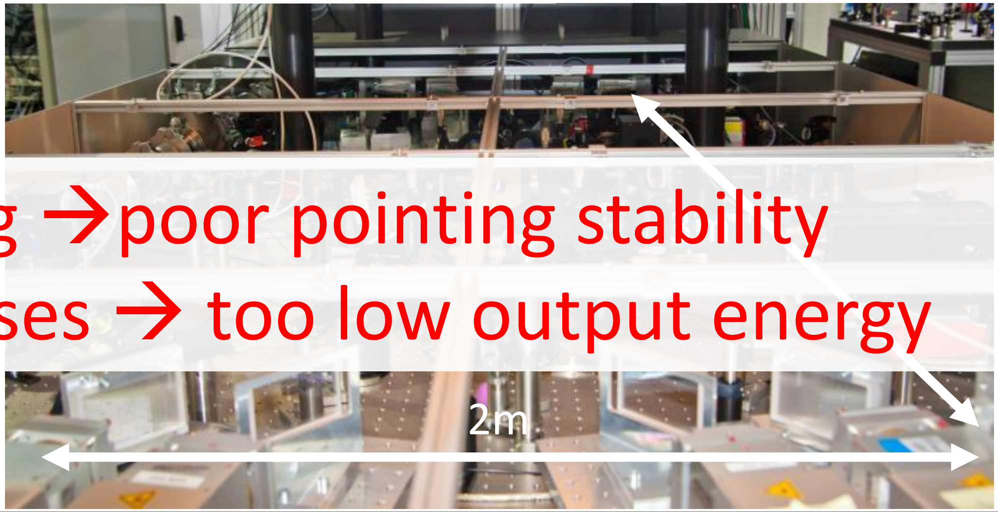


6 Passes
80mJ to 750mJ (gain factor 9) 1/10Hz
bandwidth of 12nm (13nm Seed)
8x2,5kW @2,7ms



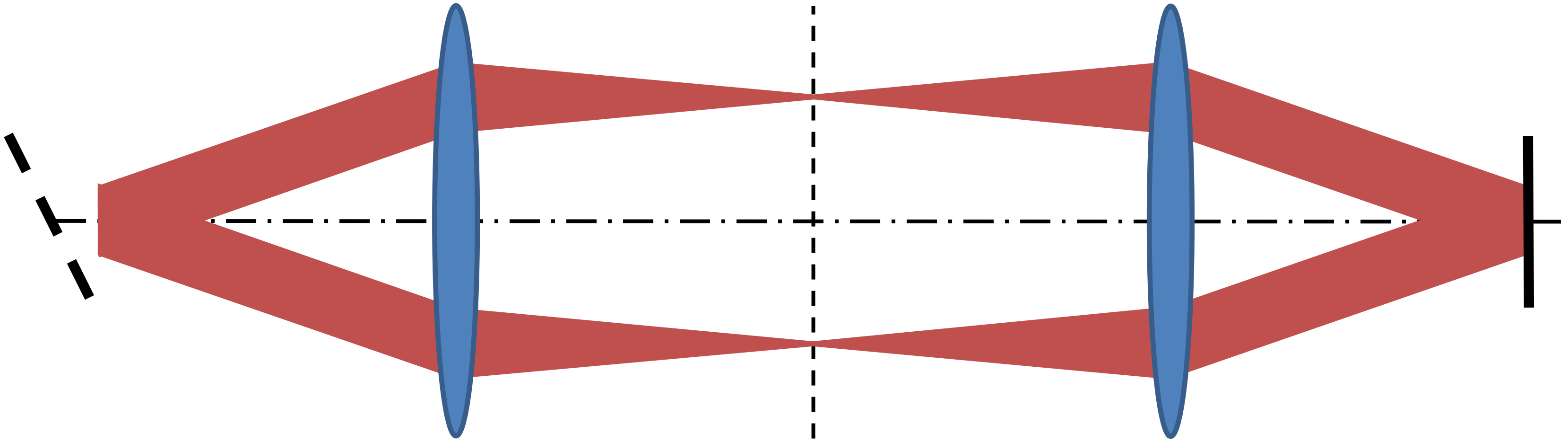


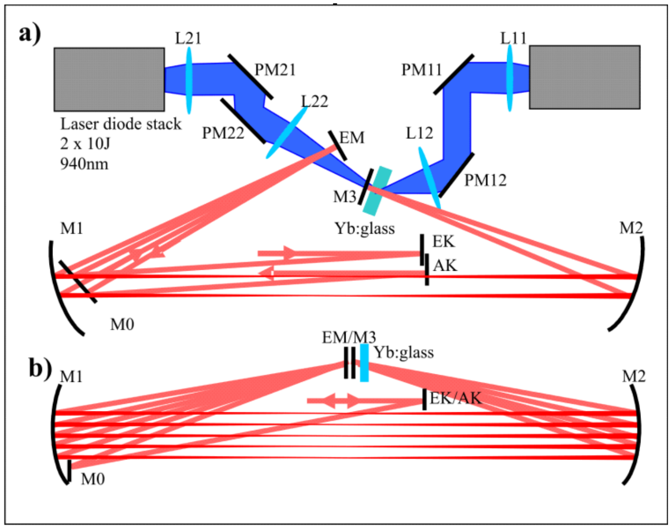


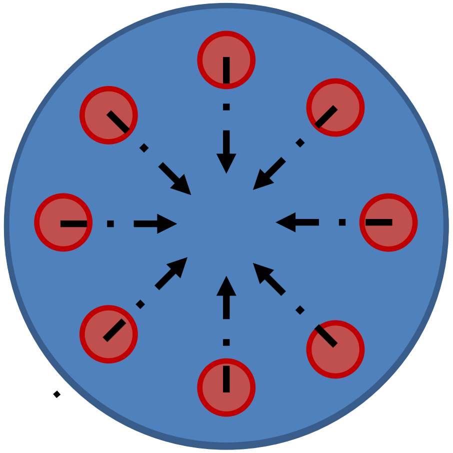


no relay imaging →poor pointing stability
low number of passes → too low output energy

basic architecture



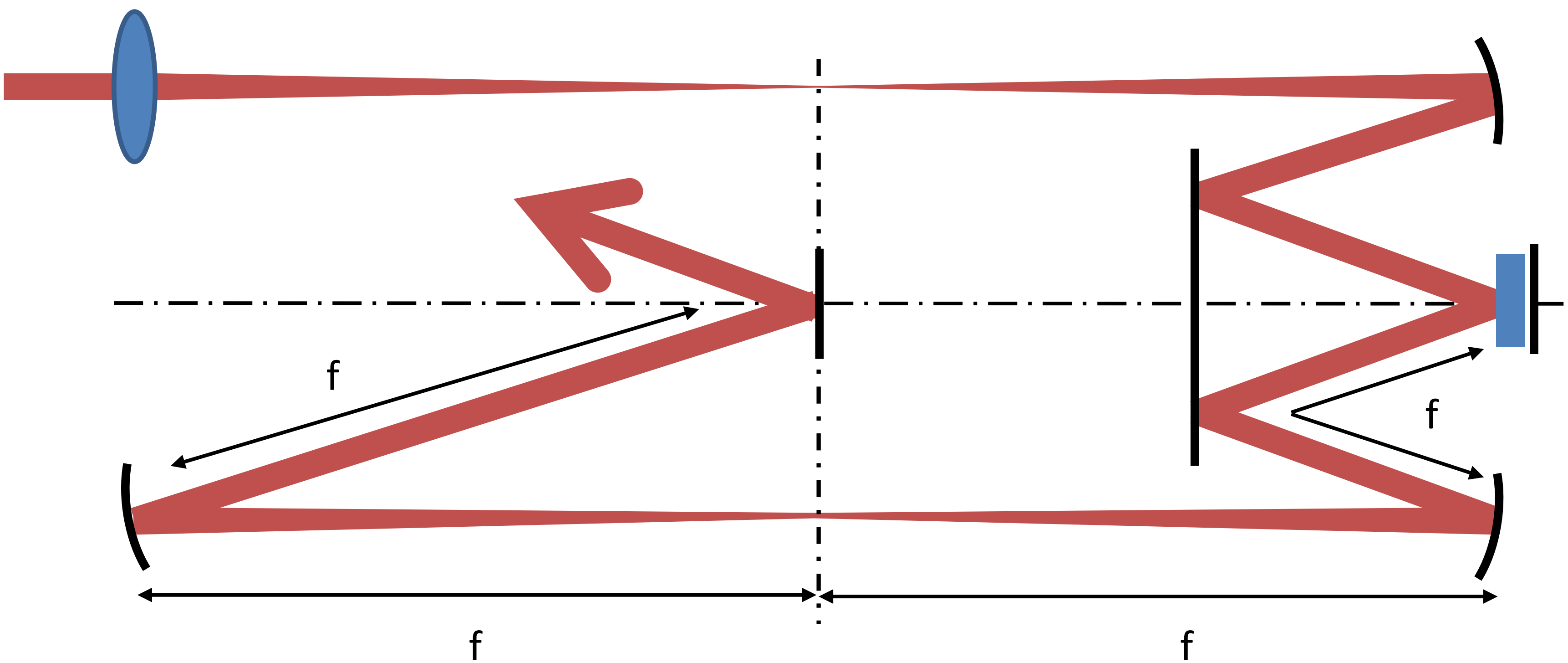




however: large astigmatism

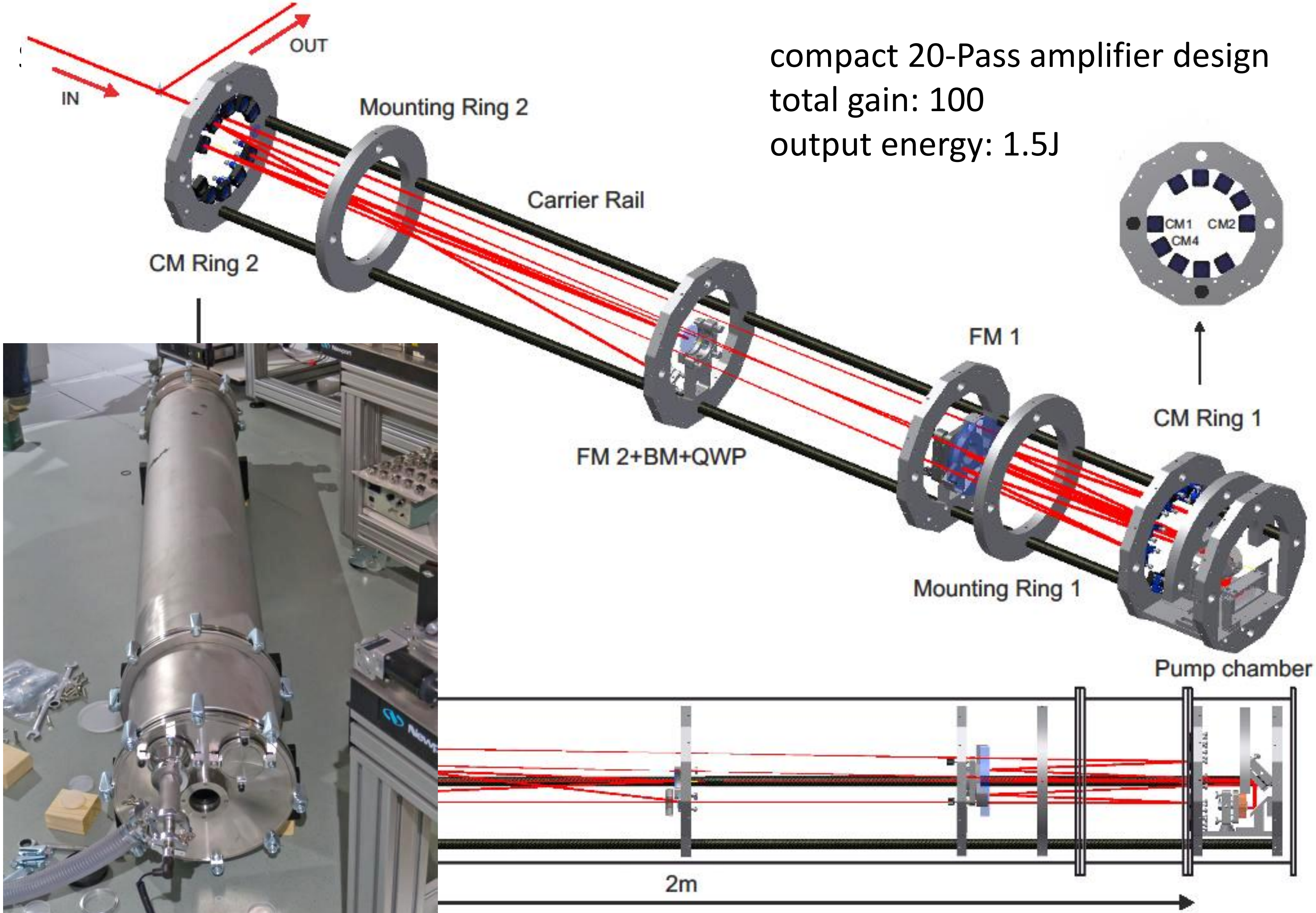
basic architecture

Solution: rotational symmetry

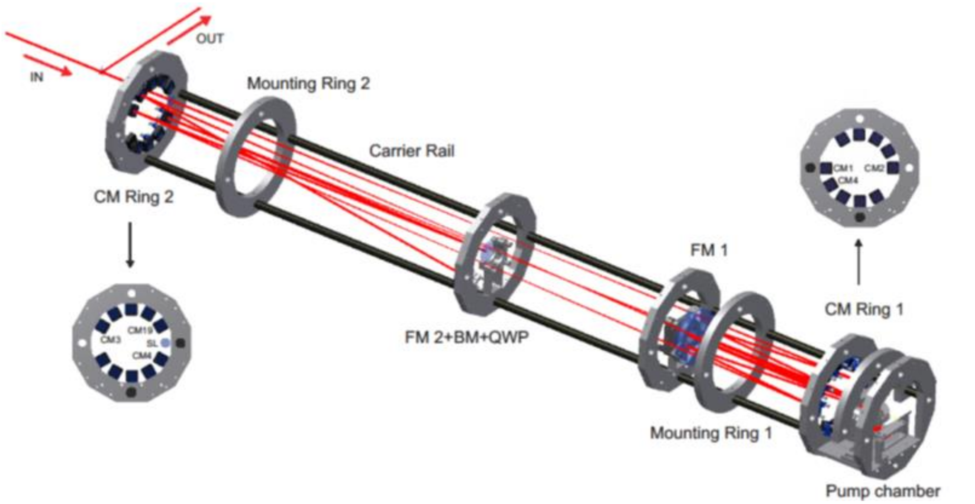


basic architecture

compact 20-Pass amplifier design
total gain: 100
output energy: 1.5J



basic architecture



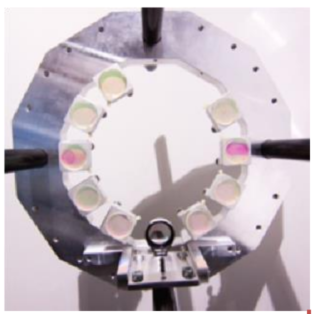
wavefront aberrations

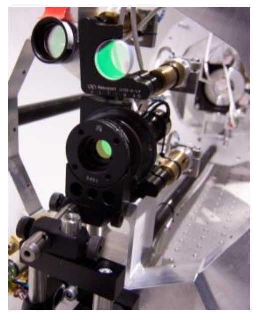
rotational symmetry:
sphere PV: 0.18µm
astigmatism PV: 0.07µm

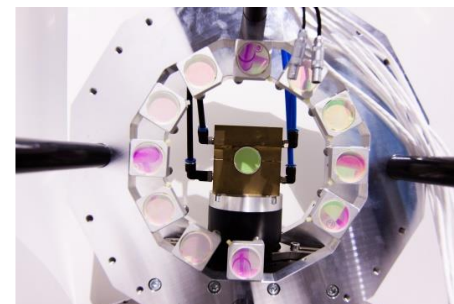
astigmatism compensated by the 3D- rotational symmetry

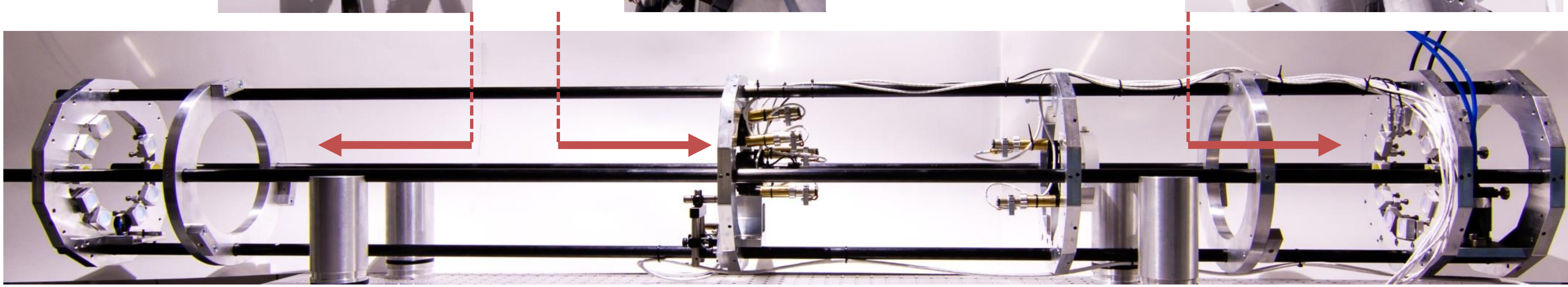
basic architecture

main properties of the new A3		main requirements of a new amplifier:
20 passes	✓	• higher energy (1.5J) → high number of passes
factor 100	✓	• gain factor >80 to replace both amplifiers
yes	✓	• relay imaging design → better pointing stability and homogeneous beam profile
3D-rotational symmetry	✓	• minimum of aberrations for good focusability
		• flat-top pump profile → smoother beam profile









basic architecture

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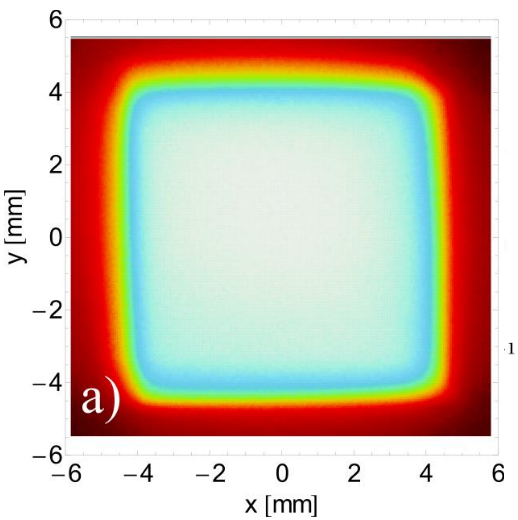
2x Lastronics pump module	✓	• flat-top pump profile → smoother beam profile



- 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

basic architecture

main properties of the new A3

main requirements of a new amplifier:

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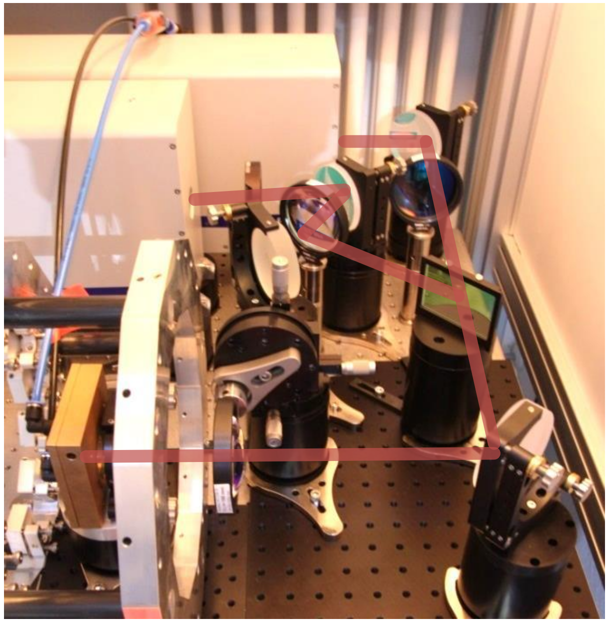
pump modules are coupled by polarization



thermal effects and compensation

fraction of pump energy transferred to heat

change of refractive index (dn/dT)

thermal expansion (α)

stress ($C_{r,\phi}$)

compensating thermal effects is highly demanded

PtV of 3.4µm → $f = 74$m per pass

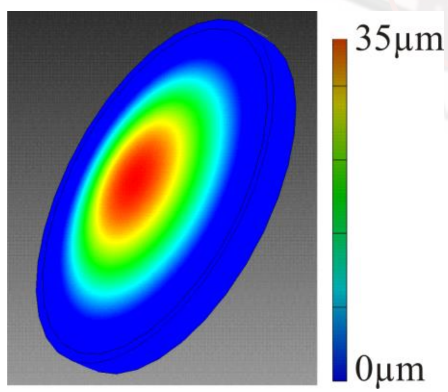
however: → $f = 3.5$m after 20 passes

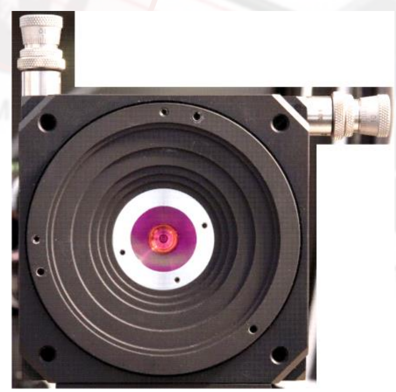
strong deformation of the beam profile

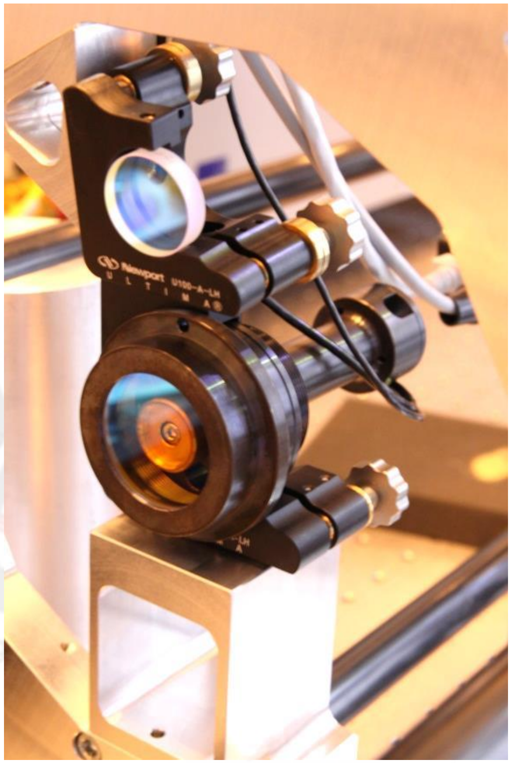
up 10% loss after 20 passes for Yb:glass

thermal effects

thermal lens compensation

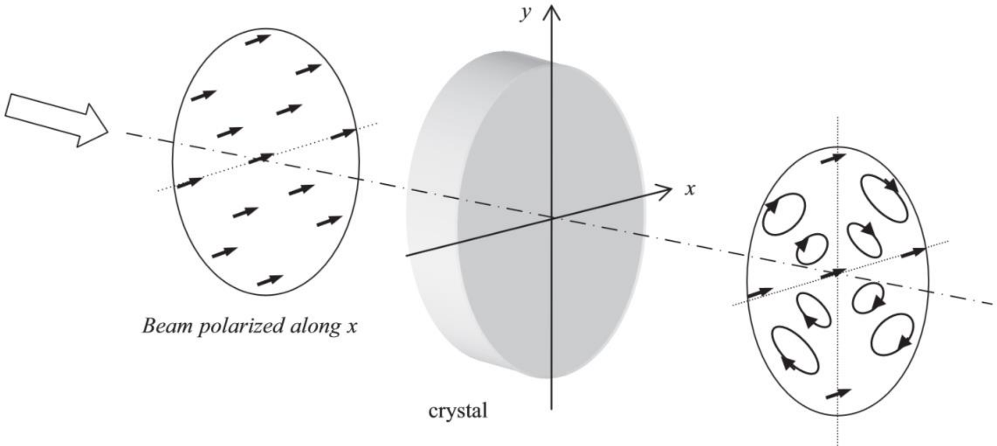




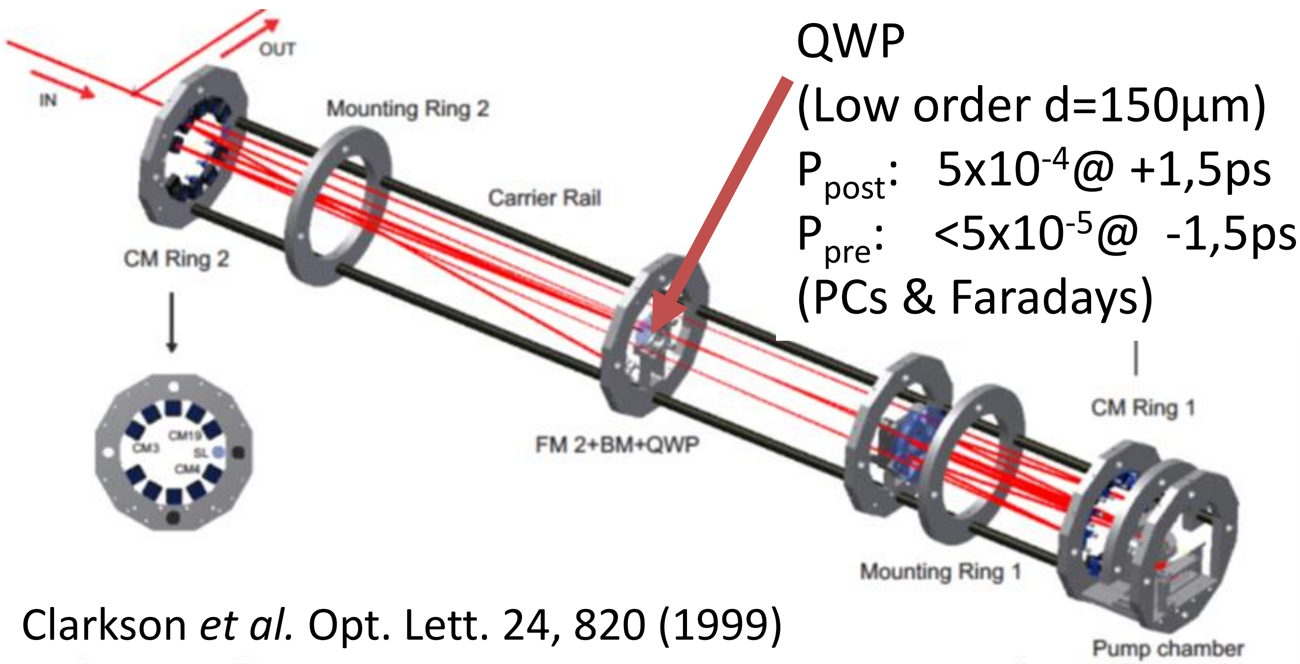


thermal effects

depolarization compensation



S. Chénais et al. Progress in Quantum Electronics 30, 89-153 (2006)

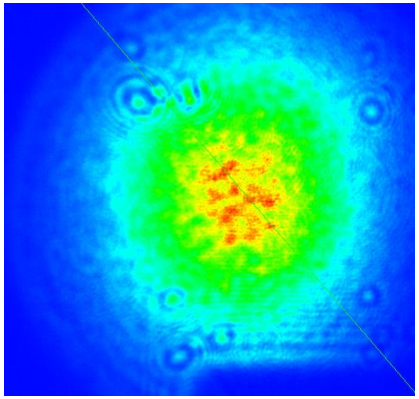


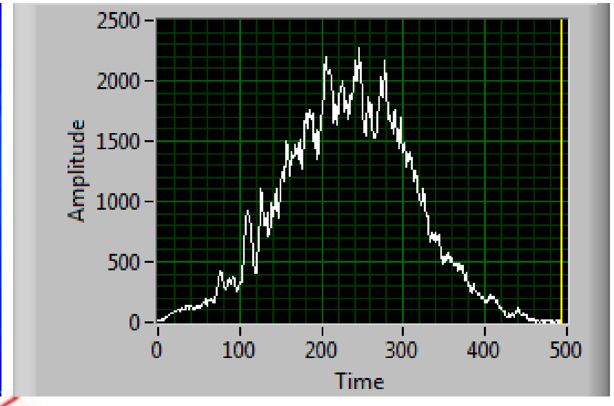
QWP
(Low order d=150µm)
P_{post}: $5x10^{-4}$@ +1,5ps
P_{pre}: $<5x10^{-5}$@ -1,5ps
(PCs & Faradays)

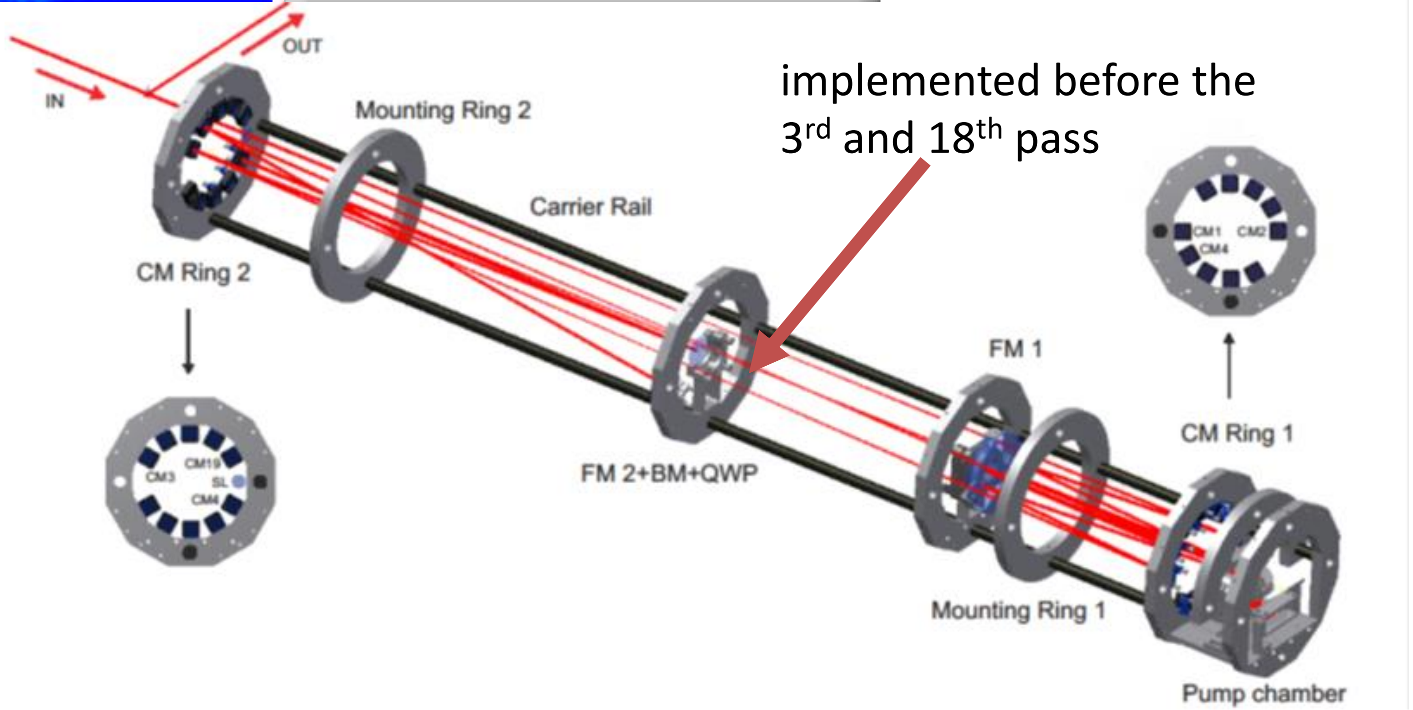
Clarkson *et al.* Opt. Lett. 24, 820 (1999)

basic architecture

high frequency modulations





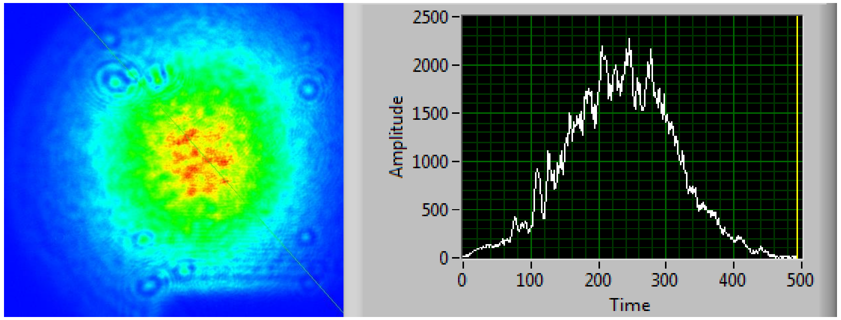


implemented before the 3rd and 18th pass

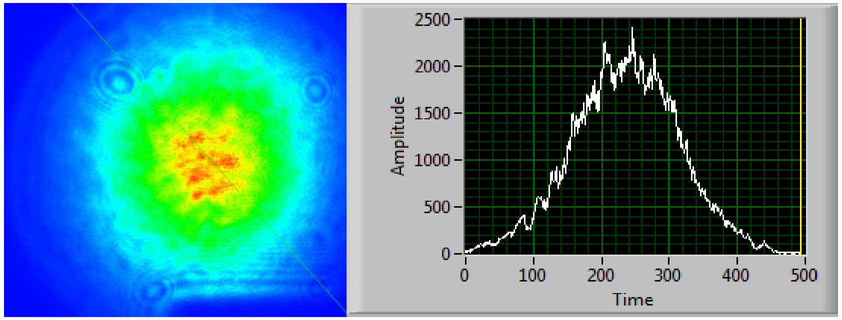
basic architecture

high frequency modulations

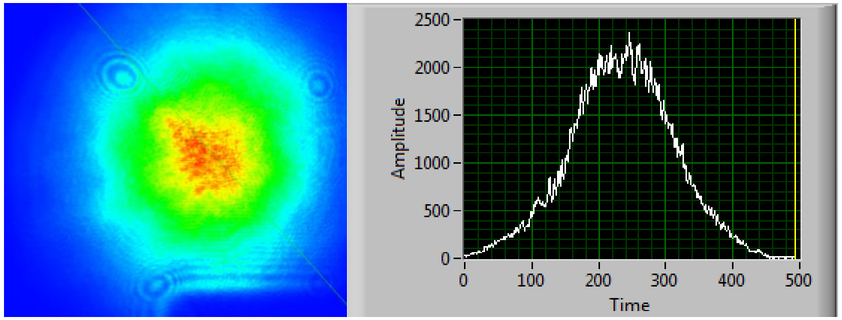
pinhole 5mm



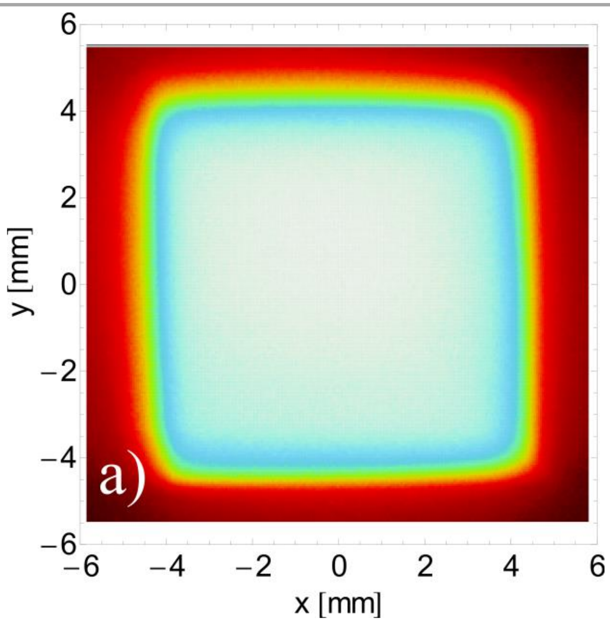
pinhole 3mm



pinhole 1mm



current results



first successful amplification test:

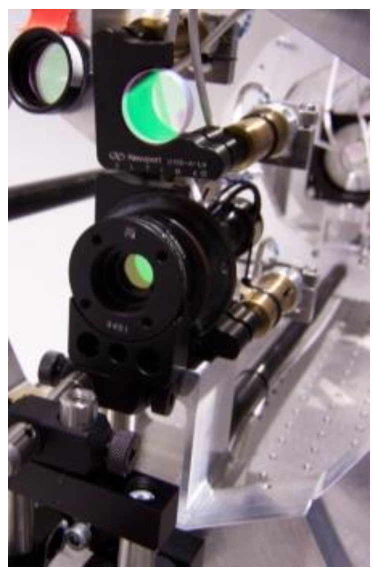
gain factor 80 to 1,1J

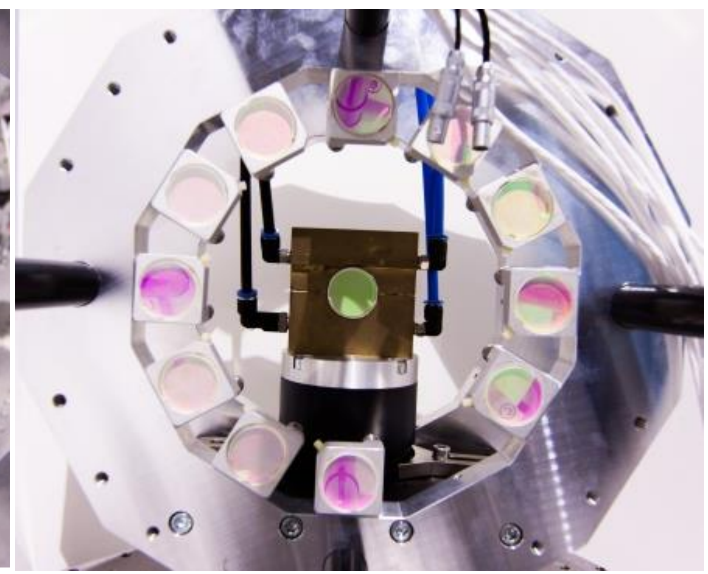
with Yb:FP20 (∅28mm d13mm)

beam size 6.1x6.5mm (FWHM) → 1J@3J/cm²

very good pointing stability

very good energy stability (3% RMS)

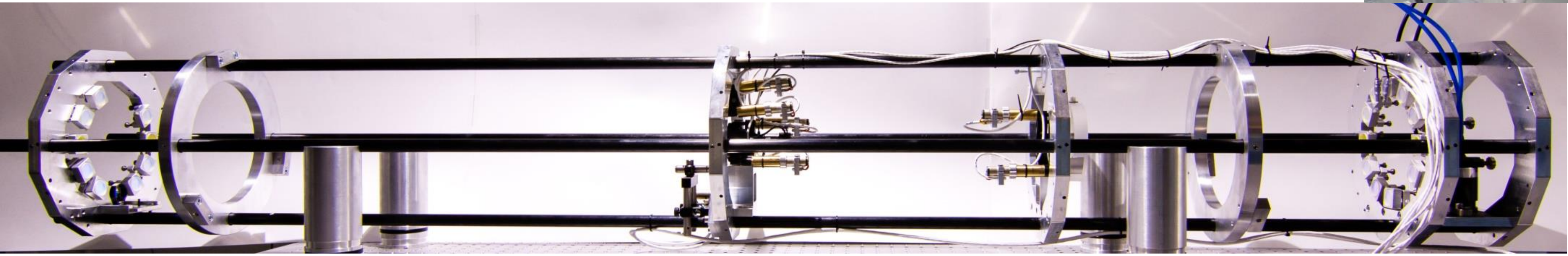




conclusion

new amplifier design based on experiences of the daily operation

- 20passes, gain 100, output (1.5J)
- very homogeneous flat-top beam profile
- Integrated spatial filtering
  → smooth beam profile
- rotational symmetric design for
  low wavefront aberrations
- compensation of thermal effects
  - (thermal lens & depolarization)
- completely operated under vacuum condition
- very stable and compact design



Thank you for your attention