Status of LZH Laser Program for Advanced LIGO

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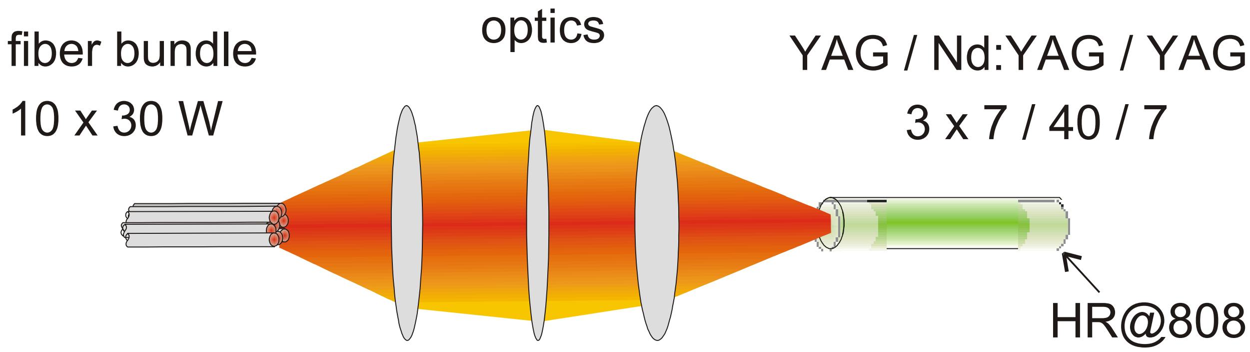
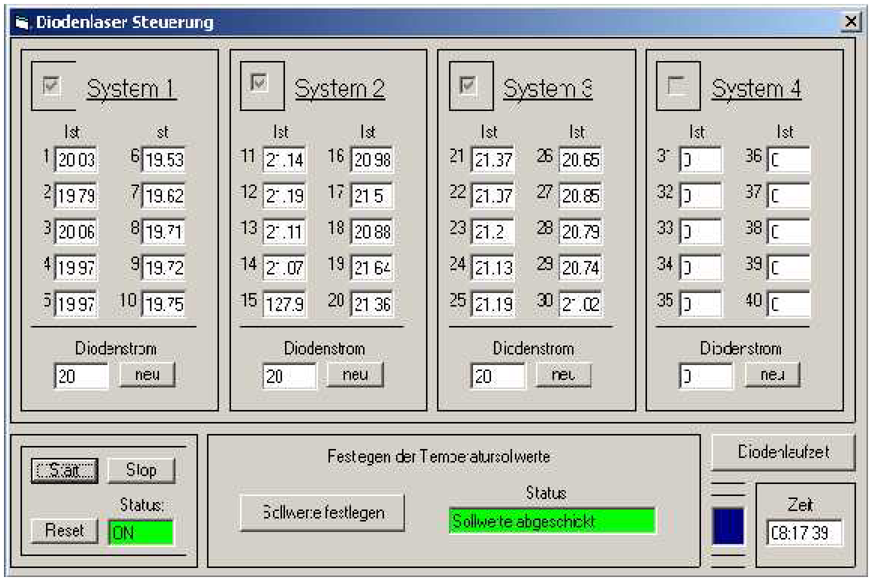
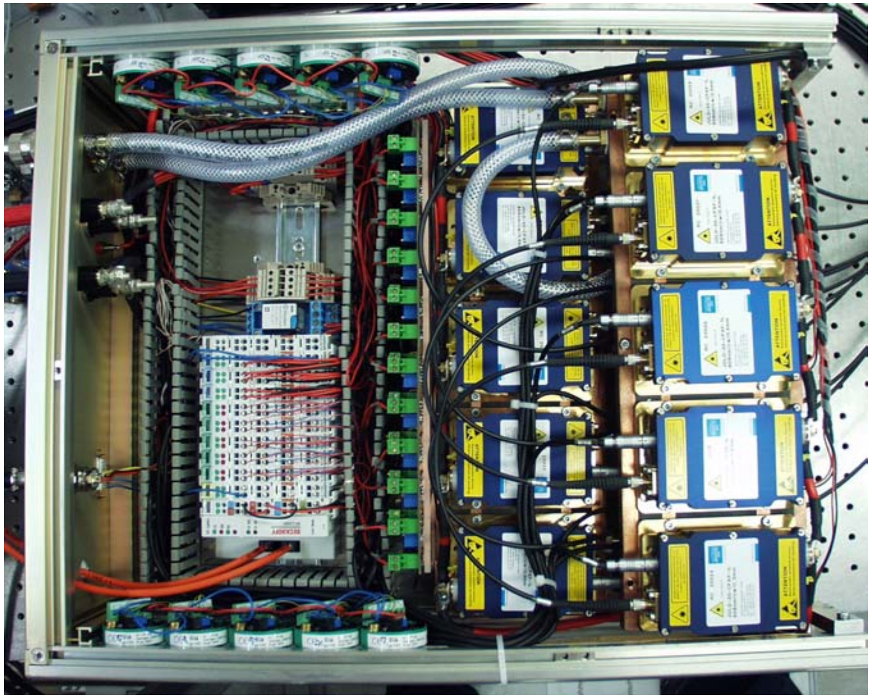
Why Using End-Pumped Rod Lasers ?



- Laser rod crystals → proven reliable design
- Cylindrical symmetry → supports $TEM_{0,0}$
- End-pumping allows:
  + Good mode / pump overlap (i.e. high efficiency)
  + Mode-selective pumping (i.e. good mode control)
  + Conductive cooling (i.e. no water at the laser-crystal)
  + Fiber coupled pump (i.e. high reliability / easy maintenance)

Computer-Controlled Pump Diodes (4 x 10 x 30 W = 1200 W)



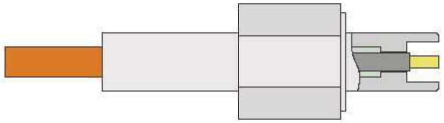


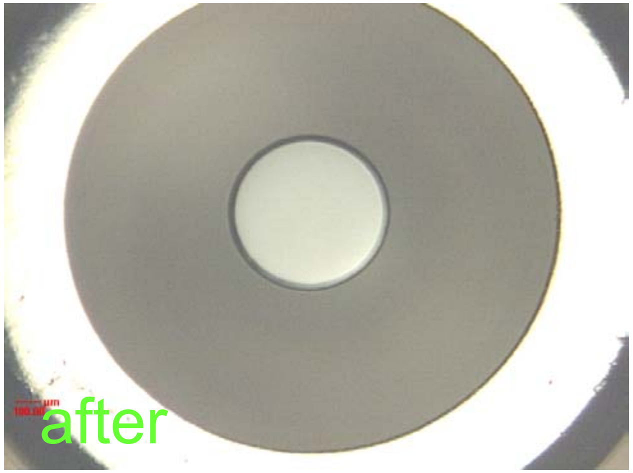
1) Temp. control of each diode
2) Power control of each diode*

* release in 2003

Improvement of Pump Fibers (@ diode side)

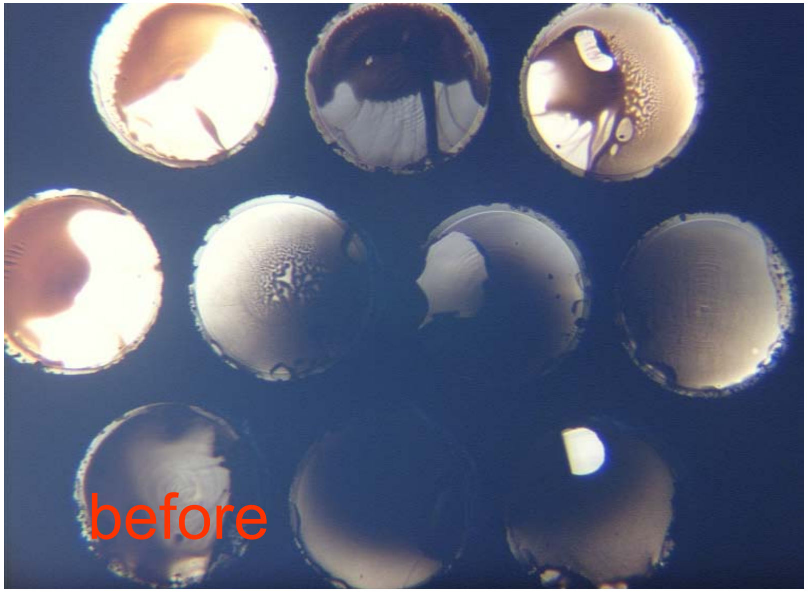
Origin under investigation



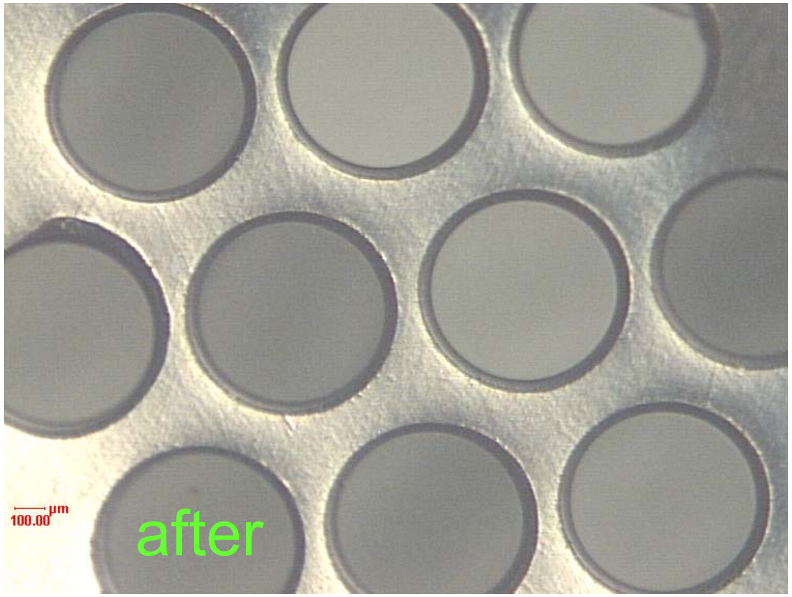


Free-standing fiber connector

Improvement of Pump Fibers (@ laser side)

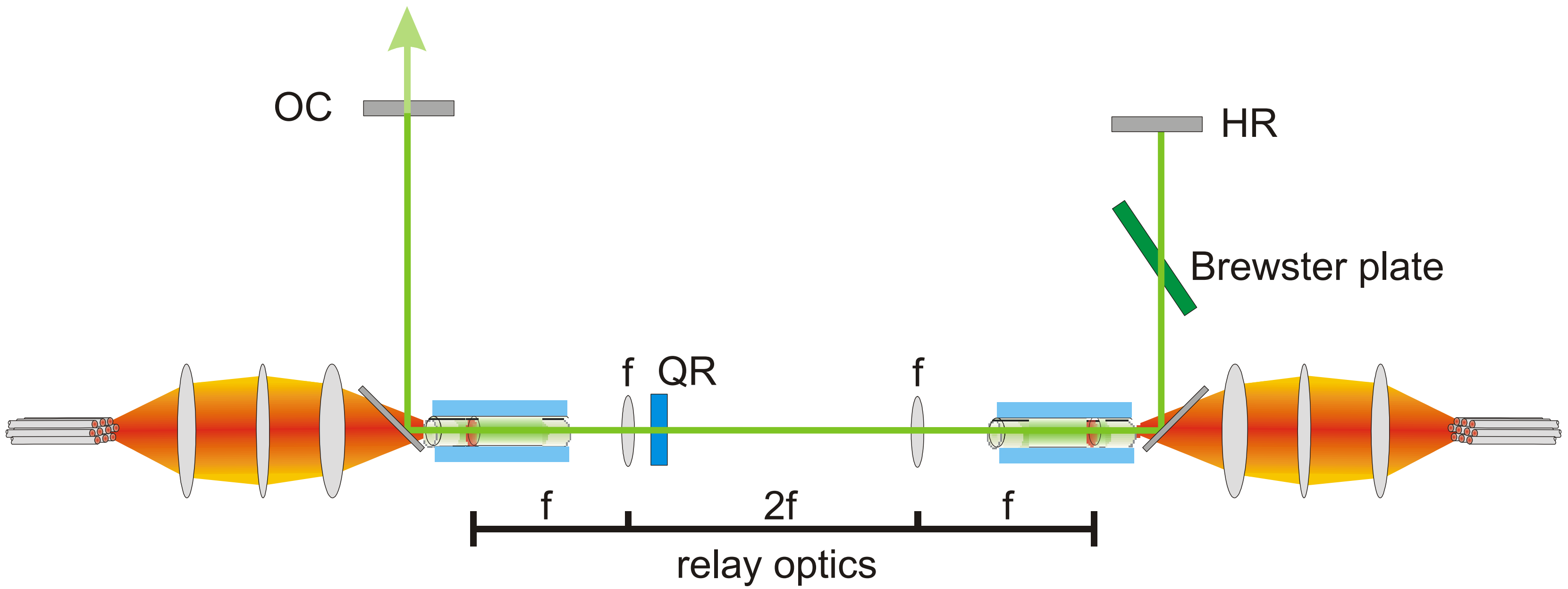


“Glue outgassing”-damage initiated by back-reflections



Fibers mounted in a fs-laser-drilled silver-plate

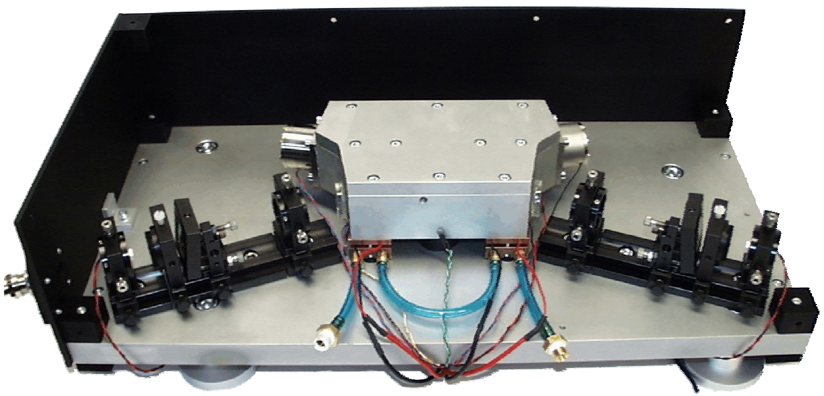
Proof of Concept (TEM_{00} @ 100 W)



P: 97 W $M^2_{x,y}$: 1.25 $\eta_{opt.}$: 25%

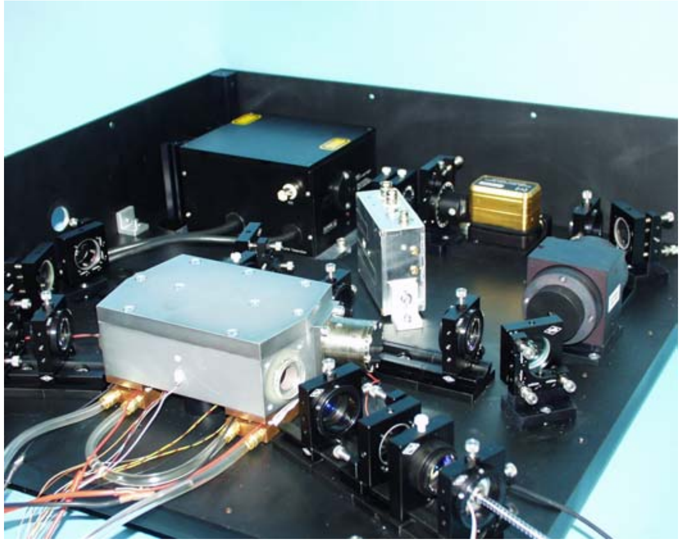
polarization >100:1   depolarization : < 0,5%

Reliable Compact Seed Sources (made by LZH)



Nd:YVO, 24 W, $M^2<1.05$

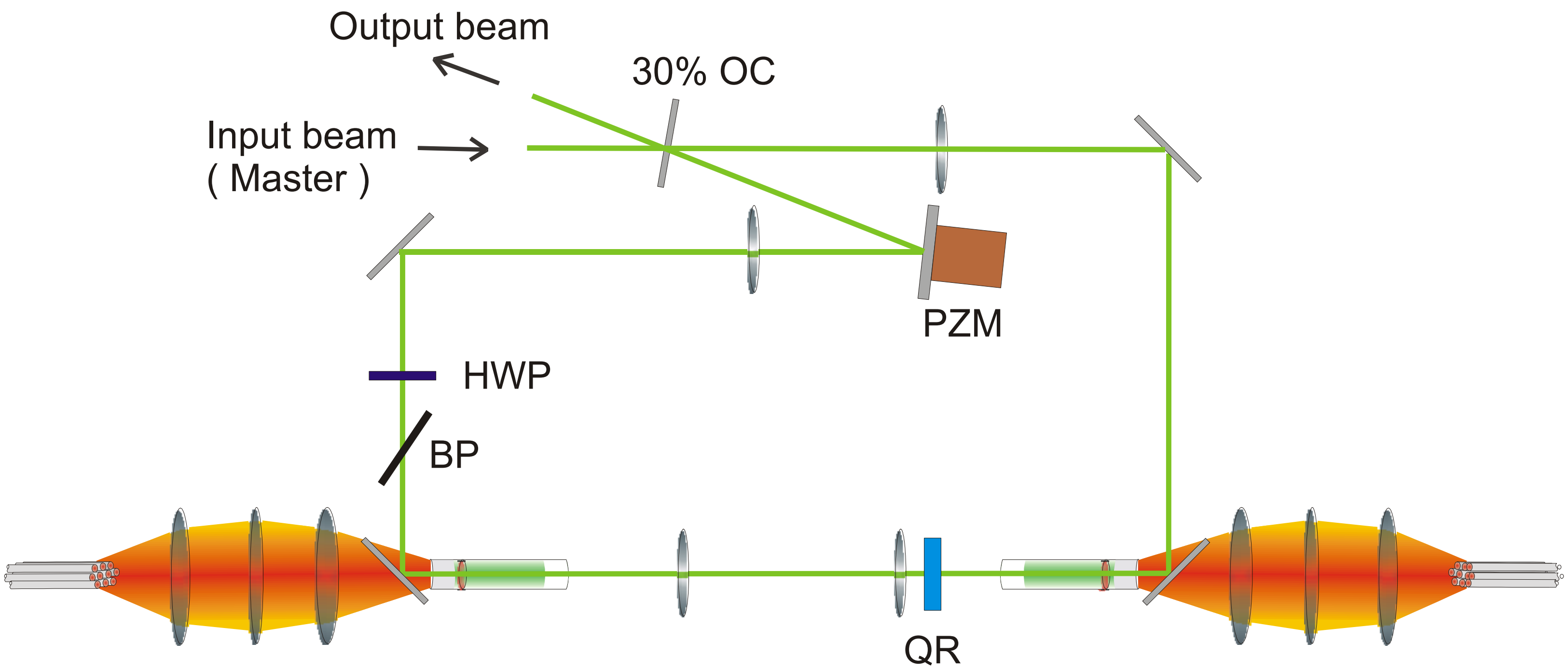
for Virgo



Nd:YAG, 14 W, $M^2<1.05$

for GEO600 (UoH, UoG),
Virgo, Uo Düsseldorf

PoC II (single-frequency operation)



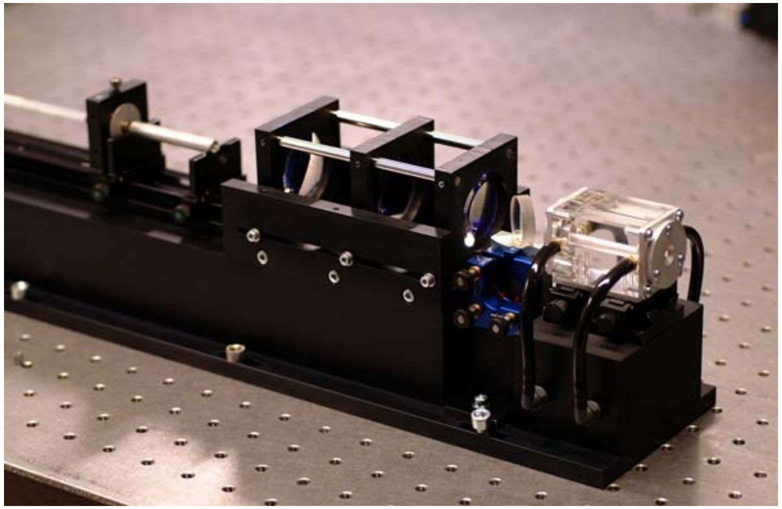
P: 87 W $M^2_{x,y}$: 1.1 $\eta_{opt.}$: 24%

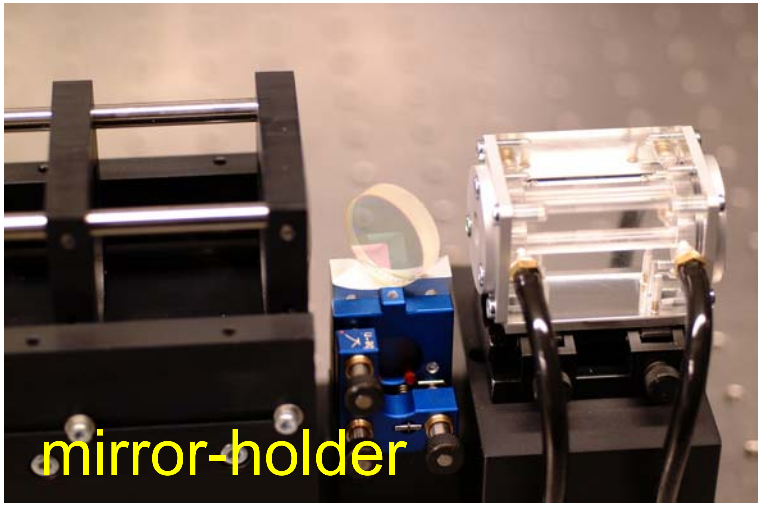
polarization >100:1 depolarization : < 0,5%

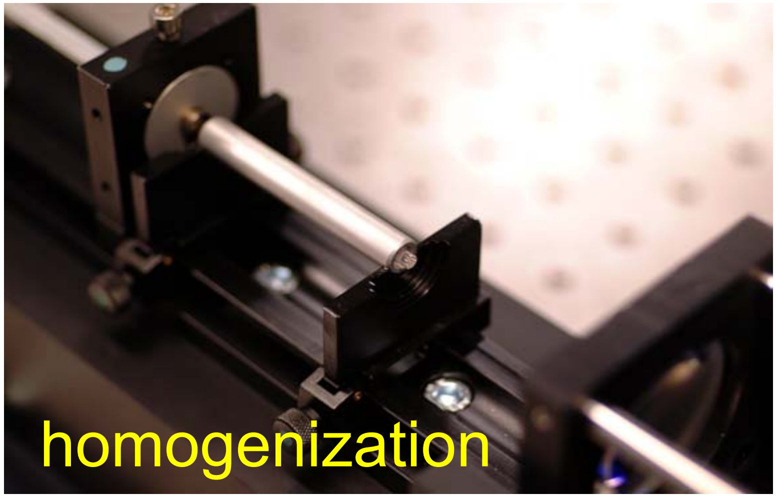
Laser-Head Optimization

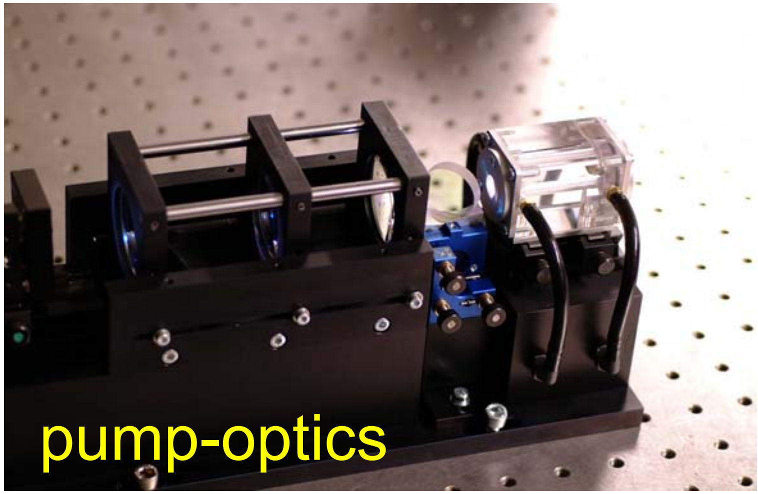
+ New mechanical design → more stable and reliable
+ Pump-spot size → increase output power
+ Pump-light homogenization → better beam-quality

Improved Mechanical Design



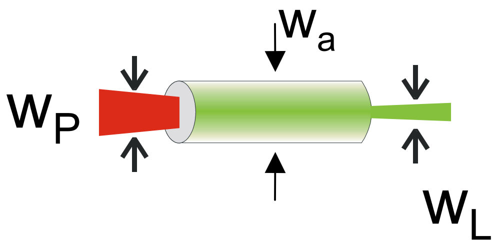






Optimization of Pump Spot Size

Negligible diffraction loss on rod aperture: $w_L[\ w_a / 3$



☹ in transversally pumped rods: $w_P = w_a$

⇒ less gain overlap

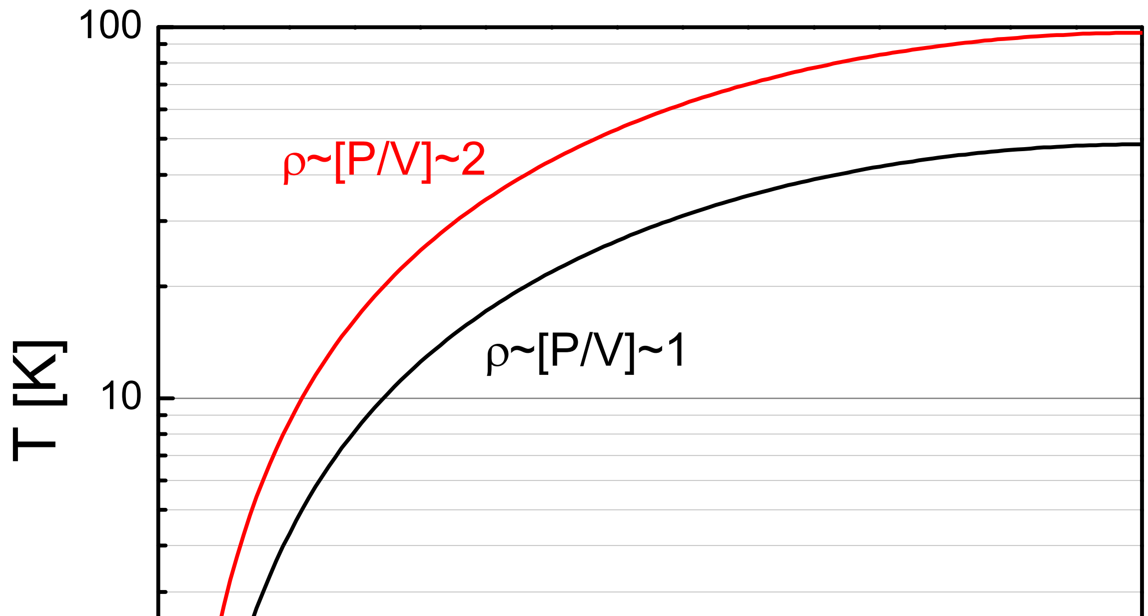
⇒ gain for higher order modes

☺ in end-pumped rods: $w_p \sim w_L$

⇒ optimized gain overlap

⇒ reduced gain for higher order modes

Influence of Pump Density

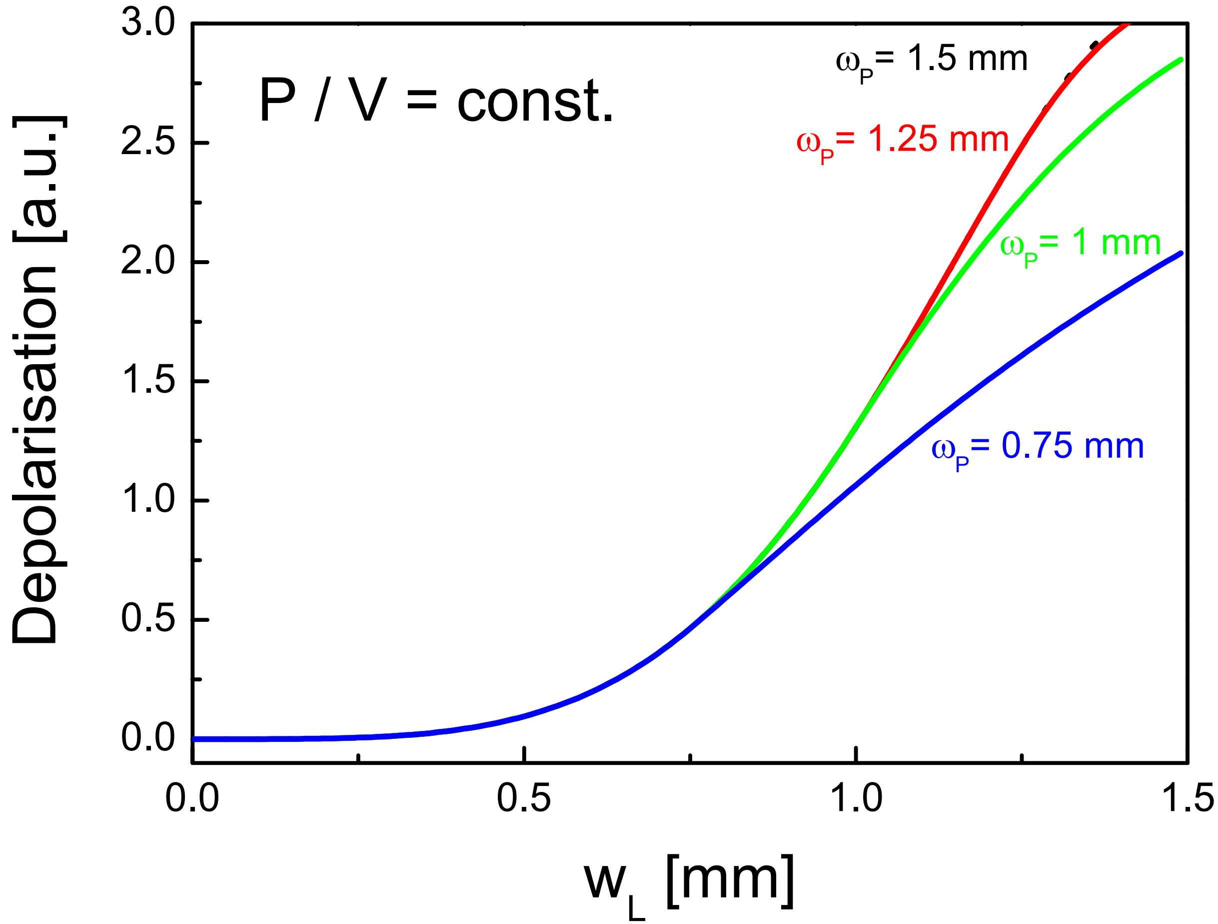


Tighter pump focus:

⇒ same gain at reduced temperature !

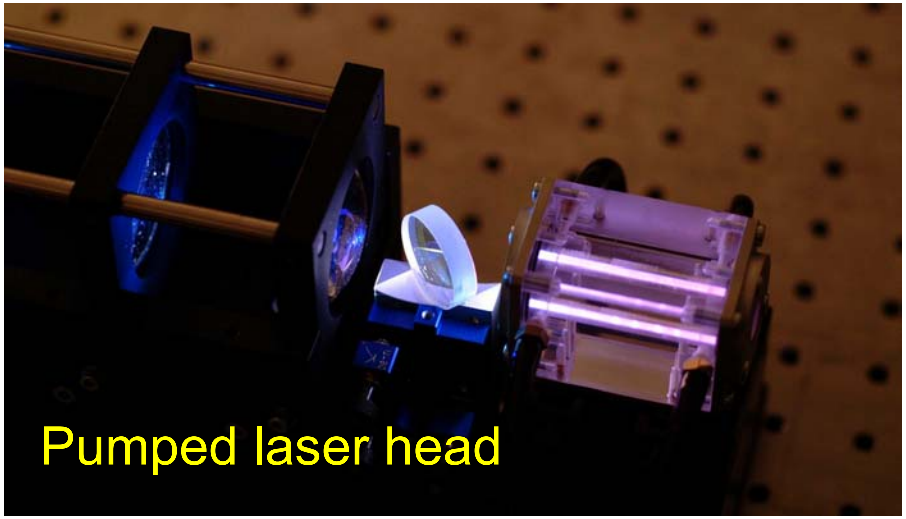
⇒ less thermal effects !

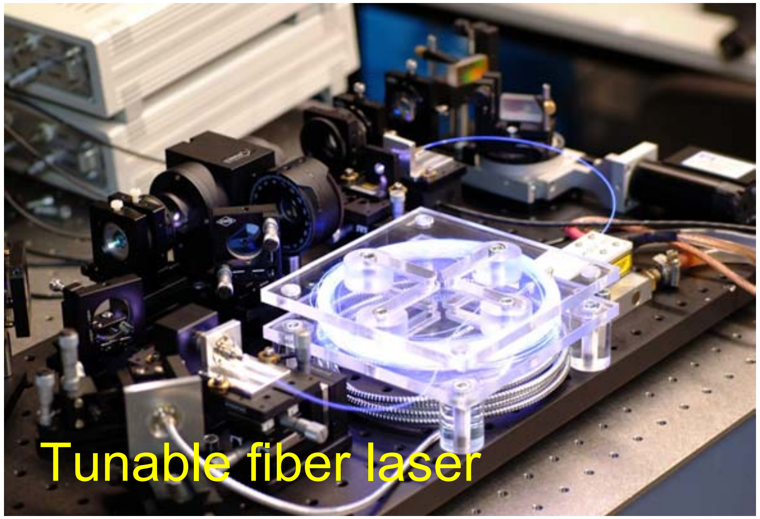
Depolarization in End-Pumped Rods

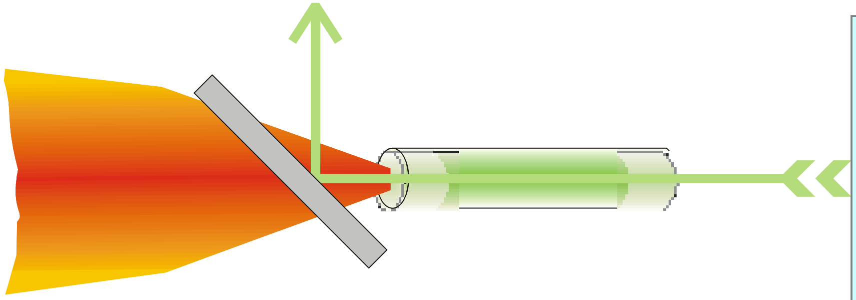


⇒ Depolarization independent of pump spot size if $\omega_P > \omega_L$

Pump-Spot Optimization







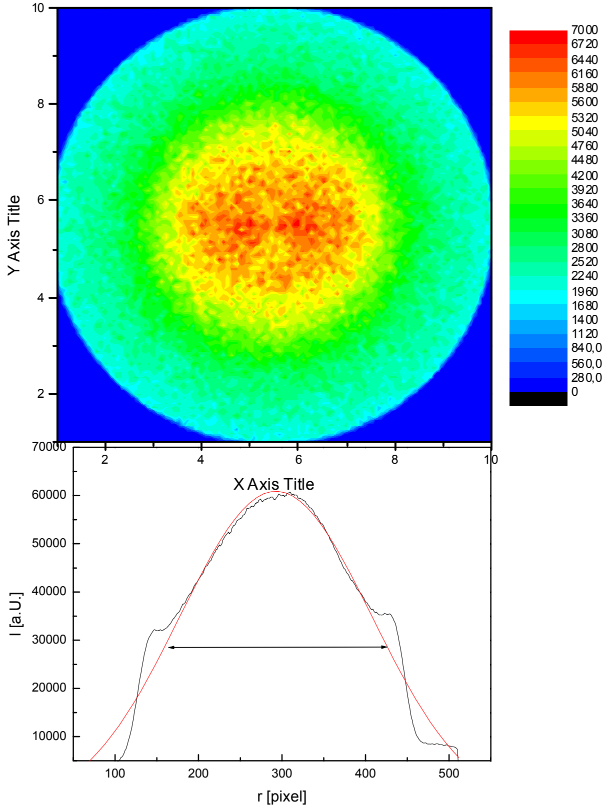
Laser for probing

gain / thermal effects

on / off gain resonance

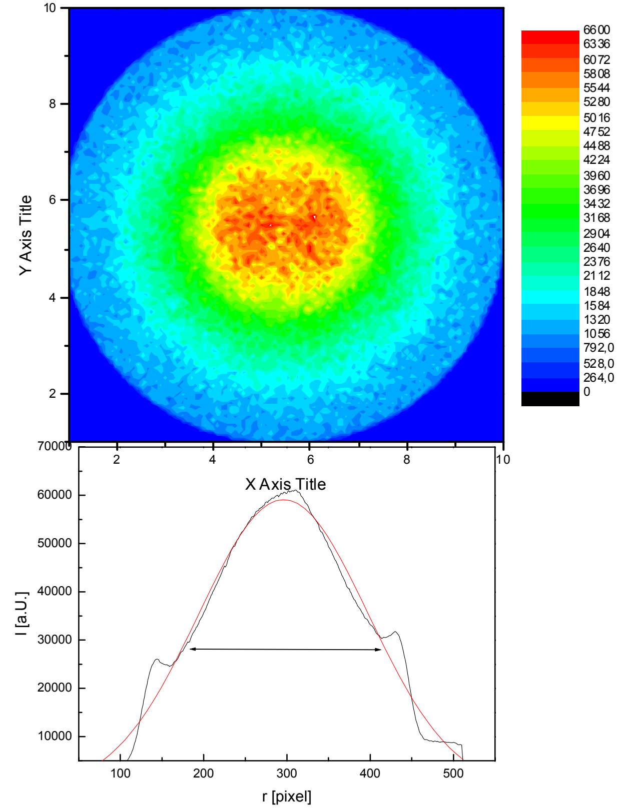
Experiments with two Different Pump-Spot-Sizes

Configuration 1



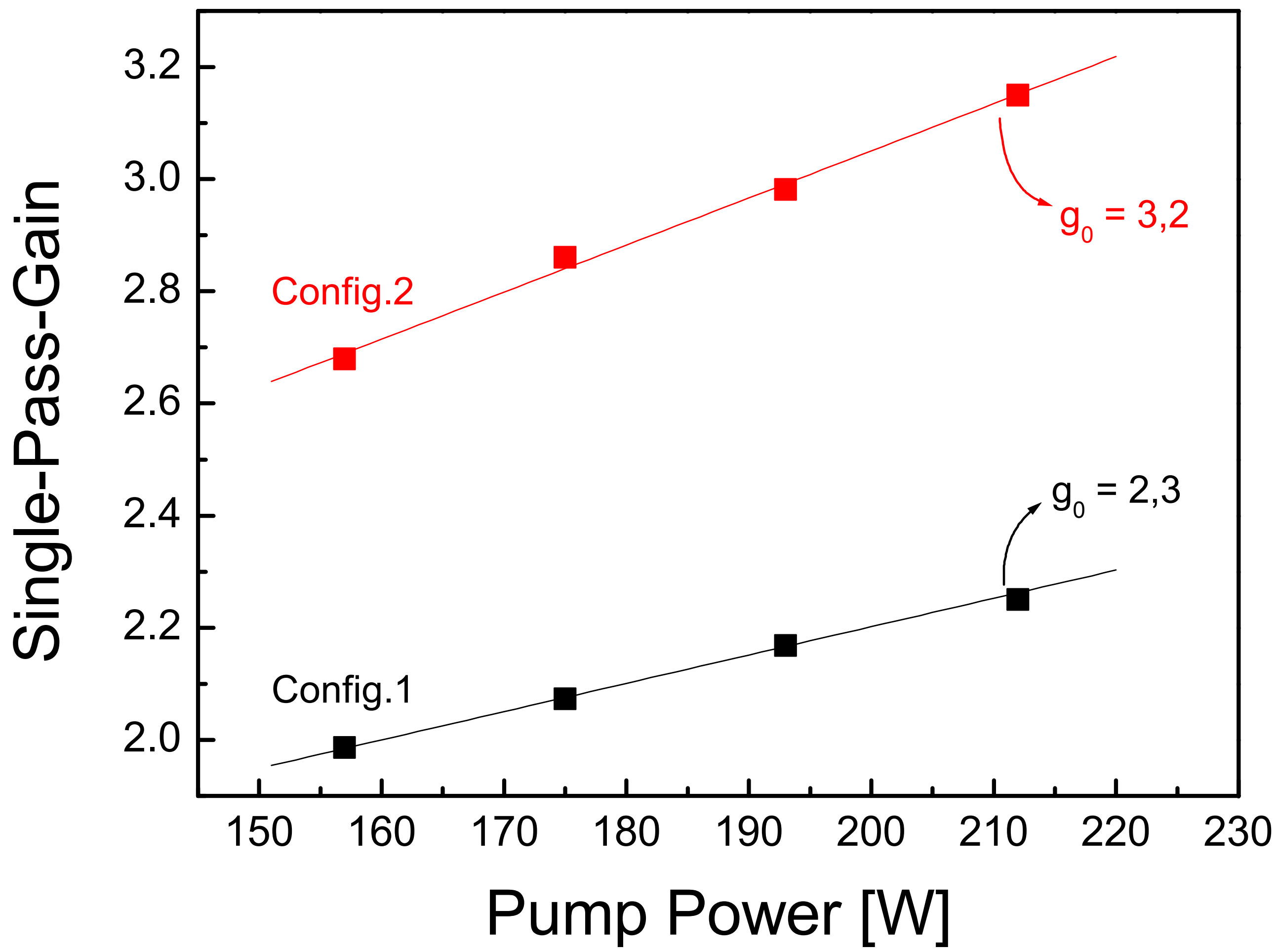
→ W_p=2.3 mm

Configuration 2

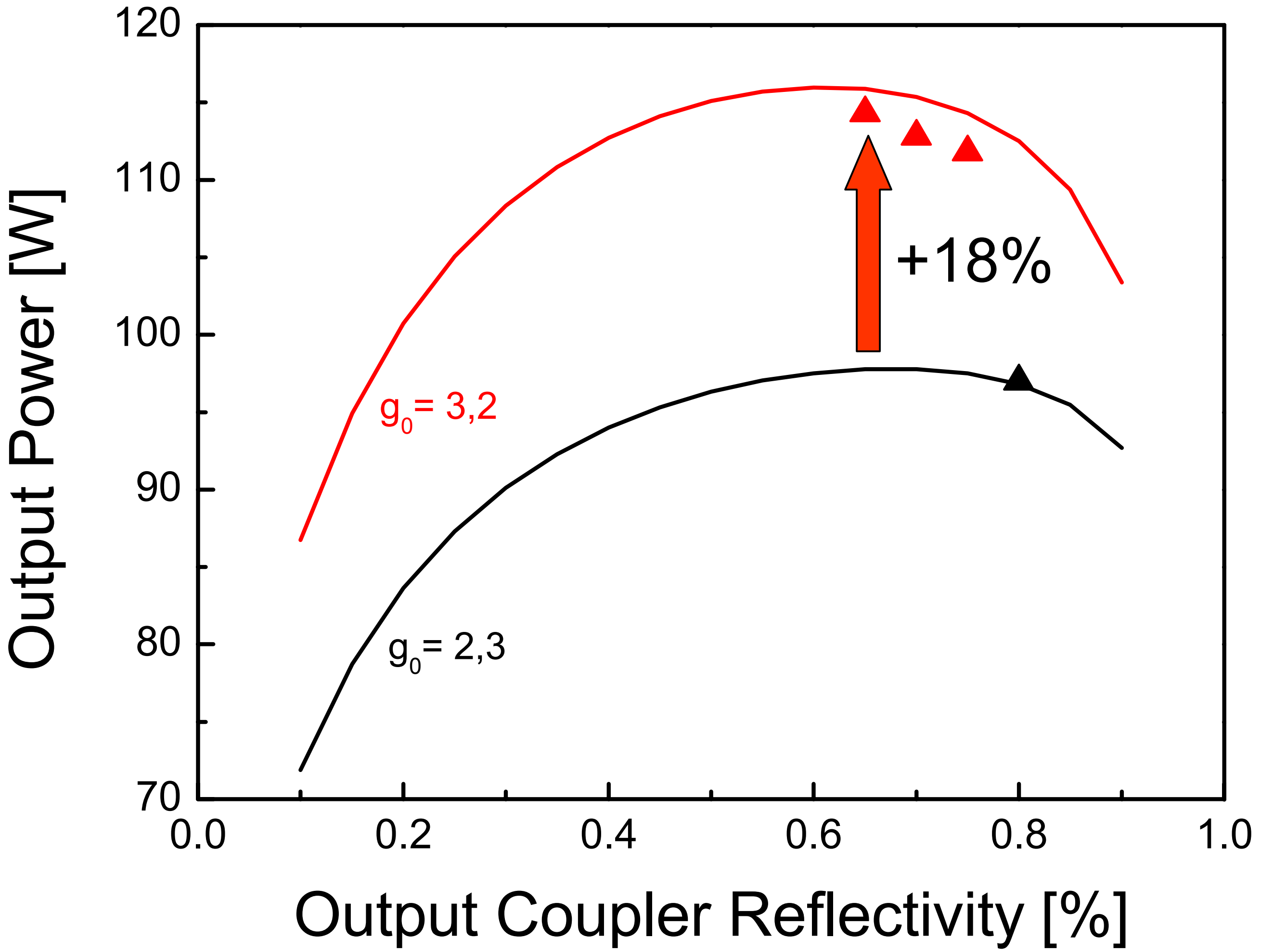


→ W_p=1.9 mm

Higher Gain with Smaller Pump Spot



More Output Power with Config. #2



Comparison

	PoC:	New Design (preliminary)	
Output power:	97 W	114,5 W	↑
Beam quality ($M^2_{x,y}$):	1.25 / 1.25	1,05 / 1.05	↑
Depolarization:	< 0.5 %	< 0.3 %	↗
Efficiency:	25 %	25 %	→
Polarization:	>100:1	>100:1	→

Summary & Outlook

- Improved beam quality: $M^2=1.05$
- Increased output power: ~115 W (i.e. +18%)
- Investigations on smaller pump-spots on the way

Next:

- Further power scaling by additional laser-heads
- Injection locking of high power laser

Thanks to ...

- Frank Seifert (AEI) for electronics support
- Workshop (AEI) for fine mechanics manufacturing
- Mario Auerbach (LZH) for the tunable fiber laser
- Ingo Freitag (Innolight) for the 2W-NPRO
- ... YOU (LSC) for your attention