High-energy, Yb:LuAG and Yb:YAG active mirror amplifiers

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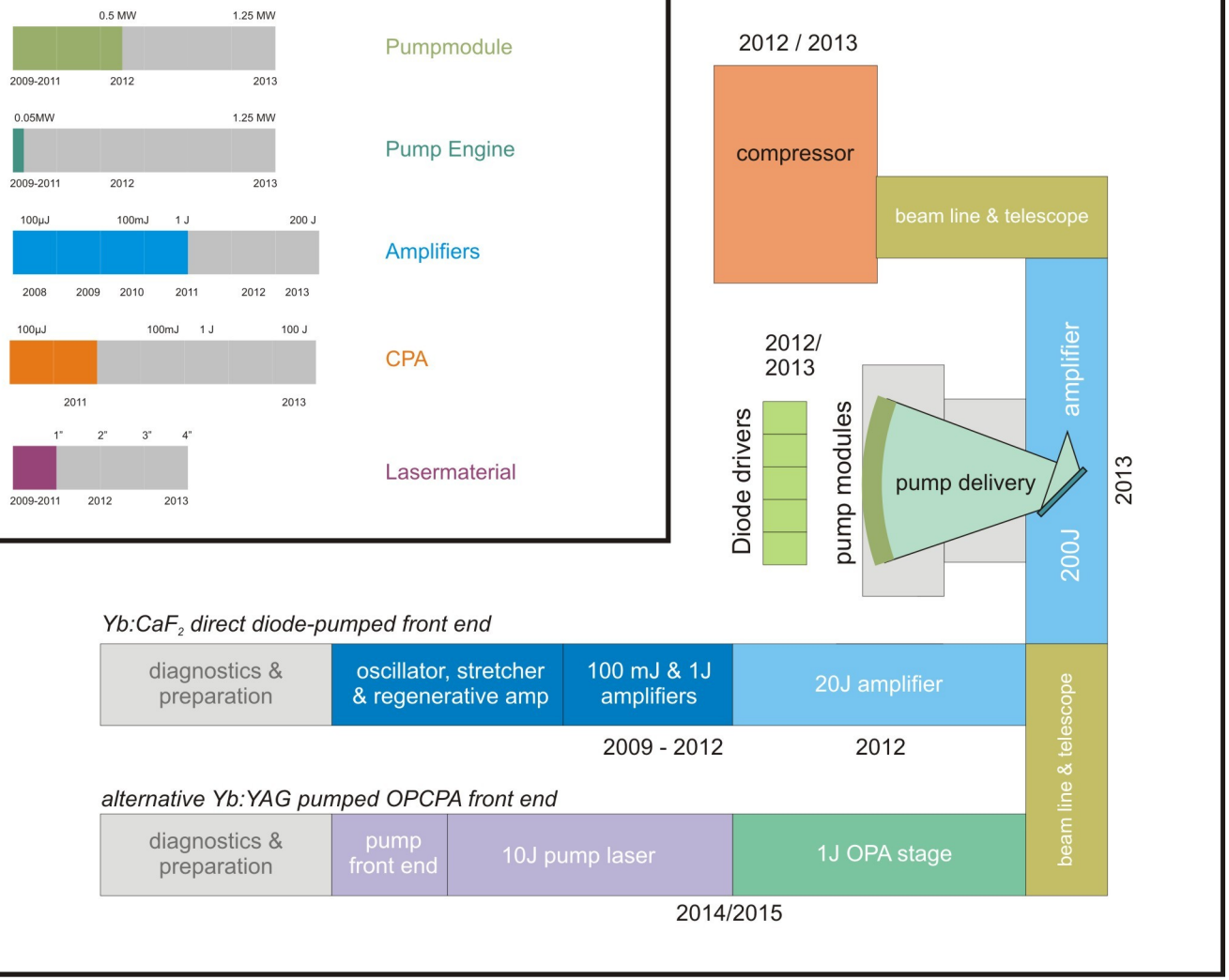
7th international HEC-DPSSL workshop
Lake Tahoe, September 11th – 14th 2012

Outline

- Motivation
- Thermal and spectrosopic properties
- Optical quality
- Amplifier Dynamic
- Near field pattern and wavefront analysis
- Conclusion

Motivation


0.5 MW
1.25 MW
2009-2011
2012
2013
Pumpmodule
0.05MW
1.25 MW
2009-2011
2012
2013
Pump Engine
100µJ
100mJ
1 J
200 J
2008
2009
2010
2011
2012
2013
Amplifiers
100µJ
100mJ
1 J
100 J
2011
2013
CPA
1"
2"
3"
4"
2009-2011
2012
2013
Lasermaterial
2012 / 2013
compressor
beam line & telescope
2012/
2013
Diode drivers
pump modules
pump delivery
amplifier
200J
2013
Yb:CaF2 direct diode-pumped front end
diagnostics & preparation
oscillator, stretcher & regenerative amp
100 mJ & 1J amplifiers
20J amplifier
2009 - 2012
2012
alternative Yb:YAG pumped OPCPA front end
diagnostics & preparation
pump front end
10J pump laser
1J OPA stage
beam line & telescope
2014/2015

Motivation

- Yb:LuAG crystals are commercial available from Crytur

- Also ceramics are possible

- First comparison of Yb:YAG with Yb:LuAG in a kW-Class Thin Disk Laser

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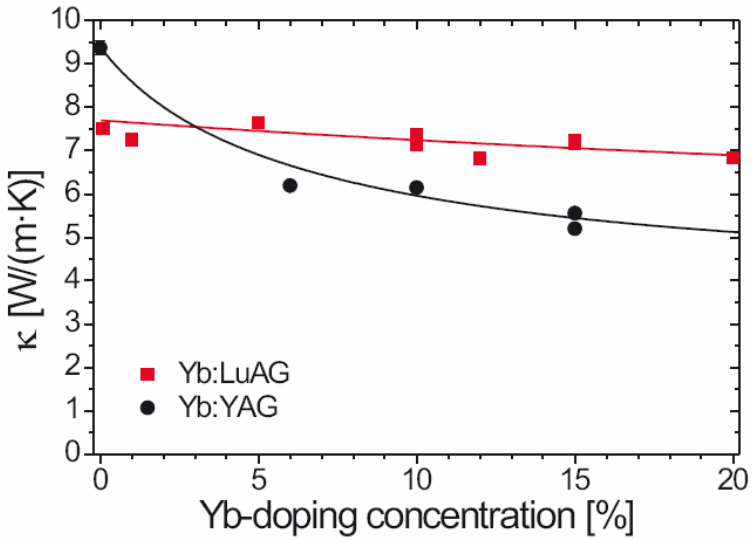
Thermal properties



$$\kappa = \kappa_m \cdot \sqrt{\frac{\chi \cdot T}{\varepsilon}} \cdot \arctan\left(\sqrt{\frac{\varepsilon}{\chi \cdot T}}\right),$$

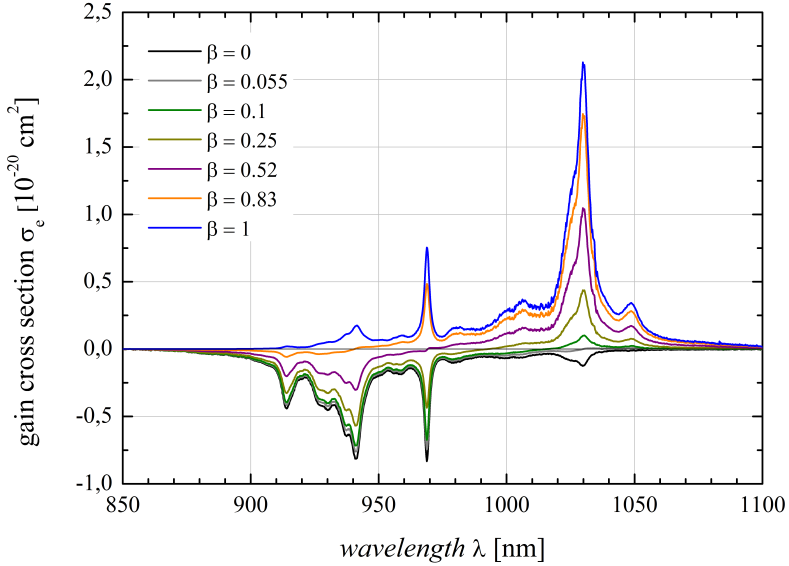
Fig. 2. (Color online) Dependency of thermal conductivity κ of Yb:LuAG and Yb:YAG on the Yb^{3+}-doping concentration. Due to the nearly identical cation densities in both materials (see Tab. 1), identical percentage-values correspond to very similar Yb^{3+}-densities. Symbols represent the measured data while the curves represent the fits according to Eq. (3).

- **Better thermal conductivity for Yb:LuAG at higher doping concentrations**

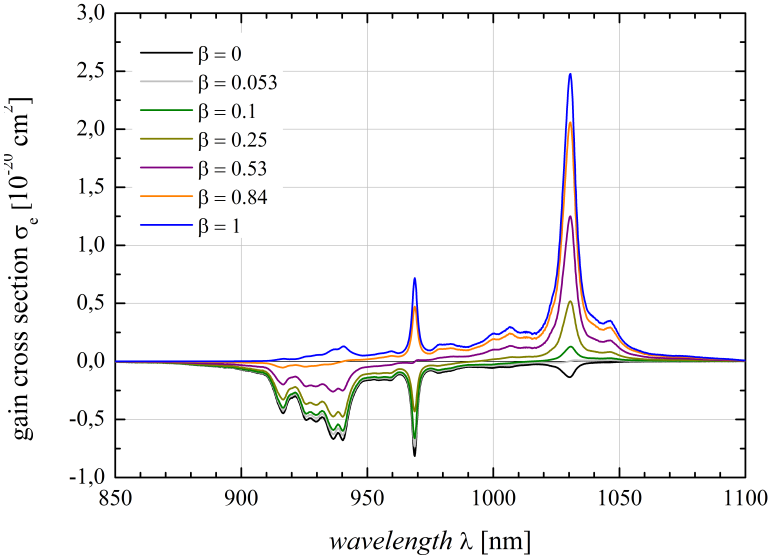
K. Beil, S. Fredrich-Thornton, F. Tellkamp, R. Peters, C. Kränkel, K. Petermann, and G. Huber, “Thermal and laser properties of Yb:LuAG for kW thin disk lasers,” Opt. Express 18, 20712–20722 (2010).

Spectroscopic properties

Yb:YAG

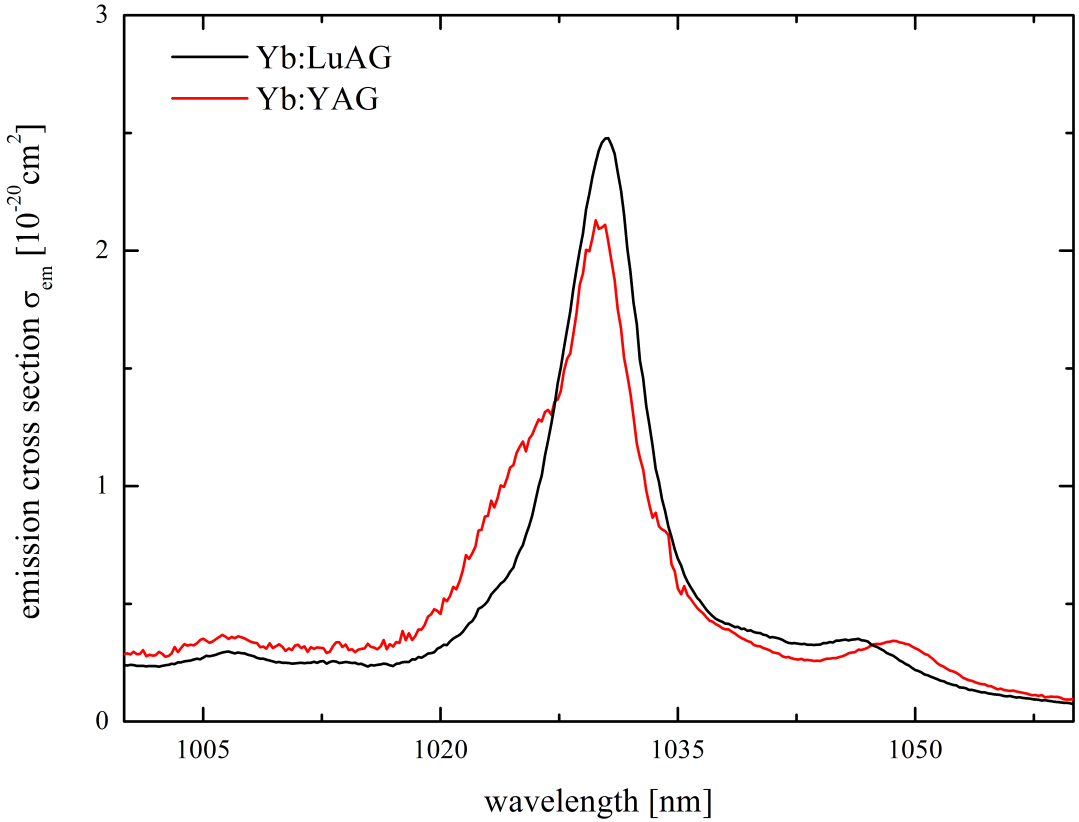


Yb:LuAG



K. Beil, S. Fredrich-Thornton, F. Tellkamp, R. Peters, C. Kränkel, K. Petermann, and G. Huber, “Thermal and laser properties of Yb:LuAG for kW thin disk lasers,” Opt. Express 18, 20712–20722 (2010).

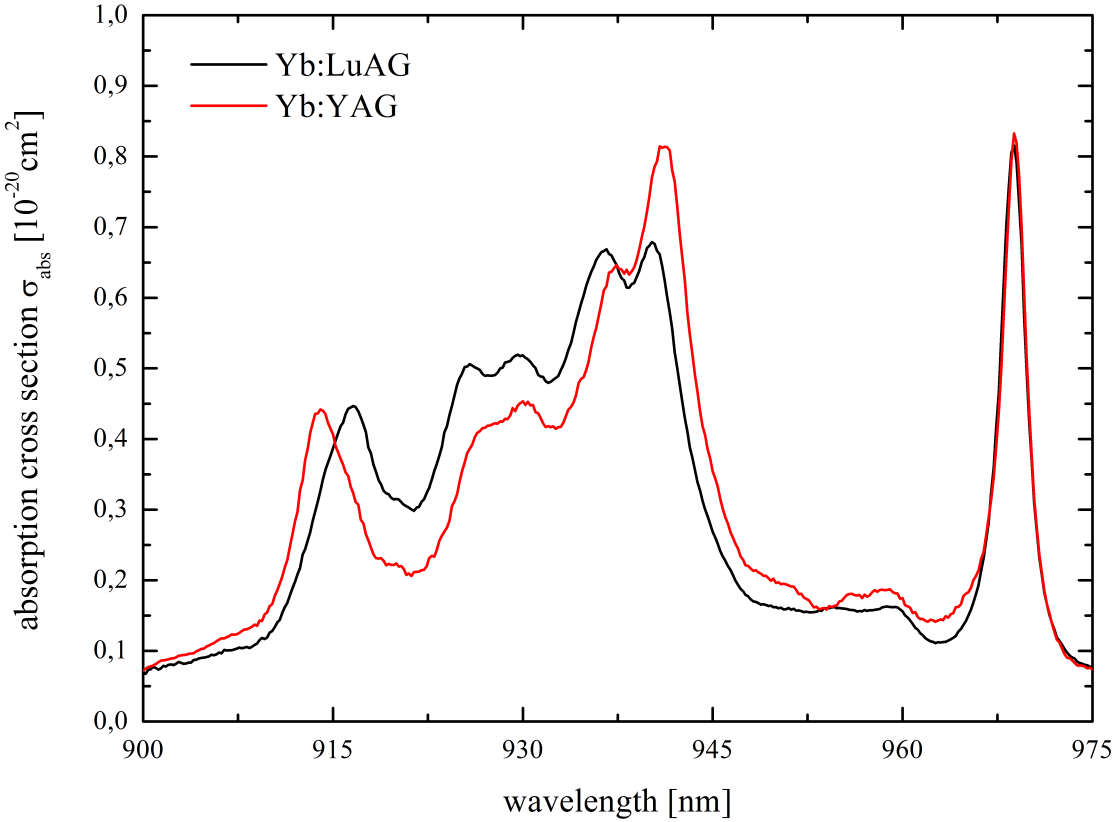
Emission cross section



- **Yb:LuAG has a smaller bandwidth, but a higheremission cross section**
- **The minimum excitation level is 5.3% for Yb:LuAG and 5.5% for Yb:YAG at 300K**

K. Beil, S. Fredrich-Thornton, F. Tellkamp, R. Peters, C. Kr¨ankel, K. Petermann, and G. Huber, “Thermal and laser properties of Yb:LuAG for kW thin disk lasers,” Opt. Express 18, 20712–20722 (2010).

Absorption cross setion



K. Beil, S. Fredrich-Thornton, F. Tellkamp, R. Peters, C. Kr¨ankel, K. Petermann, and G. Huber, “Thermal and laser properties of Yb:LuAG for kW thin disk lasers,” Opt. Express 18, 20712–20722 (2010).

Temperature dependence of σ

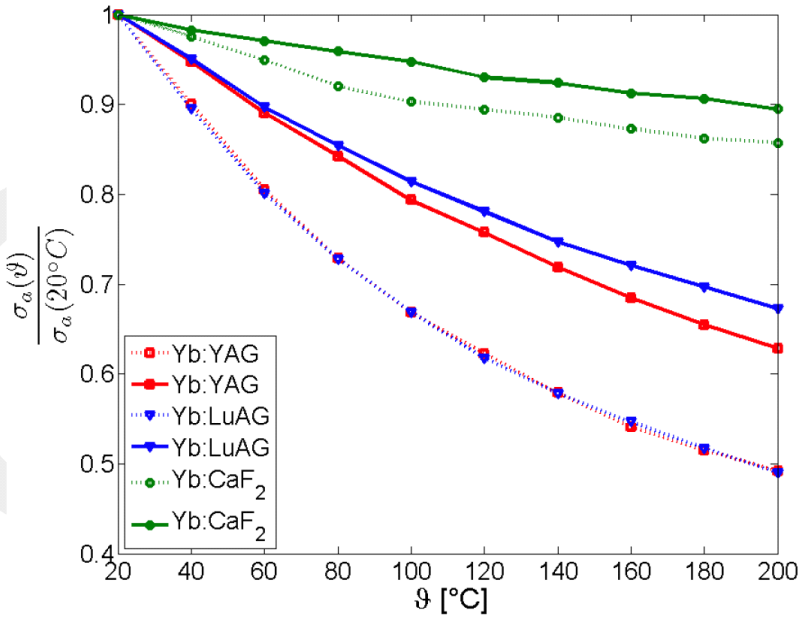


Fig. 6. Relative change in the peak absorption cross sections in different materials for about 940 nm (solid line) and near the zero phonon line (dashed line)

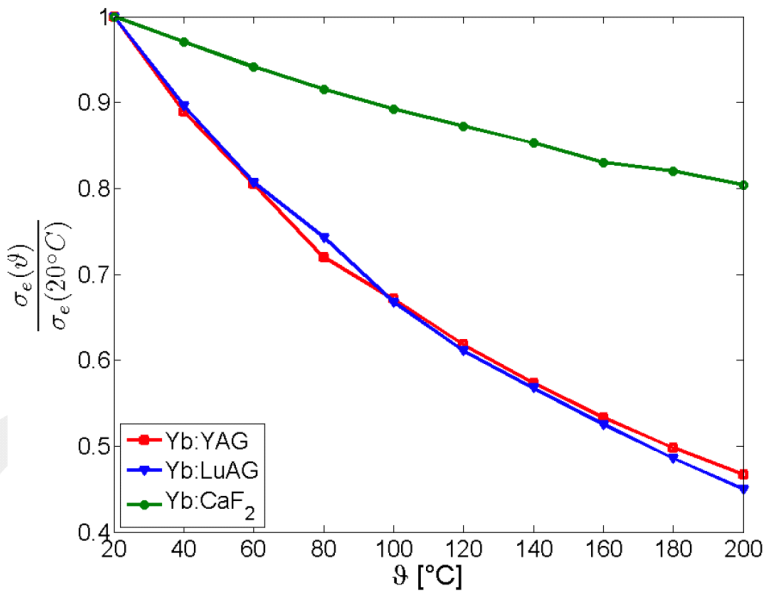
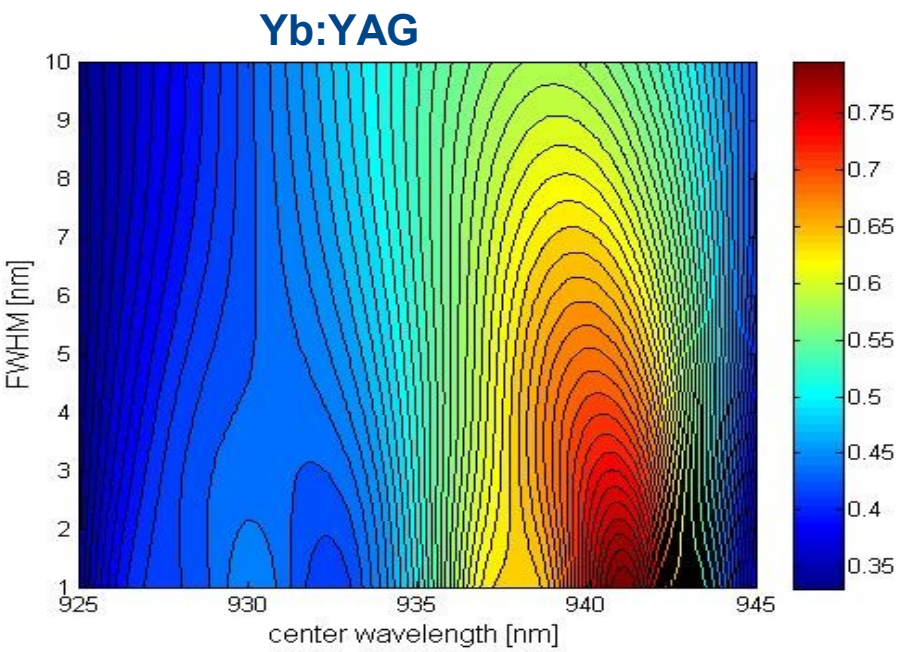


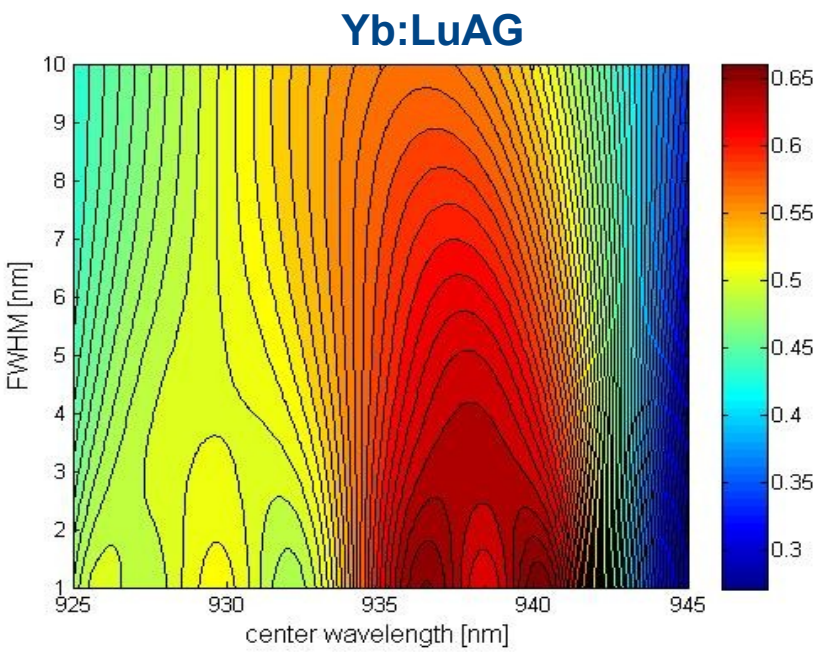
Fig. 10. Relative change in the peak emission cross sections in different materials for 1030 nm

J. Koerner et. al., "Measurement of temperature-dependent absorption and emission spectra of Yb:YAG, Yb:LuAG, and Yb:CaF2 between 20 °C and 200 °C and predictions on their influence on laser performance," JOSA B 29, 2493—2502 (2012).

Spectroscopic properties

Effictive absorption cross section for different laser diode parameters





- Gauss shaped laser diode spectrum
- Less absorption for Yb:LuAG but broader absorption peak

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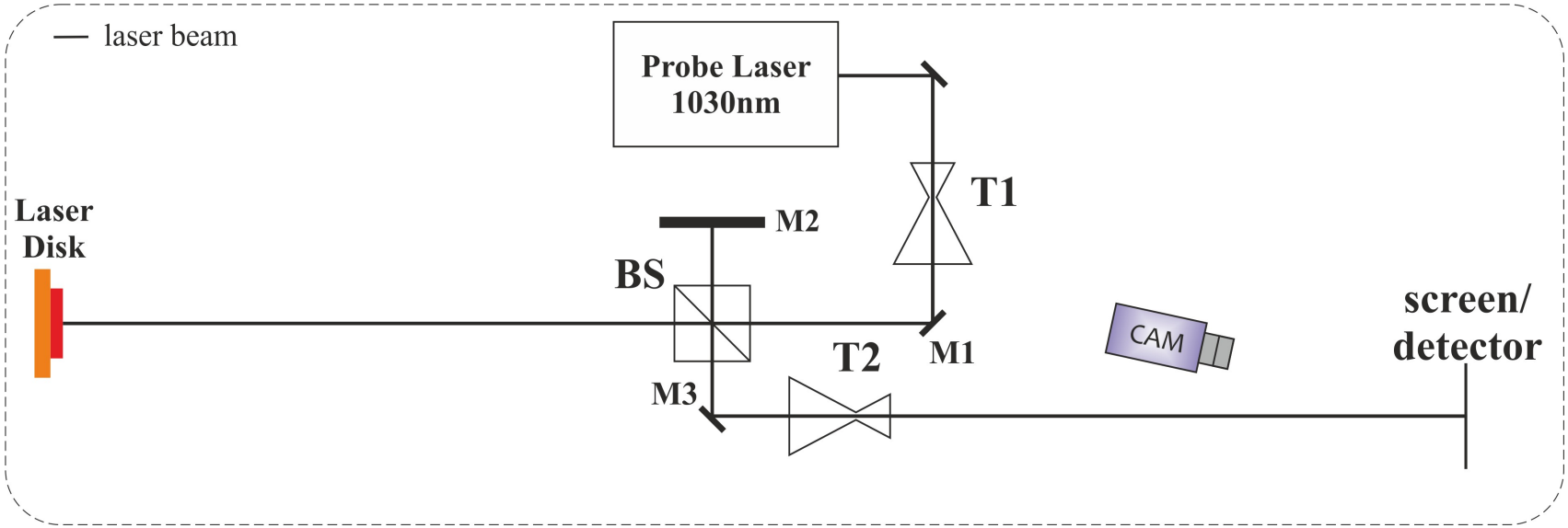
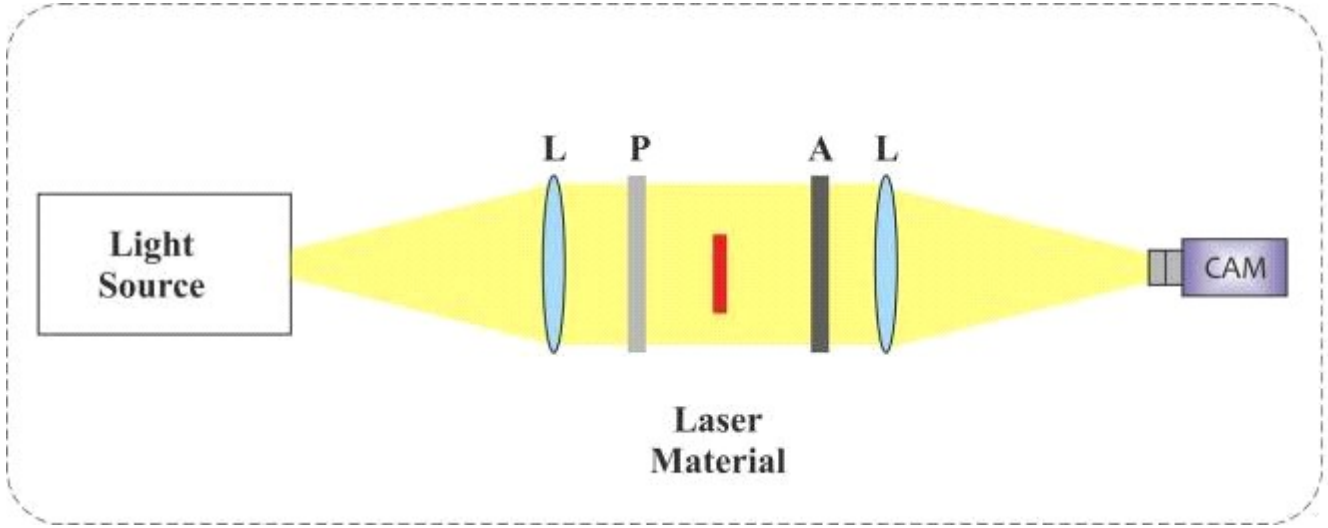
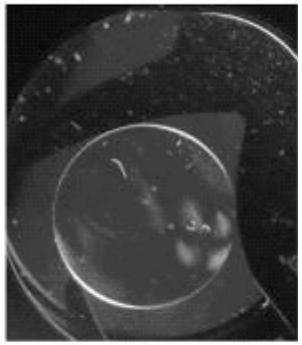
Optical quality measurement setup



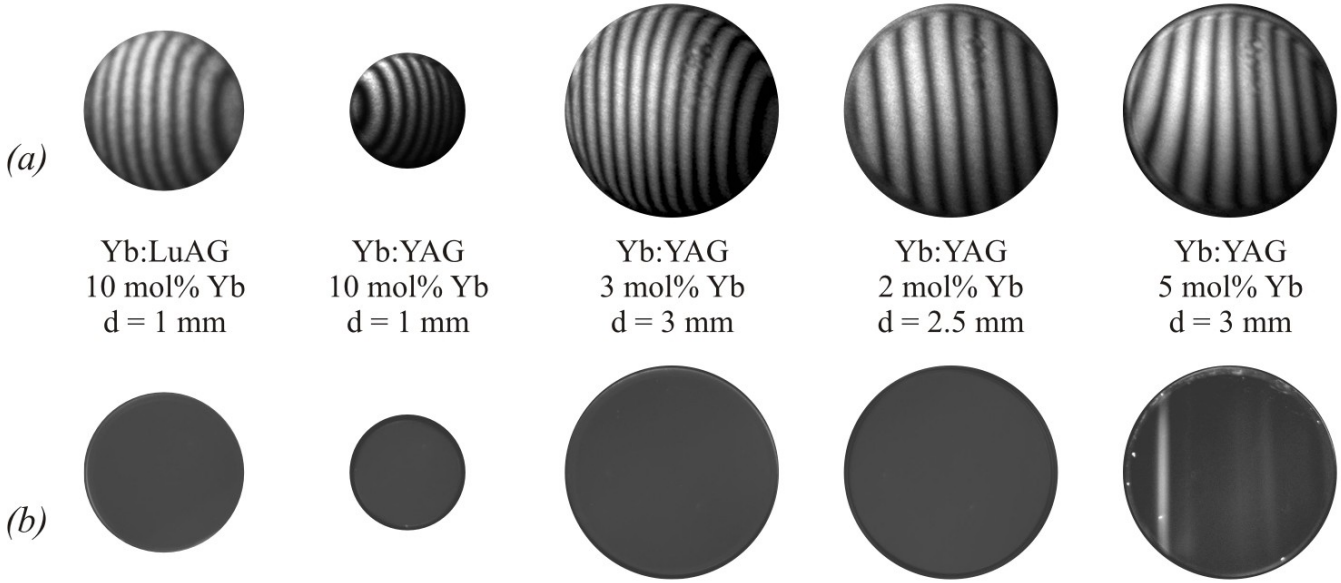




Lasermaterials

	Yb:LuAG	Yb:YAG	Yb:YAG	Yb:YAG	Yb:YAG
diameter	18mm	25mm	25mm	25mm	12.5mm
doping con.	10.2at%	2at%	5at%	3at%	10at%
supplier	Konoshima	Laserayin	Laserayin	FEE	FEE
thickness	1mm	2.5mm	3mm	3mm	1mm

Optical quality



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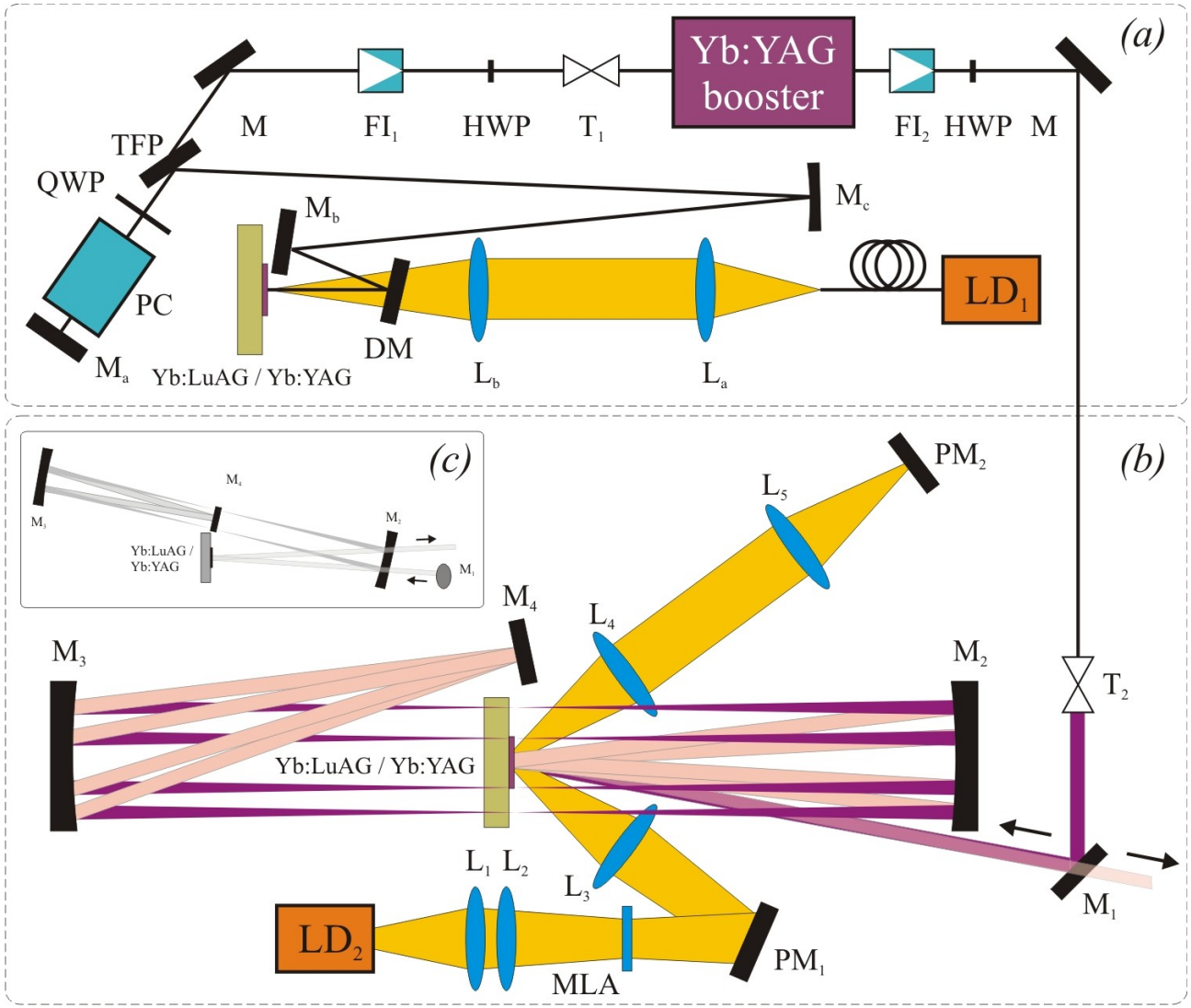
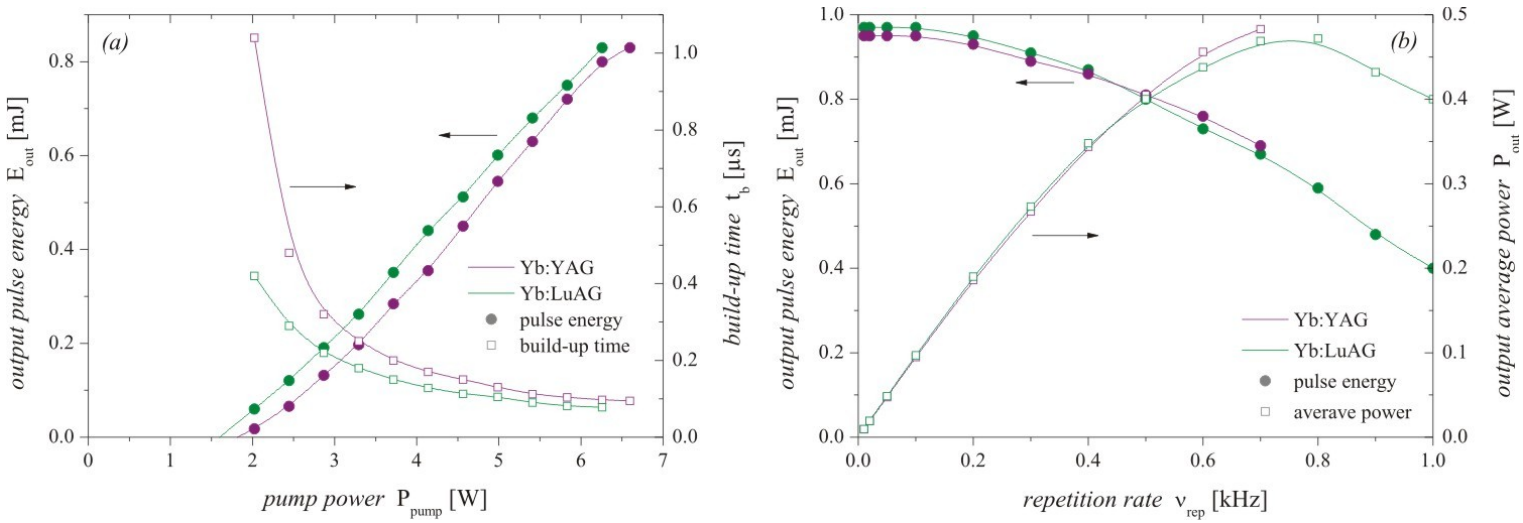
Experimental Setup

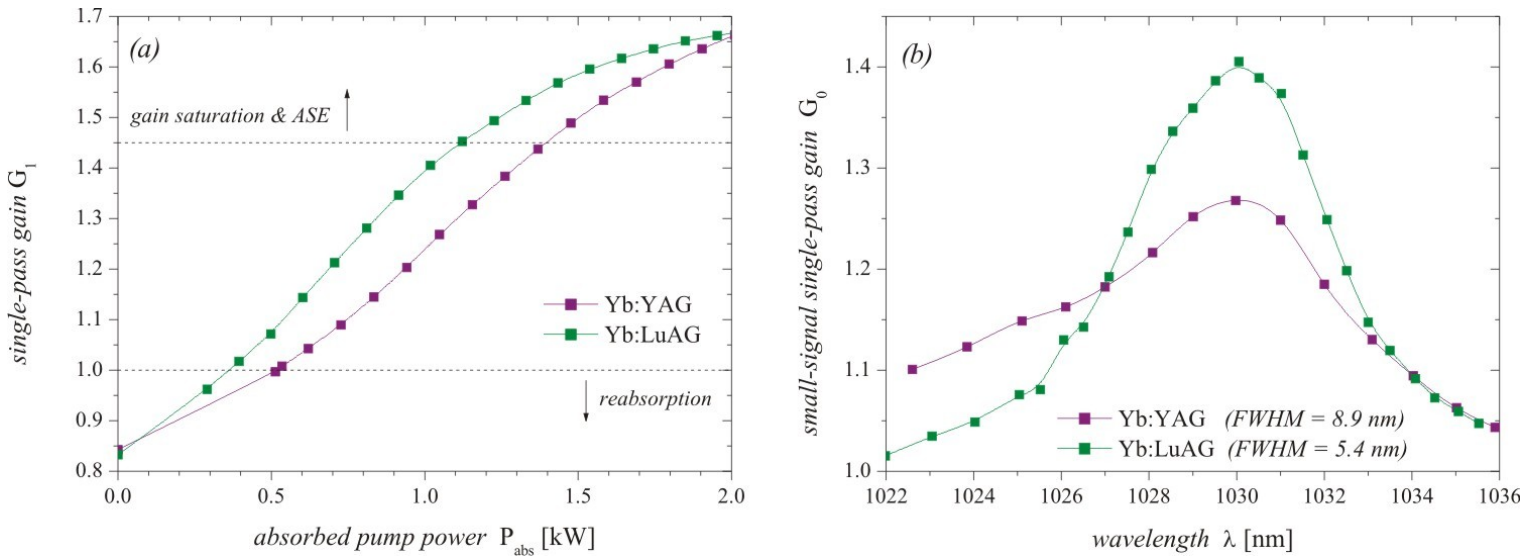


Dynamic of the cavity-dumped ns-oscillator

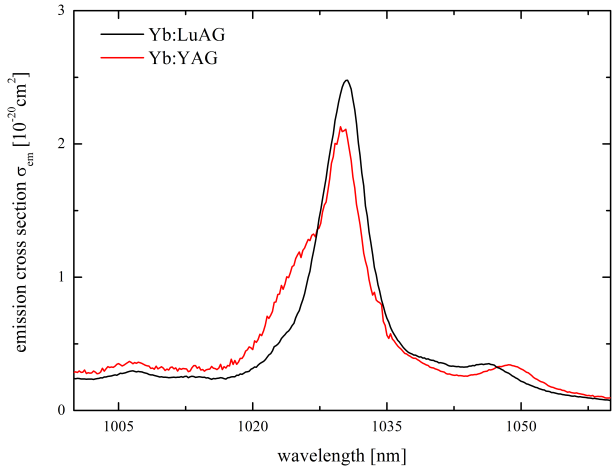


- **Comparison of the 1mm thick Yb:YAG crystal with the Yb:LuAG ceramic**
- **Low threshold in the case Yb:LuAG**
- **Lower biult-up time to saturate the gain for Yb:LuAG due to the higher σ_{em}**

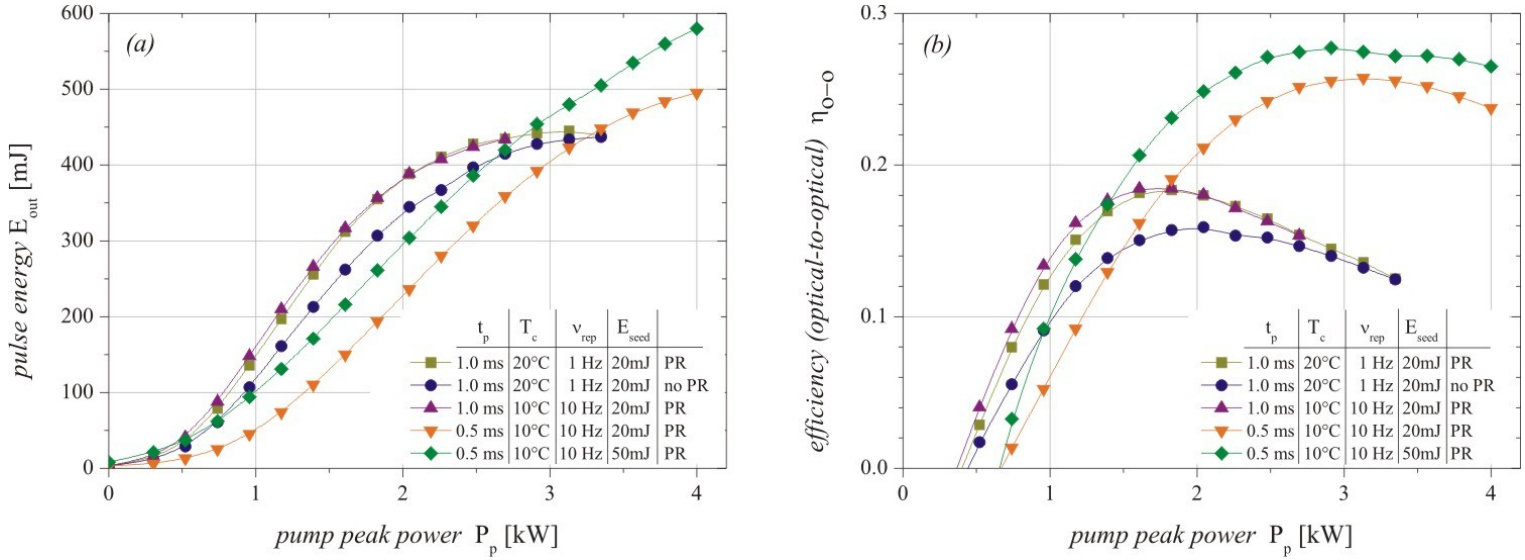
Single-pass gain and tuning range



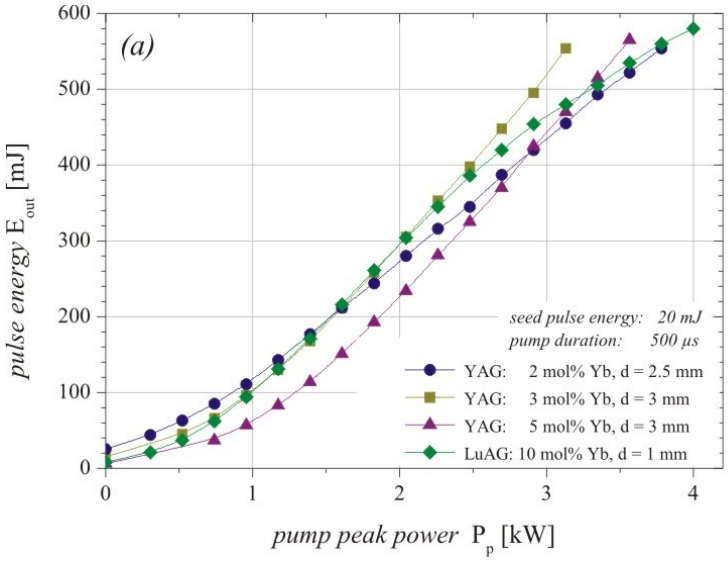
- **Higher small-signal gain for Yb:LuAG, but a smaller tuning range**

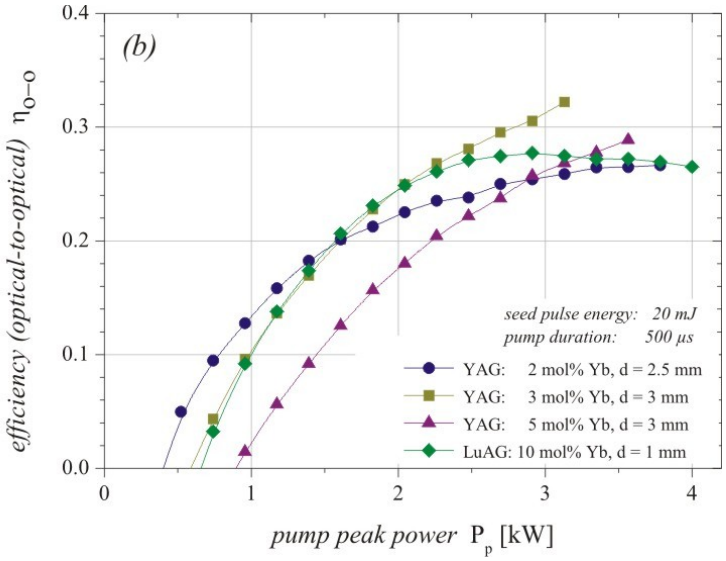


Dynamic of the Yb:LuAG Multi-pass Amplifier



Comparison Yb:YAG vs. Yb:LuAG





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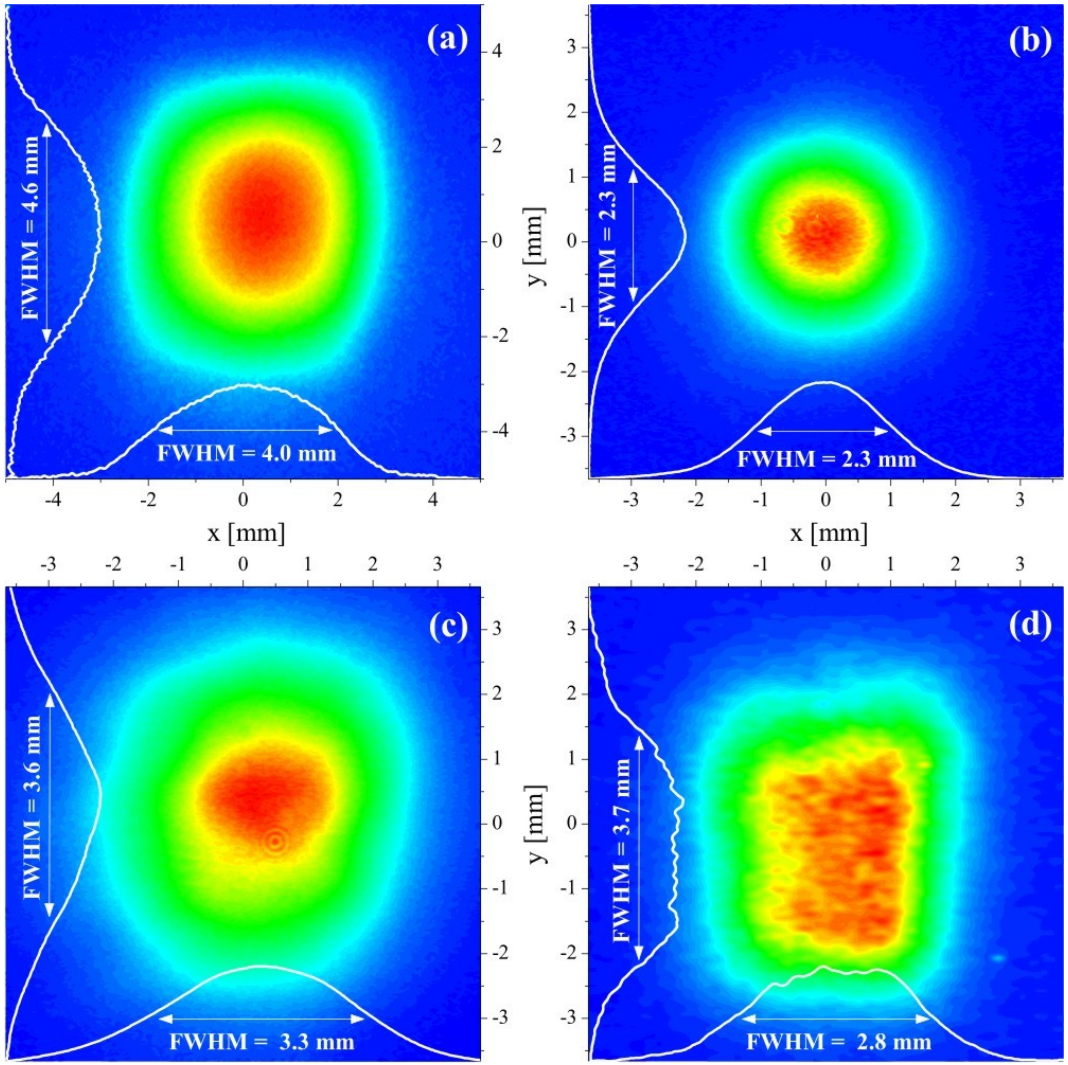
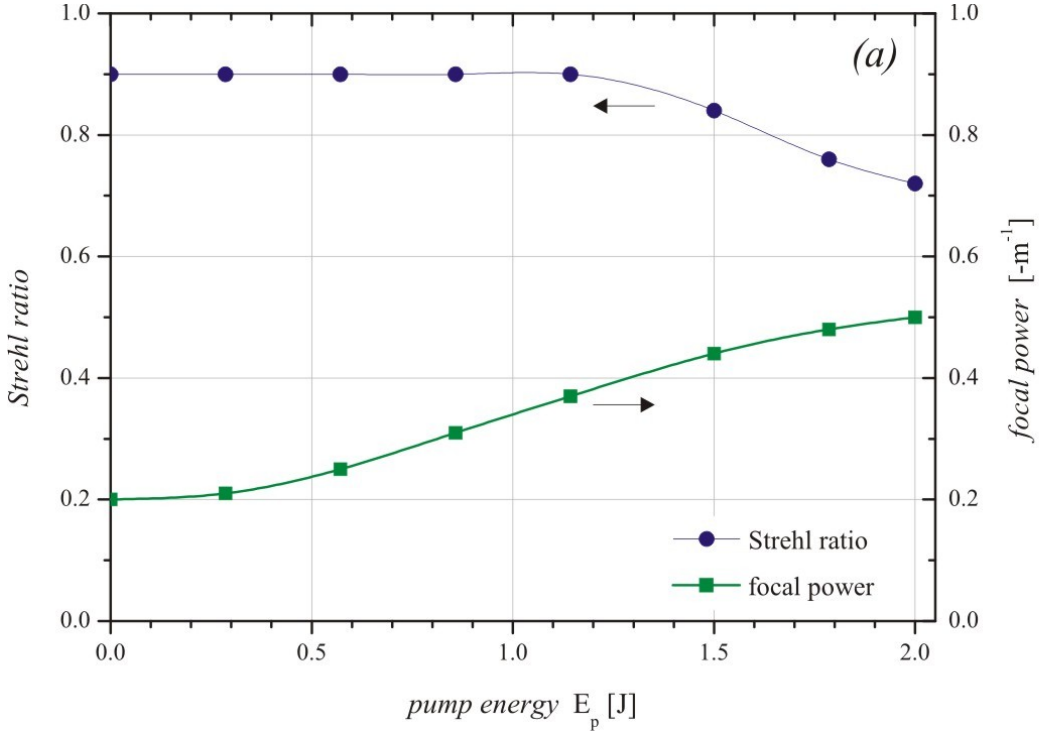
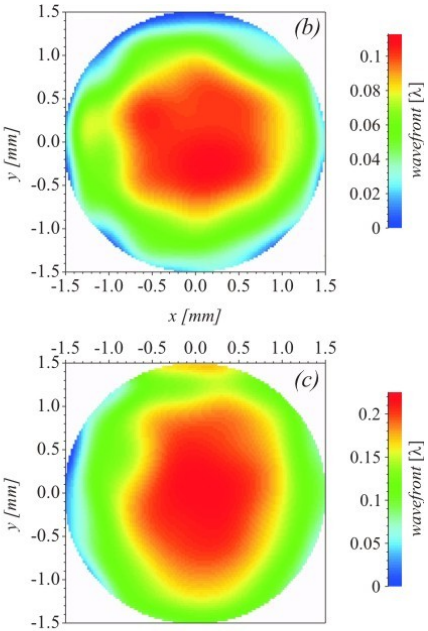
Beam profiles of the final amplifier



Wavefront analysis





Conclusion

- 0.5J @ 30% efficiency at room temperature
- Bending of active mirror under intense pumping vs. thermal lens + spatial gain narrowing
- LuAG vs. Yb:YAG:
  - broad pump spectrum @ 940nm
  - Lower reabsorption losses
  - 5nm instead of 10nm tuning range

High-energy, ceramic-disk Yb:LuAG laser amplifier

M. Siebold, M. Loeser, F. Roeser, M. Seltmann, G. Harzendorf, I. Tsybin, S. Linke, S. Banerjee, P. D. Mason, P. J. Phillips, K. Ertel, J. C. Collier, and U. Schramm »View Author Affiliations

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Thank you