Deliverable 5.3: Thin-disk multipass amplifier with 500W, 1MHz, sub-500fs

Dissemination Level: Public

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<u>**Context**</u>

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Task: 5.2 Assembly & characterization of a Yb:YAG thin-disk

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1 Version History

Version	Summary of Change	Written By	Approver	Date
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1.0				
1.1.				

2 Introduction

This document provides an overview about the Assembly and characterization of the thin-disk multipass amplifier. Here, the goal was to build up a multipass amplifier being able to amplify the pulses of the 50 W laser described in WP 3 to 500 W in a first step. In a second step, the upgraded 200 W laser shall be amplified to 1 kW of output power using the same amplifier. The design of the thin-disk multipass amplifier which was elaborated in such a way that it can be used for both the 500W and the 1000W experimental goals. .

3 Experimental results

3.1 Experimental setup

Fig. 1

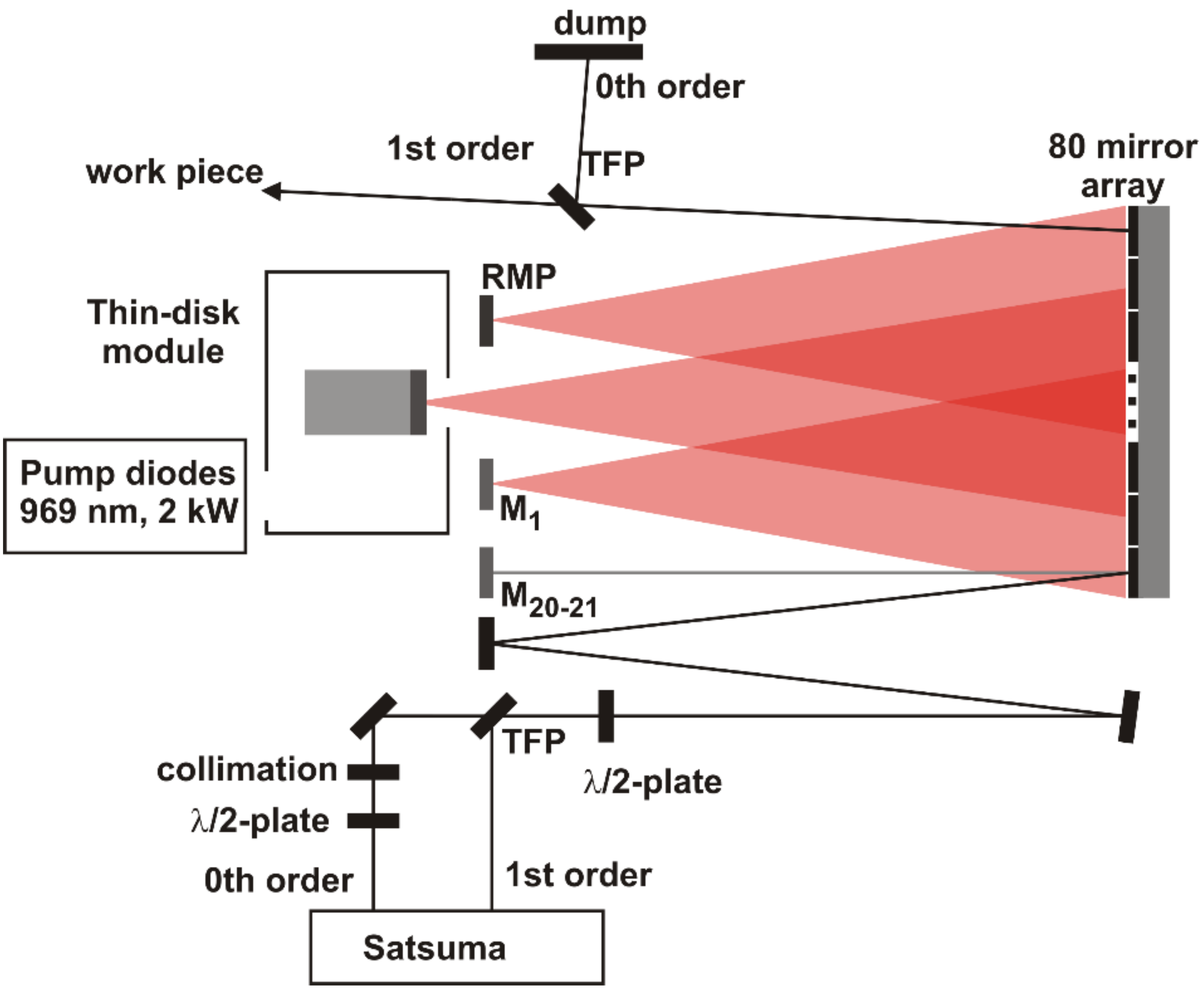
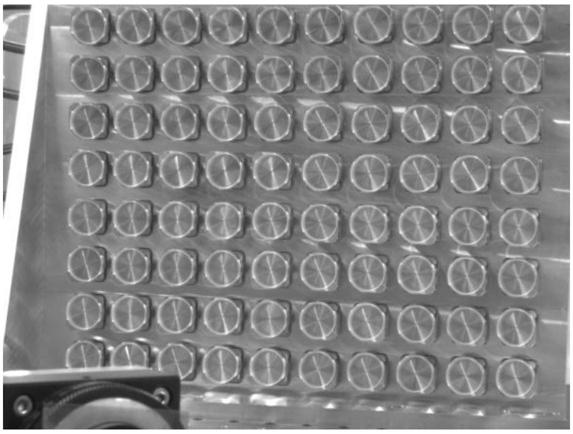


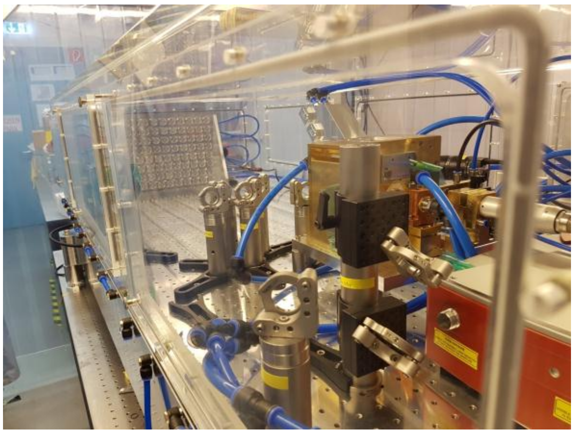
Fig. 1

The experimental Setup consists of the components depicted in Fig. 1. We have used a Yb:YAG disk with a diameter of 17 mm which was glued on a diamond heat sink. The diameter of the pumped area on the disk was approximately 5.2 mm. The crystal was placed in a 24-pass pump module and pumped at a central wavelength of 969 nm. The array used to direct the beam multiple times over the gain medium consists of 80 highly reflective optics coated for an angle of incidence of 0-10°. The complete setup is placed on a water cooled, temperature stabilized, aluminium cast breadboard to improve thermo-mechanical stability of the system.

Parts of the experimental setup are illustrated in fig. 2.



Array.



View from behind pumping module on array.

Fig. 2

3.2 Amplifier performance

The amplifier was seeded with pulses with 330 fs FWHM ($sech^2$ shape assumed) pulse duration and a pulse energy of 39 µJ. The seed was operated at 1280 kHz, delivering an average output power of 50 W. Using a single multipass, corresponding to 40 reflections from the thin-disk, without pulse picking scheme, 605 W of output power were measured, corresponding to a maximum pulse energy of 473 µJ. The output power and optical efficiency (with seed power subtracted) are illustrated in fig. 3. The pulse duration at 600 W output power was measured to be 393 fs FWHM (assuming a $sech^2$ shape), as illustrated in fig. 4. From this, the peak power is calculated to be 1.05 GW. The measured spectra of the incident, unamplified and amplified beams, as well as the pulse duration in dependence of the pump power are depicted in fig. 5 and fig. 6. The far field intensity distribution, as well as the measured caustic are depicted in fig. 7 and fig. 8, indicating a close to diffraction limited beam. A long-term measurement of the output power was performed and is shown in fig. 9, indicating very stable behavior after thermalisation. Long-term measurements of the output power after several breaks (without realignment) are shown in fig. 10, indicating reproducible results within long time break periods.

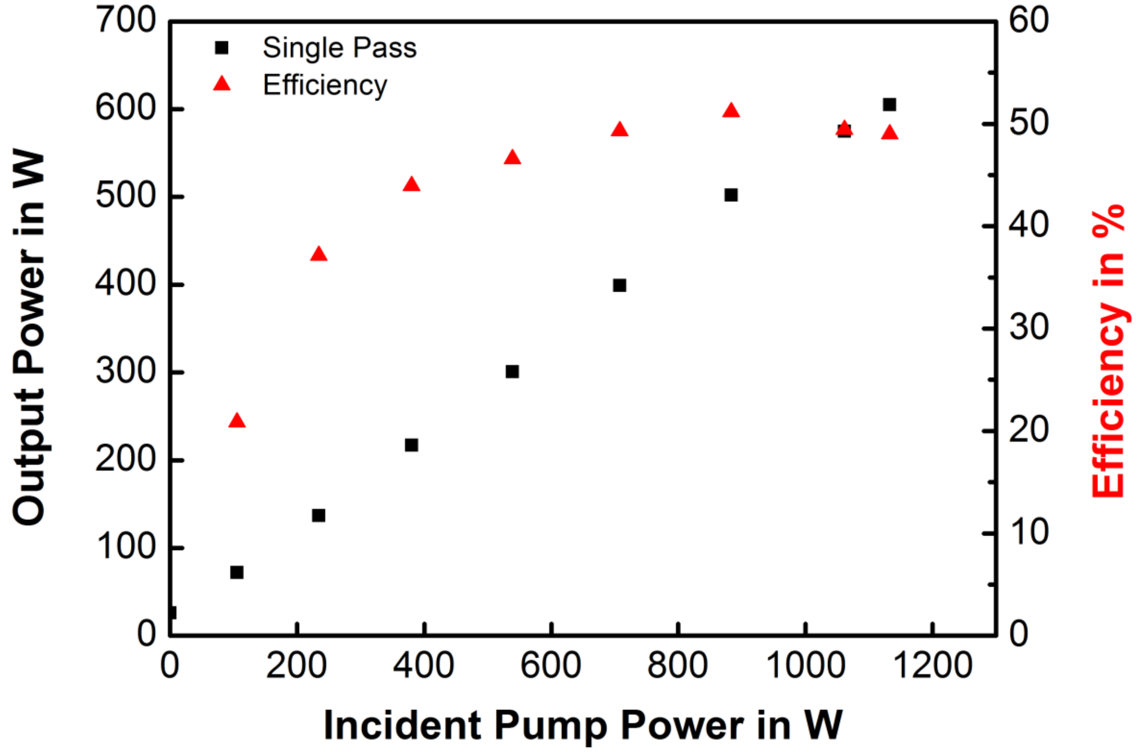


Fig. 3: Output power and optical efficiency using a single multipass amplification scheme.

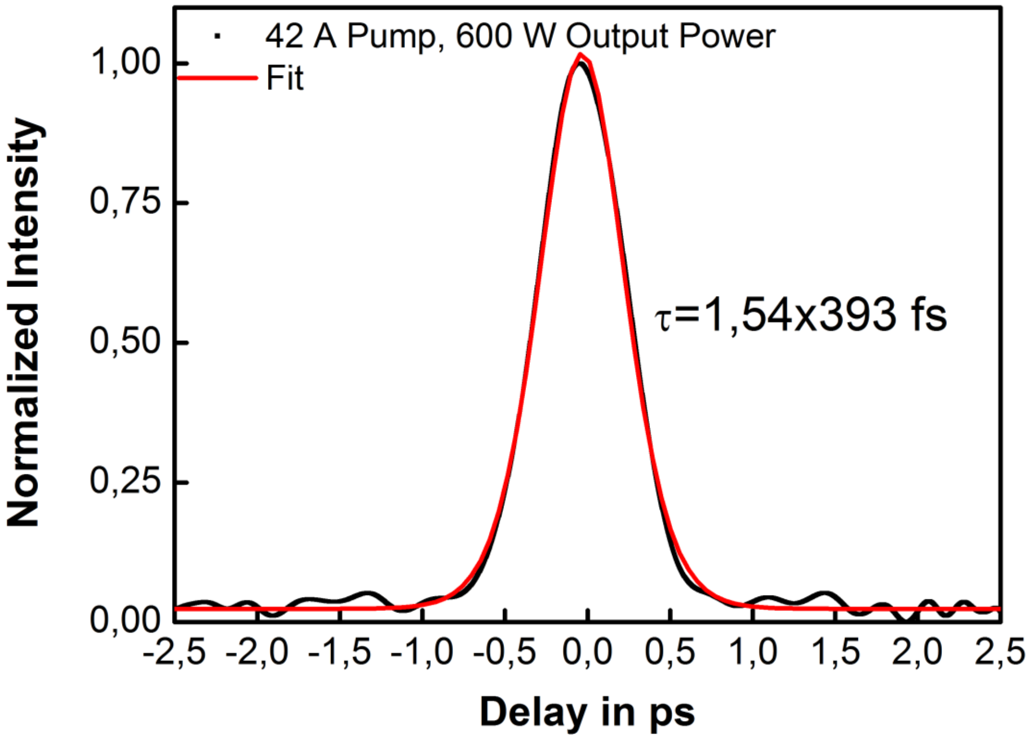


Fig. 4: Autocorrelation of output pulses at 600 W of average power.

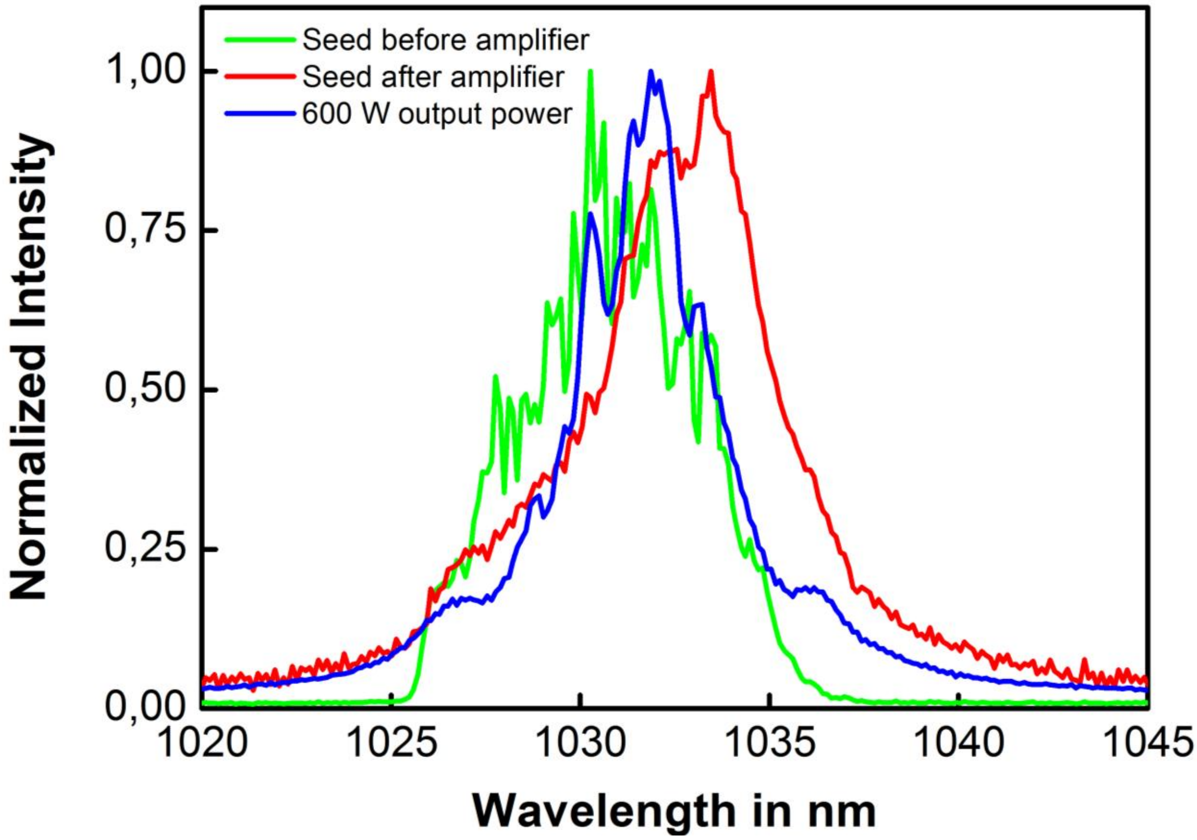


Fig. 5: Spectra of the incident, unamplified and amplified beams.

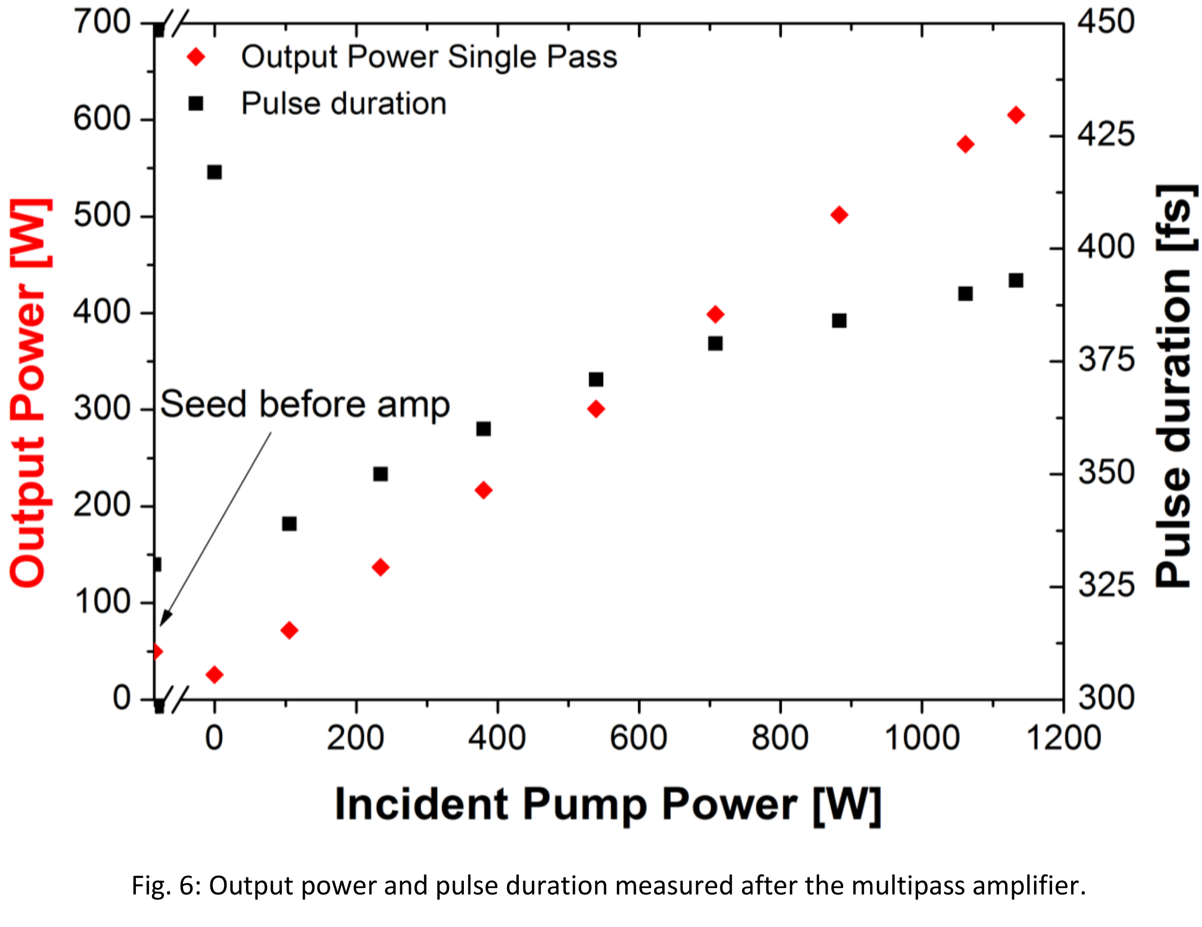


Fig. 6: Output power and pulse duration measured after the multipass amplifier.

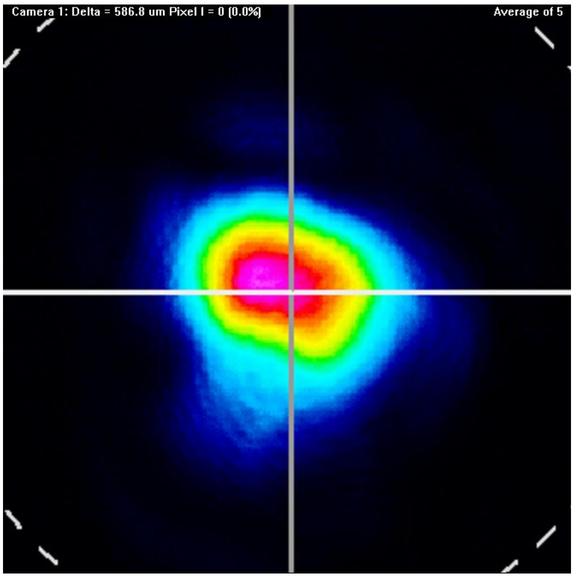


Fig. 7: Farfield intensity distribution of the amplified beam at 600 W output Power. Only slight aberrations are visible.

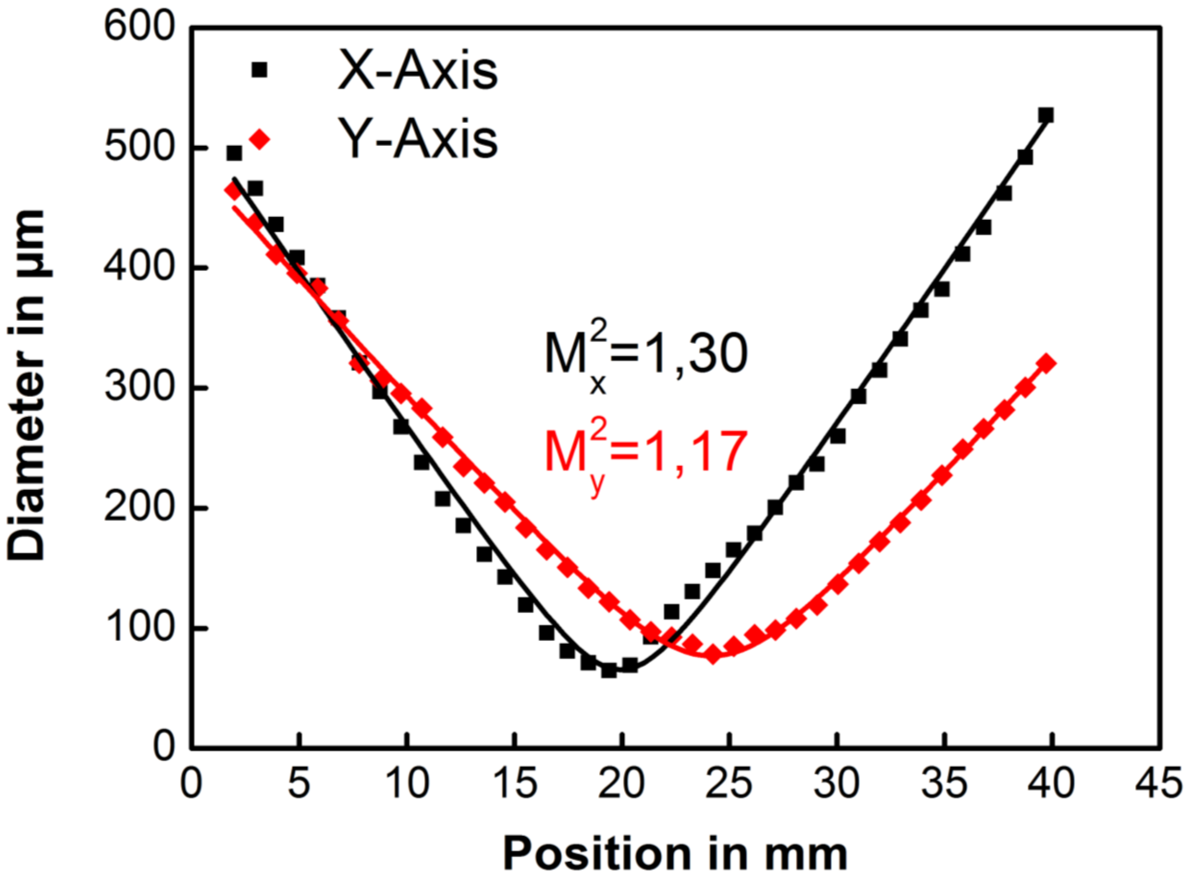


Fig. 8: Caustic of the beam at 600 W output power.

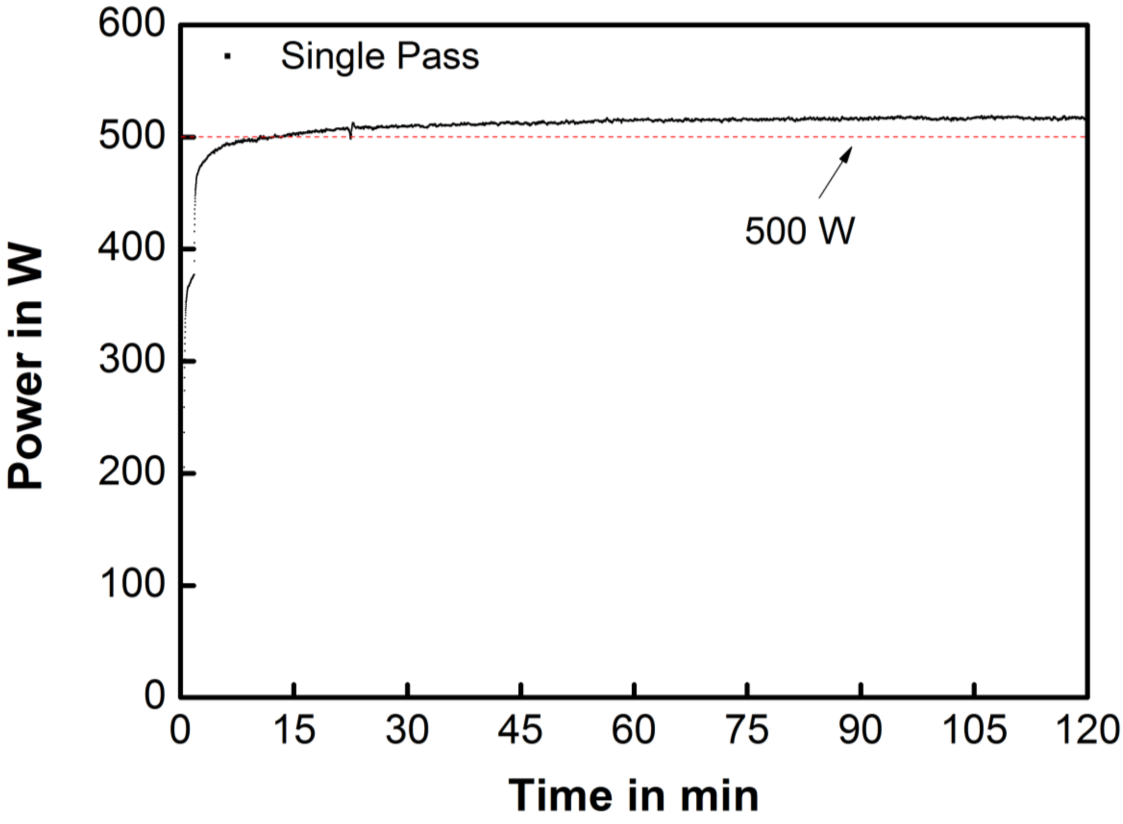


Fig. 9: Long-term measurement of the output power.

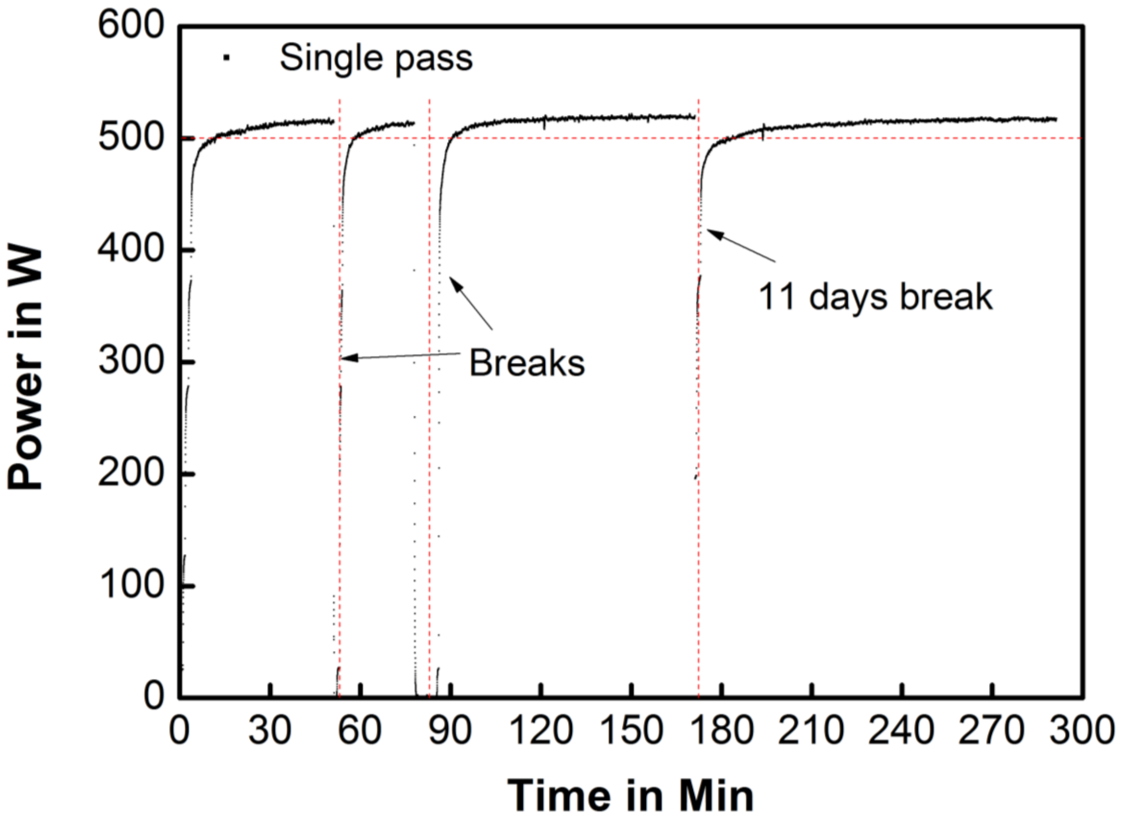


Fig. 10: Long-term measurements of the output power after several breaks.

4 Conclusion and Summary

In summary, an amplifier capable of delivering 600 W of maximum output power with close to diffraction limited beam quality was demonstrated. The generated pulses have a pulse energy of 468 µJ and a pulse duration of sub 400 fs, corresponding to a pulse peak power of 1.05 GW.

References:

[1] A. Antognini et al.,"Thin-Disk Yb:YAG Oscillator-Amplifier Laser, ASE, and Effective Yb:YAG Lifetime", IEEE J. Quant. Electron., 45 (8), 2009

[2] J. Negel et al., "1.1 kW average output power from a thin-disk multipass amplifier for ultrashort laser pulses," Opt. Lett. **38**, 5442-5445 (2013)

[3] J. Negel et al., "Ultrafast thin-disk multipass laser amplifier delivering 1.4 kW (4.7 mJ, 1030 nm) average power converted to 820 W at 515 nm and 234 W at 343 nm," Opt. Express **23**, 21064-21077 (2015)