A 265W and 782 fs amplified radially polarized beam emitted by a thin-disk multipass amplifier (Post-deadline Oral)

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Abstract: The amplification of a high-power radially polarized beam in a thin-disk multipass amplifier is presented. Up to 265W output power at a pulse duration of 782 fs and a high degree of radial polarization is achieved.

OCIS codes: (140.3580) Lasers, solid-state; (140.3615) Lasers, ytterbium; (140.4050) Mode-locked lasers; (140.3280) Laser Amplifiers; (140.7090) Ultrafast lasers;

1. Introduction

The benefit of beams with radial polarization for many applications has often been reported in the last decades. However, at high outputpower the main interest is material processing [1]. Besides cutting of metal sheets, drilling applications using radial or azimuthal polarization states can benefit from such beams in order to increase the process efficiency when compared to standard (linear or circular) polarization states. Furthermore, ultrafast laser systems have gained a tremendous interest in various micro-processing applications like drilling, surface structuring, etc… In this paper, we present –to the best of our knowledge- the highest average output power of beams with radial polarization at sub-1ps pulse duration. A thin-disk multipass amplifier with similar architecture of the one in [2] s used to achieve up to 265 W of amplified donut LG_{01} beam with radial polarization and at a pulse duration of 782 fs.

2. Design and implementation of the thin-disk multipass amplifier for radially polarized beams

Figure 1 represents schematically the amplifier system presented in this paper and developed by the IFSW of the University of Stuttgart. A mode-locked oscillator (provided by JDSU) combined to multi-stage single-crystal-fiber amplifiers (provided by CNRS and Fibercryst) [3] is used as seed laser for the multipass amplifier. This seed laser delivers a linearly polarized beam with up to 60 W ($M^2 < 1.2$) of power at a pulse duration of 727 fs and a repetition rate of 20 MHz. In a sub-sequent step, the linear polarization of the seed laser is converted to radial by means of a linear to radial/azimuthal polarization converter (LRAC) composed of 8 half-wave segments [4].

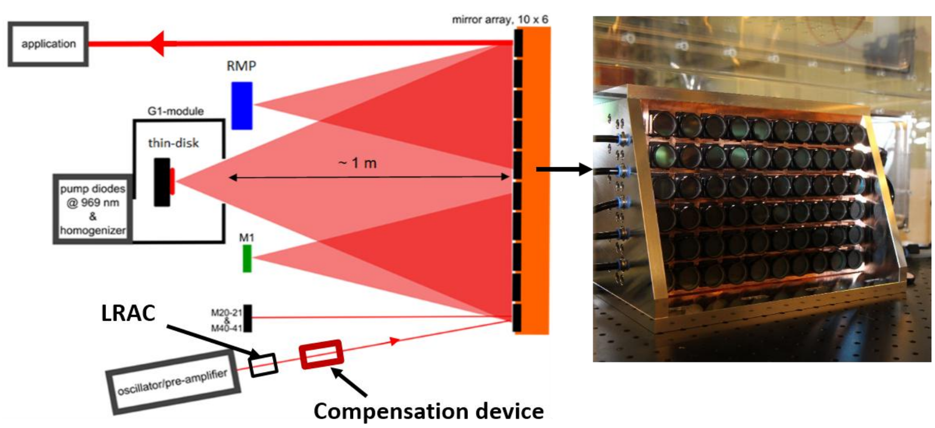

Figure 1: Schematic representation of the thin-disk multipass amplifier (left). A Photograph of the mirror array is shownon the right side.

After the LRAC a radially polarized beam with 50W of output power is obtained. Figure 2 shows the recorded intensity distribution of the converted beam without and with polarization analyzer at different orientation confirming the radial polarization behavior of the transmitted laser beam.

The multipass amplifier is similar to the one reported in [1] but it uses an mirror array of 60 individually adjustable mirrors instead of 40 as previously reported [1], since the amplifier is operated in a single pass configuration due to the cylindrical polarization.. An Yb:YAG thin-disk with a diameter of 15 mm, a radius of curvature of around 20 m, a thickness of approximately 115 µm and 11% doping concentration was mounted on a diamond heat sink at the IFSW and is used as amplifier medium. The disk is pumped at 969 nm wavelength (with stabilized laser diode provided by DILAS) by a multi-pass cavity with 24 passes (standard “G1-module” as commonly provided by IFSW). The pumped spot has a diameter of approximately 5.2 mm. The radially polarized seed beam is collimated with a beam radius of 2.2 mm

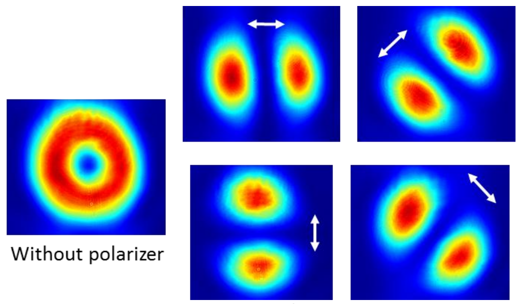

Figure 2: Seed beam (left) converted to radial polarization which is confirmed by rotating a polarizer in front of a camera (right). White arrows indicate the transmission axis of the polarizer.

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Radally polarized laser beams are very sensitive to phase-shifts which can be introduced by the optical components composing the multipass amplifier (especially the 45° folding mirrors). In a multipass amplifier this effect is accumulating due to the high-number of passes through these components. Therefore, the polarization of the propagated beam through the multipass amplifier was first analyzed without amplification process. As expected, a strong degradation of the radial polarization purity can be seen in figure 3-a. Sub-sequent simulation and experimental implementation allowed us to compensate for the accumulated phase-shift by using a pre-compensation device at the entry of the multipass amplifier. By a proper adjustement of this pre-compensation device, one could almost completely recover the high radial polarization quality as shown in the qualitative polarization analysis of figure 3-b.

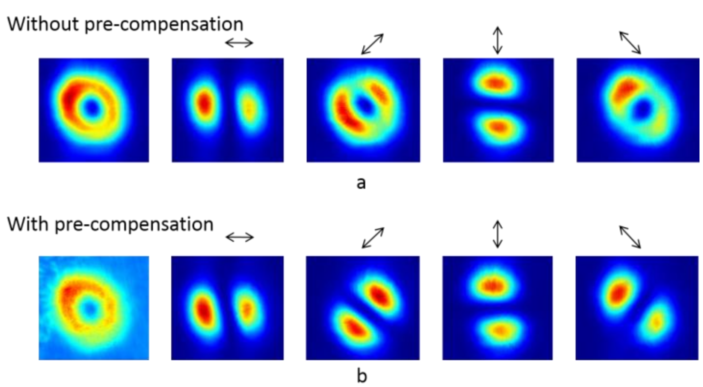

Figure 3: Polarization analysis at the exit of the multipass amplifier (without amplification process) without (a) and with the pre-compensation (b). Balck arrows indicate the transmission axis of the polarizer.

3. Experimental results

Figure 4 shows the extracted output power versus the incident pump power at a seed power of 50 W. As can be seen up to 265 W of average output power (at a pump power of 750 W) could be extracted in a single pass configuration. This corresponds to a gain of 5.3 and a slope efficiency of 38.3%.

The qualitative polarization analysis of the extracted beam at an output power of 250W is shown in figure 4-b. As can be seen, the radial polarization is preserved thanks to the pre-compensation approach.

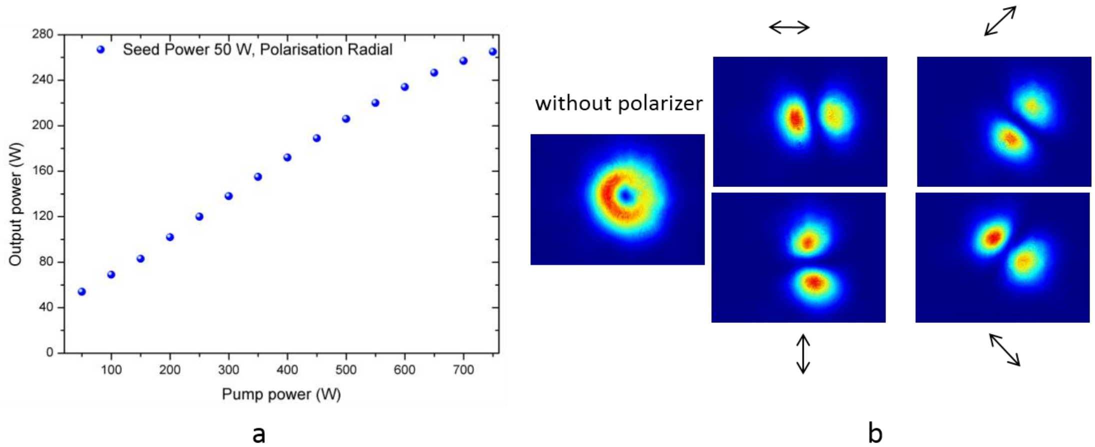

Figure 4: a) Extracted power versus pump power for 30 reflections over the disk with a 50 W radially polarized seed beamand b) polarization analysis of the output beam at 250W of extracted power. Balck arrows indicate the transmission axis of the polarizer.

The measured optical spectra before and after the multipass amplifier are shown in figure 5a) and the pulse duration after the multipass is shown in figure 5 b). Assuming a sech² temporal shape, a pulse duration of 727 fs was measured at the entrance of the multipass amplifier and 782 fs at the output of the multipass amplifier.

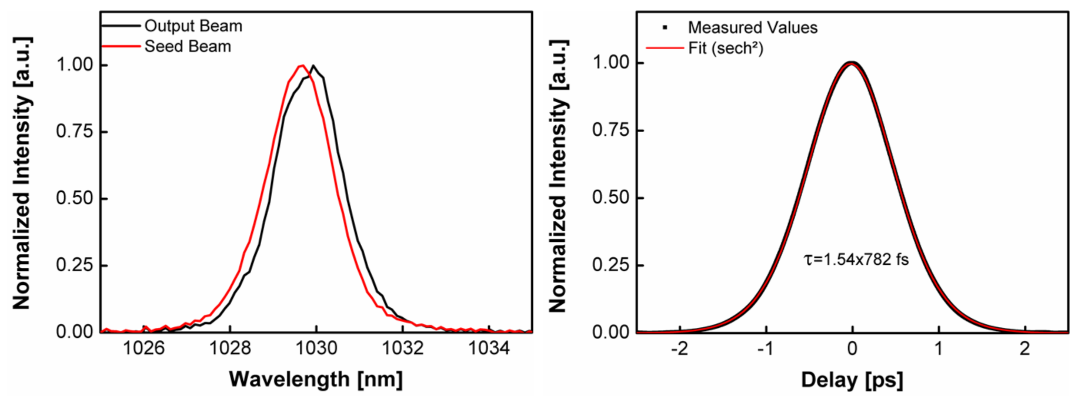

Figure 5: a) Spectra and b) autocorrelator trace of the output beam.

In conclusion, we have demonstrated an efficient amplification of beams with radial polarization in a thin-disk multipass amplifier. Up to 265 W of average output power could be generated at a pulse duration of 782 fs and a repetition rate of 20 MHz. To the best of our knowledge, this is the highest average output power of amplified beam with radial polarization in a sub-ps regime. Furthermore, a method to compensate for phase-shifting, which can occur during propagation through all optical components, has been demonstrated to be satisfactory to maintain a high degree of radial polarization and will be discussed in more details during the talk.

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4. References

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