Ultrafast_RAZIPol
Thin-disk multipass amplifier delivering radially polarized beams with kW-class output power and femtosecond pulse duration

The results presented here have been achieved within the project Ultrafast_RAZIPOL which aims at the development of ultrafast lasers with radial and azimuthal polarizations for high-efficiency micro-machining applications. Applications include drilling of holes (e.g. injection nozzles, spinnerets) with high aspect ratios (>20:1) with a decreased process time at high precision as well as large area structuring (e.g. lab-on-chip). Ultrafast_RAZIPOL will combine fast scanners with a three stage MOPA system to achieve 1 ps pulses at 20 MHz repetition rate and 500 W of average power. This system will be dedicated for the large area structuring applications. A second system which will be coupled to a trepanning stage for the drilling of high-aspect ratio holes shall deliver 5-6 ps pulses with 1 mJ pulse energy at an average power of 200 W.

In the following, we present the amplification of femtosecond beams with radial polarization in a thin-disk multipass amplifier architecture as described in references [1,2]. Figure 2 shows a photo of the array of 60 mirrors used for the thin-disk multipass amplifier. The Single Crystal fiber amplifier (SCF) delivers a linearly polarized beam with an output power of up to 60 W (M^2 < 1.25) at a pulse duration of 727 fs and a repetition rate of 20.5 MHz. In a subsequent 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. After the LRAC, a radially polarized beam with an output power of 50 W is obtained. Figure 3 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 array of 60 individually adjustable mirrors instead of 40, since the amplifier is operated in a single pass configuration due to the radial polarization. An Yb:YAG thin-disk...
Fig. 4: a) Extracted power versus pump power for 30 reflections over the disk with a 50 W radially polarized seed beam and b) polarization analysis of the output beam at 250 W of extracted power. White arrows indicate the transmission axis of the polarizer.

Fig. 6: Polarization analysis of the output beam at 580 W of extracted power. White arrows indicate the transmission axis of the polarizer.

The measured pulse duration after the multipass as well as the measured optical spectra before and after the multipass amplifier are shown in figure 5 a) and b), respectively. 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.

In a further optimization step of the SCF and the thin-disk multipass amplifier, we could extract beams with radial polarization with an output power of up to 580 W at an optical efficiency of 50.7%. Figure 6 shows the recorded intensity distribution of the amplified beam at 580 W, without and with polarization analyzer at different orientation confirming the radial polarization behavior of the transmitted laser beam.

In conclusion, we have demonstrated an efficient amplification of beams with radial polarization in a thin-disk multipass amplifier. Laser pulses at femtosecond pulse duration with an average power of 580 W and an optical efficiency of 50.7% could be generated.

References:

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