Dissertation title:

Analysis of Ytterbium-doped materials for ultra-short pulsed thin-disk lasers

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Ultrafast laser sources with pico- and femtosecond pulse duration open new prospects for applications in industry and medicine. In material processing ultra-short pulse durations are used for high-precision material ablation of different materials, for example processing carbon-fibre reinforced plastics (CFRP) of high quality. In medicine high intensities and short pulse durations are used for ablation and for systematic influencing of tissues by irradiation, respectively. All these applications rely on reliable, compact, innovative, powerful, and efficient ultrafast laser sources.

This work focuses on the generation of femtosecond pulses in passively mode-locked thin-disk lasers. The combination of SESAM and thin-disk laser allows for a compact and reliable ultrafast laser source with high pulse energy and high average output power in a diffraction-limited beam. The key advantage of the thin-disk technology is thereby the high-power capability in combination with good beam quality and high optical-to-optical efficiency due to the nearly one dimensional heat flow. The primary element of a thin-disk laser is thereby the thin active crystal which has the geometry of a disk with a thickness of typically 100 to 300 µm and a diameter of 6 to 20 mm. The efficient heat dissipation is achieved due to the high ratio of cooled surface to pumped volume. Due to the combination of large pump spot and short optical length inside the laser crystal, the limiting non-linear effects occur at several orders of magnitude higher pulse energies. Therefore high pulse energies can be achieved without the need for temporal stretching.

The aim of this work is the investigation of the suitability of various ytterbium-doped laser crystals for high-power femtosecond thin-disk laser systems. Several laser crystals have therefore been selected and tested due to their beneficial properties - such as thermal conductivity and the broad emission bandwidth - for high average output power and short pulse durations: Yb:Sc_2SiO_5, Yb:$CaGdAlO_4$, Yb:CaF_2, Yb:Lu_2O_3, Yb:$YAl_3(BO_3)_4$, and epitaxially grown Yb:$KY(WO_4)_2$ or Yb:$KLu(WO_4)_2$. Due to their availability only the first four could be used for experimental studies. The potential of these crystals for high-power thin-disk laser operation could be demonstrated with a maximum CW output power of 280 W for Yb:Sc_2SiO_5, 152 W Yb:$CaGdAlO_4$, 250 W for Yb:CaF_2 and 670 W for Yb:Lu_2O_3. In a Yb:Sc_2SiO_5

passively mode-locked thin-disk laser an average output power of 27.8 W with 298 fs of pulse duration was demonstrated. For $Yb:CaGdAlO_4$ pulse durations of 300 fs with an average output power of 28 W and shorter pulses with 197 fs with 20 W could be achieved. These pulses were nearly transform limited (TBP < 0.315). The beam propagation factor was measured to be $M^2 < 1.1$.