Diode-pumped amplification of 7-picosecond-pulses with repetition-rates up to 100 kHz and 22 W average output power

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Diode end-pumped solid-state lasers are outstanding by their high efficiency and beam quality. Ultra-short-pulse high peak-power lasers are desired for material processing and frequency conversion for example. Here a diode-pumped Nd:YVO₄-laser amplifier system is described. It consists of an electro-optically switched regenerative amplifier and three subsequent 2-pass amplifiers (booster)[1]. Laser pulses with a length of 10 ps at a center wavelength of 1064.4 nm and 0.55 nm bandwidth are emitted. A maximum output power of 22 W is achieved with repetition rates up to 100 kHz. At a repetition rate of 30 kHz the maximum pulse energy of 660 µJ is reached.

In the regenerative amplifier we use a thin slab 0.78 % doped Nd:YVO₄ segmented crystal manufactured by FEE from Idar-Oberstein (Germany). The crystal is 8 mm long, 1 mm high and 4 mm broad. The crystal is pumped co-linearly by a laser-diode-bar at 808 nm with a power of 18 W. A simple but efficient pumping scheme was implemented consisting of a fast axis collimation lens and a spherical lens (f=17.5 mm). The pump beam profile is kept elliptical with an aspect ratio of 1:50. To match the pumping beam profile to the transverse mode of the regenerative amplifier a cylindrical lens was placed into the cavity. The pump design was developed by JENOPTIK [2]. In order to achieve TEM₀₀-mode operation a plane-plane cavity for the regenerative amplifier with a length of 1.16 m was designed. For quality-switching a BBO-Pockels cell with an aperture of 3.6 mm and a quarter-wave plate was inserted in the cavity. A thin-film polarizer is placed at an angle of 66° in the laser cavity in order to couple the pulses into and out of the cavity. As seed-source a mode-locked Nd:YVO₄ laser (4 W, 7 ps, M²<1.03) is used. In connection with a RTP-Pockels-cell and a Glan-Thompson polarizer as a pulse picker it allocates 7 ps-pulses with a pulse energy of 49 nJ. The seed-laser with a repetition rate of 82 MHz is set as master clock for the electronic trigger pulse generation. The input and the output beams are separated with a Faraday-rotator, a half-wave plate and a second Glan-Thompson. The same pumping geometry as in the regenerative amplifier was used for the booster amplifiers. In difference to the regenerative amplifier the crystals are non-segmented and aspherical lenses (f=12.5 mm) are used to focus the pumping beam. The crystals are passed by the pulses two times. For maximum power extraction this is sufficient because the saturation intensity of 1.1*10⁷ W/cm² is reached. A half-wave plate rotates the polarization of the laser beam before passing the booster.

Using the regenerative amplifier as a cw-laser (without a Pockels-cell) a maximum output power of 10 W at a pumping power of 20 W is available. A slope efficiency of 57 % and a laser threshold of 1.3 W was measured. The beam quality was determined to M²=1.03. The beam diameter of the continuous-wave output is 1.3 mm. Inserting the BBO-Pockels cell into the cavity and switching the quality nanosecond pulses are generated. In this case an output power in excess of 22 W is available from 20 kHz to 100 kHz with a pulse length of 6 ns. At 100 kHz the pulse takes over 400 ns to build up from noise. A maximum pulse energy of 1.1 mJ at 20 kHz was reached. The maximum repetition rate is limited by the Pockels cell driver. In case of amplifying 7 ps-pulses a maximum average output power of 22 W within a repetition rate ranging from 30 kHz to 100 kHz was reached. The length of the amplified pulses increases due to gain narrowing from 7 ps to 10.4 ps. The number of round trips inside the cavity required to saturate the gain increases linearly with the repetition rate as expected. At 50 kHz a pulse needs 14 round trips. Laser operation has shown to be stable over several hours.

We demonstrate the effective use of a Nd:YVO₄-laser amplifier system with a segmented crystal and a BBO-Pockels cell. A pulse energy of 440 µJ at 50 kHz and a good beam quality is well suitable for modern material processing. Due to the bandwidth limit of 548 pm pulses with a minimum length of 3 ps may be amplified.

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References