38-mJ, single frequency, sub-nanosecond, kilohertz, Nd based laser system

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Compact and reliable laser systems providing both high-energy (in the tens of mJ range) and high-peak power (>10MW) pulses at kHz repetition rates with diffraction-limited beams are desirable for a number of applications, e.g. new materials synthesis, remote imaging, chemical sensing, LIDAR [1], materials processing [2], high efficient nonlinear optical conversion and optical parametric processes. However, in the vast variety of the existing single mode kHz ns-laser systems the output pulse energy is not much than few mJ while, on the other hand, the repetition rate of the presently existing high pulse-energy systems does not exceed 100-Hz. Furthermore in the majority of the cases the high energy lasers are not single TEM_{00} mode and single frequency sources. In this work, we report an amplification of pulses from a near-diffraction limited, single frequency, passively Q-switched Nd:YAG laser (240-µJ, 830-ps at 0.5-kHz) up to 38-mJ in one Nd:YVO_4 preamplifier and two diode-pumped boost YAG amplifiers, whilst preserving pulse duration, beam quality and linear polarization.

The signal from the master oscillator is pre-amplified in one pass through an end-pumped, 9-mm long Nd:YVO_4 crystal, with 0.25 at. % doping. The pre-amplifier is longitudinally pumped by a fiber-coupled quasi-cw diode laser array (Jenoptik Laser GmbH, JOLD70-QPXF-1L) driven with 120-µs 80-A current pulses (60W peak power) at 0.5-kHz repetition rate. Further amplification is done by utilizing two boost amplification stages operated in double-pass schemes with transversely diode-pumped Nd:YAG modules. The first stage employs a 0.6 at. % doped Nd:YAG crystal (dia. 3-mm and 50-mm long), pumped by three linear stacks of laser diode bars in a three-fold geometry; each stack composed of five 100-W quasi-cw laser diode bars. The second stage employs a 0.6 at. % doped Nd:YAG crystal (dia. 4-mm and 60-mm long), pumped by the same diode configuration and each stack is composed of five 40-W quasi-cw laser diode bars.

By taking advantage of the low saturation density of Nd:YVO_4 (0.12-J/cm^2), we are able to achieve gain of 4.2 in a single pass through the preamplifier reaching pulse energy of 1 mJ (10% extraction efficiency) at 0.5-kHz repetition rate. With the seed from the preamplifier and a depolarization-compensating scheme the achieved output pulse energy from the first boost amplification stage is 28 mJ, which corresponds to 18% extraction efficiency. In the second boost amplifier, the double-pass scheme was a ring configuration with quartz polarization rotator and thin-film polarizer as an input/output coupler. The produced output energy is 38-mJ with 830-ps pulse duration. The beam quality after the master oscillator is measured to be M_x^2 x M_y^2=1.2 x 1.4 and no significant deterioration is observed until the second amplification stage after which the beam quality is measured to be M_x^2 x M_y^2=1.35 x 1.6.

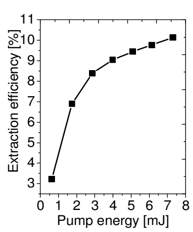

Fig. 1. Saturation of the amplification in the single pass through the Nd:YVO_4 pre-amplifier

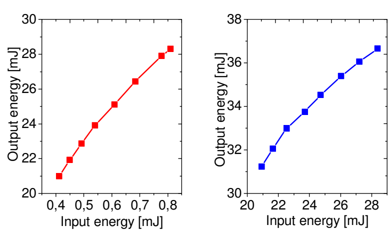

Fig. 2. Output energy vs. input energy for double-pass amplification in the first amplification stage (left panel) and in the second stage (right panel).

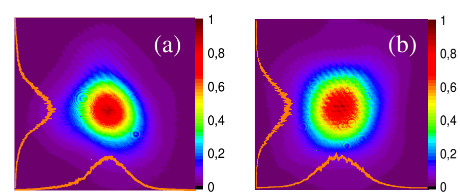

Fig. 3. Laser beam profile after the first boost amplifier (a) and after the second boost amplifier (b).

In conclusion, we have demonstrated a sub-nanosecond single-frequency laser system generating single-mode 830-ps pulses with energy of 38 mJ at 0.5-kHz repetition rate and near diffraction-limited beam quality. The proposed approach preserves pulse duration and beam quality of the oscillator and is easily scalable towards higher pulse energies.

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References

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