28-mJ, single frequency, sub-nanosecond Nd-MOPA system, at kHz repetition rate

B. Oreshkov[1], D. Chuchumishev[1], A. Gaydardzhiev[1], I. Buchvarov[1]

[1] *Department of Physics, Sofia University, 5 James Bourchier Blvd., BG-1164 Sofia, Bulgaria*
b.oreshkov@gmail.com

A number of scientific and industrial applications can benefit from reliable laser system providing both high-energy (in the tens of mJ range) and high-peak power (>10-MW) at repetition rate around one kilohertz. These include but are not limited to: high efficient nonlinear optical conversion [1], optical parametric processes [2], LIDAR and remote sensing [3]. However, in the vast variety of the existing kHz ns-laser systems the output pulse energy is not much than few10-ths of mJ while, on the other hand, the repetition rate of the presently existing high pulse-energy systems does not exceed 100-Hz. Besides in the most of the cases the high energy lasers are not single TEM_{00} mode and single frequency lasers. In this work, we report on the 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 28-mJ in a one Nd:YVO_4 preamplifier and a diode pumped boost YAG-amplifier, 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 (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 a boost amplification stage operated in a double-pass with transversely diode-pumped Nd:YAG module. The second stage employs a 0.6 at. % doped Nd:YAG crystal (dia. 3-mm and 90-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. Two double-pass amplification configurations are realized and studied. The duration of pulses from the oscillator and from the output of the MOPA system are measured by a 1.5-GHz oscilloscope and an InGaAs photodiode. Beam quality is characterized with a CCD beam-analyzer.

The efficient energy extraction from an amplifier stage increases by choosing the energy density of the input pulse close to the saturation density of the laser material used. Nd:YAG has a saturation density of 0.66-J/cm^2 and the diameter of the used crystal is 3-mm, therefore it is needed to reach an energy of ~1-mJ for the ~0.8-ns input pulses in order to achieve efficient amplification. By taking advantage of the low saturation density (0.12-J/cm^2) of Nd:YVO_4, we were able to achieve high amplification in a single pass through the preamplifier. The preamplifier is operated in a saturated regime, providing 1-mJ energy pulses at 0.5-kHz repetition rate, with 10% extraction efficiency and near-diffraction-limited beam quality. The achieved output pulse energy from the boost amplification stage is 28-mJ, at 0.5-kHz repetition rate, which corresponds to 18 % extraction efficiency. The beam quality after the master oscillator was measured to be M_x^2 x M_y^2=1.2 x 1.4 and no significant deterioration was observed after the pre-amplifier and at the output of first stage.

The presented work shows an intermediate stage in a development process aimed at the construction of a high-energy (~100mJ) and high-average power (~100W) master-oscillator power-amplifier system. We plan to equip this system with a down-conversion stage for mid-IR generation in order to explore its potential for advanced medical applications and laser ablation.

Acknowledgements: We acknowledge financial support under bilateral scientific project between Romania and Bulgaria (grant DNTS 02/24/2010) and grant DDVU 02/105/2010 of the Bulgarian national science fund.

References: [1] P. Cerny, H. Jelinkova, P. G. Zverev and T. T. Basiev, Quantum Electronics **28,** 113 (2004).
[2] T. Debuisschert, Quantum and Semiclassical Optics **9,** 209 (1997).
[3] S. T. Du, J. Zhou, F. B. Zhang, Y. T. Feng, Q. H. Lou and W. B. Chen, Microwave and Optical Technology Letters **50,** 2546 (2008).