Near Diffraction Limited Pulses with 52-mJ, 1.2 ns at 0.5 kHz, Generated by Nd-based MOPA

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Reliable high-energy (>10 mJ) laser systems with high-peak power (>10MW) pulses at kHz repetition rates, having diffraction-limited beams are highly desirable for a number of industrial, military and scientific applications, e.g. chemical sensing, various LIDAR, materials synthesis and processing, highly efficient nonlinear frequency conversion, etc. However, in the vast majority of kHz ns-laser systems the output pulse energy is below few tenths of mJ whilst, the repetition rate of the presently existing high pulse-energy systems does not exceed 50-100 Hz and are far from single TEM_{00} mode. In this work, we report the amplification of laser pulses from a near diffraction limited, passively Q-switched Nd:YAG master oscillator (0.58 mJ, 1.2 ns at 0.5 kHz) up to 52-mJ in a 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 a single pass by an end-pumped, 9-mm long Nd:YVO_4 crystal, with 0.25 at. % Nd doping. The pre-amplifier is longitudinally pumped by a fiber-coupled QCW diode laser with 120 μs, 60W peak power pulses at 0.5 kHz repetition rate. Further amplification is achieved with two transversely diode-pumped Nd:YAG stages: operated in a double-pass and in a single-pass, respectively. Both stages employ a 0.6 at. % doped Nd:YAG crystals pumped by linear stacks composed of 100 W QCW laser diode bars in three-fold and five-fold geometry, respectively. First stage is equipped with a 3 mm in diameter, 55 mm long crystal, whereas the second is with 5 mm in diameter and 65 mm long rod. By taking advantage of the low saturation density (0.12 J/cm^2) of Nd:YVO_4, we are able to achieve high amplification in a single pass pre-amplifier, thus reaching pulse energy of 1.48 mJ (17 % efficiency, fig. 1) at 0.5 kHz repetition rate. The signal from the pre-amplifier is subsequently amplified in a two-pass boost amplification stage employing a depolarization-compensating scheme [1] resulting in a polarized pulse output with energy up to 24 mJ (fig. 2). A theoretical model describing the amplification of short (ns to ps) laser pulses, accounting for the finite lower state lifetime and the ASE has been developed. There is a very good agreement between experimental data and the theoretical model in single pass amplification schemes (Fig.1 and Fig.2- blue and black curves). However, at the present state the model is not optimized for the decreasing population inversion in the second pass in two pass amplification schemes and shows minor divergence from the experimental results in such schemes at high input energy (Fig.2 - red curve). Finally, after one pass in the second amplification stage the output energy is scaled to 52 mJ with 1.2 ns pulse duration, of which 90 % are linearly polarized. The beam quality factor after the master oscillator is measured to be M_x^2 x M_y^2=1.18 x 1.04 and no significant deterioration is observed after the second amplification stage (M_x^2 x M_y^2=1.3 x 1.1).

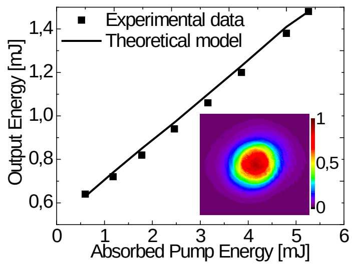

Fig. 1. Amplification in single pass Nd:YVO_4 pre-amplifier (inset pre-amplifier output beam profile).

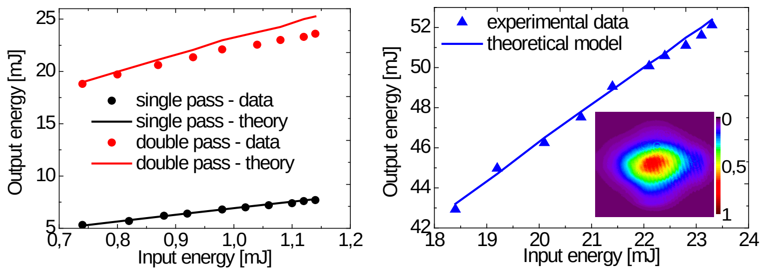

Fig. 2. Output energy vs. input energy for single and double pass amplification in the first amplification stage and in the second stage (output inset beam profile).

In conclusion, we have demonstrated a MOPA laser system generating single mode 1.2 ns pulses with energy up to 52 mJ at 0.5 kHz repetition rate and near diffraction limited beam quality. The proposed approach preserves pulse duration and beam quality and is easily scalable towards higher pulse energies. The system can also operate in single frequency regime when seeded with single frequency microchip oscillator. The currently achieved intensity level and beam characteristics make the MOPA system an attractive source for pumping of nonlinear frequency conversion devices as well as for LIDAR applications and material ablation.

[1] M. Ostermeyer, G. Klemz, P. Kubina, R. Menzel, "Quasi-continuous-wave birefringence-compensated single- and double-rod Nd:YAG lasers", Applied Optics 41(36), p.7573-7582 (2002)