1.5 kW Burst of Picosecond Pulses with Scalable Energy and Average Power Generated by Diode Pumped Nd-laser System

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Generation of high-power and high-reproducibility ultra-short laser pulses is demanded by a wide range of applications such as materials processing, medicine and optical spectroscopy. Passive mode-locking of CW-pumped lasers is the conventional and most robust approach for obtaining steady-state laser operation but their single-pulse energy and average power are quite limited e.g. to ~100 W at 80-110 MHz repetition rate. Although the Yb^{3+}-based thin-disk laser oscillators can operate with ~1-kW output power in CW mode, mode-locking is demonstrated up to ~275 W at repetition rate of 16 MHz [1]. In addition, this method for generation a train of ps-pulses requires a high degree of system complexity and development of passive mode-locking techniques applicable to oscillator with high average power. An alternative approach to meet the application requirements of ps-pulses with high-energy and average power is to generate a burst of picoseconds pulses with a kilohertz repetition rate and controllable duration and energy. Besides, such time structure is shown to be effective for a broad area of applications based on laser material interaction [2].

In this work, we report an longitudinally pumped, double-pass $Nd:YVO_4$ preamplifier with two stage transversely diode-pumped Nd:YAG rod power amplifiers used for amplification of a 6 picosecond, 95 MHz burst of pulses with tunable macro-pulse (train) duration (10 µs - 100 µs) at 0.5 kHz repetition rate. The pulses were derived from a near diffraction limited ($M^2 < 1.3$), CW pumped, passively mode-locked $Nd:YVO_4$ master oscillator [3]. The preamplifier is comprised by a 9-mm long $Nd:YVO_4$ crystal, longitudinally pumped via 600-um fiber with 65-W, 808-nm laser pulses from a QCW laser diode, with duration of 24 µs – 120 µs (for the 10 µs and 100 µs macro-pulse duration), and 0.5-kHz repetition rate. The absorption is measured to be 90 % of the incident pump power. After a double pass through the preamplifier stage we were able to achieve macro-pulse energy of 0.17 mJ for the 10 µs and 1.9 mJ, for the 100 µs pulse duration. The delay between the seed pulse train and the pump, and the duration of the pump pulse itself are optimized in such way to achieve flat macro-pulse (all the pulses in the macro-pulse are amplified equally). The pulse train is further amplified in two-stage power amplifier. Double-pass amplification in both stages is realized by a polarizer and a 45 degree Faraday rotator for each stage. A telescope with the necessary magnification is placed in the input of each stage to form the required beam in the diode pumped module. After the first pass through Nd:YAG rod the beam is relay imaged onto itself by 1:1 telescope and a highly reflecting mirror through the Faraday rotator. With this setup we can assure that after the reflection the beam passes through the same trajectory as at the first pass. As a result nearly perfect compensation of depolarization of Nd:YAG rod is achieved. At the output of the system, the macro-pulse energy reached 15.1 mJ for the 10 µs macro-pulse and 43.1 mJ, for the 100 µs pulse, which corresponds to a 1.51 kW and 0.43 kW in macro-pulse. Summary of the results is shown in Table 1.

	τ_{train}=10µs	τ_{train}=20µs	τ_{train}=30µs	τ_{train}=40µs	τ_{train}=60µs	τ_{train}=80µs	τ_{train}=100µs
$E_{oscilator}$ [mJ]	0.026	0.050	0.080	0.104	0.158	0.208	0.258
$E_{pre-amplifier}$ [mJ]	0.168	0.332	0.508	0.698	1.09	1.504	1.926
$E_{1st\ stage}$ [mJ]	3.6	6	8.0	9.5	11.7	13.5	14.9
$E_{2nd\ stage}$ [mJ]	15.1	21.9	27.1	30.8	36.5	40.4	43.1
$P_{peak\ 2nd\ stage}$ [W]	1510	1094	904	769	608	506	431

Table 1. Output energy at different stages for different macro-pulse duration.

The beam quality and beam profile of the system are measured with a commercial CCD based beam-analyzer at the output of the oscillator ($M^2 < 1.3$) and after the second power amplifier stage ($M^2 < 1.9$).

In conclusion, we have demonstrated compact and reliable, easily scalable, diode pumped Nd-laser system generating burst of picosecond pulses with kW level macro-pulse power at kHz repetition rate.

References

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