1 MW Peak Power Passively Q-switched Composite Sapphire/Nd:YVO_4 Microchip Laser

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The current level of technologies enables to increase the application number were MW of peak power Nd:YAG/Cr^{4+}:YAG passively Q-switched laser systems can be used like engine ignition [1] or mass imaging spectroscopy were UV laser light is used for the soft ionization [2]. Although current Nd:YAG/Cr^{4+}:YAG based systems reached peak power of 4.3 MW at 266 nm, the repetition rate is still low and equals to 100 Hz [3]. To reduce the measurement speed, higher repetition rates are required.

To meet this demand, we are applying another way for making high energy laser with the use of other conventional *a*-cut Nd:YVO_4 crystal. But at room temperature such crystal has more than 4 times larger emission cross-section compared to Nd:YAG crystal – $2.5x10^{-18}$ cm^2. Large emission cross-section makes vanadate crystal less favorable for high energy Q-switch pulses, but with crystal temperature control it is possible to decrease cross-section value by -0.5%/K [4]. With smaller emission cross-section, it is possible to increase pulse energies and lower pulse durations. In this work we propose a method to increase Q-switch output energy by heating up a gain medium and thus achieve 1 mJ of energy.

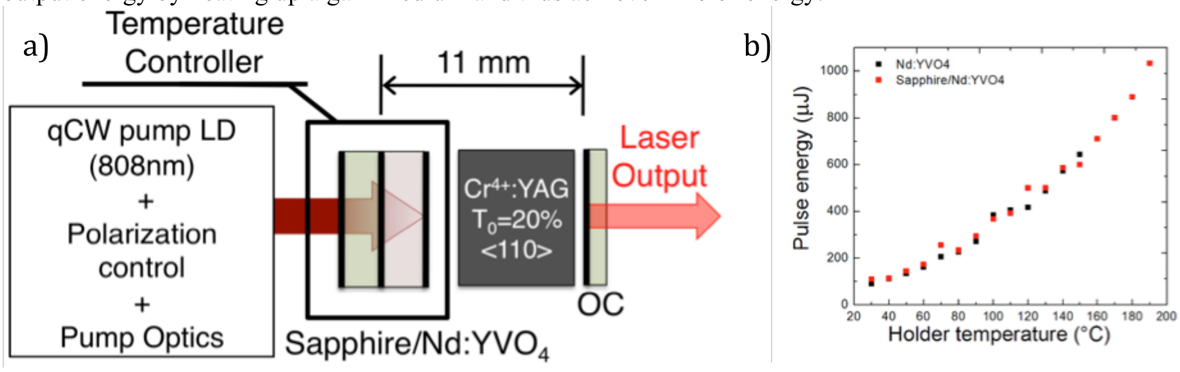

Figure 1. Experimental setup (a) and Q-switch output energy (b).

The laser (Fig. 1.a) comprises of Nd:YVO_4 crystal combined with a Sapphire plate under the optical contact the temperature in the crystal. The Nd:YVO_4 crystal is 1 mm thick, 1 at.% doped *a*-cut crystal. The saturable absorber is a 4 mm thick <110> Cr^{4+}:YAG crystal with initial transmission 20 %. Output coupler is a flat mirror with 50 % of reflection. Sapphire plate is 1 mm thick with AR/AR coating for 808 nm and 880 nm. The coatings on the Nd:YVO_4 crystal are favorable for pump wavelength at 808 nm and 880 nm and HR coating on the output side, for double pass to increase the absorption. The input face of gain crystal has also HR coating for 1064 nm. Output surface of the crystal as well as both Cr^{4+}:YAG crystal surfaces are coated for AR@1064 nm.

The composite Nd:YVO_4/sapphire chip is placed inside the heater, which is able to heat up to more than 200 °C. Due to limitations in design, minimum cavity length was 11 mm. The pump source used in this work is Jena 400 W fiber coupled laser diode with pump wavelength of 808 nm. The crystal was pumped in qCW mode by 100 Hz pulses with 213 W of peak power after passing through polarization control optics and focused to a 1 mm beam diameter.

By changing the heater temperature, the emission cross-section σ_{em} of a Nd:YVO_4 crystal is controlled with increase in the output energy of a Q-switched pulse (Fig. 1.b). By varying the crystal holder temperature from 30 °C to 190 °C the energy was increased from 100 µJ up to 1 mJ. At the same time the pulse duration decreased from 2 ns to below 0.9 ns. With this control the peak power reached 1 MW. By comparison, additional experiment was done with a single Nd:YVO_4 crystal where operational range was up to 150 °C and energy reached only 640 µJ. Also 1 kHz operation was tried by optimization is still required in order to achieve stable Q-switched operation.

The results in this work showed increase in peak power by using temperature control. Although operation at higher repetition rates required we are looking for the ways to improve it.

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