300 mJ electro-optically Q-switched 2.79 µm Cr:Er:YSGG laser

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Abstract: We report on a 2.79 µm flash lamp pumped electro-optically Q-switched Cr:Er:YSGG laser. The maximum output energy of 300mJ was demonstrated in 15 ns pulses at a 3 Hz repetition rate.

1. Introduction

Despite a strong demand for many research and industrial applications and the long history of 3 µm Er³⁺ lasers advancement, the reliable operation of these lasers in the actively Q-switched regime is still under development. These laser systems’ major limitation is the lack of adequate and high optical damage middle-infrared electro-optical (EO) or acousto-optical materials. Recently we reported a flashlamp-pumped mechanically Q-switched 2.94 µm Er:YAG laser based on a spinning mirror with the highest output energy of 0.8 J at a pulse duration of 61 ns [1]. However, many research and industry applications require external triggering with a small pulse jitter which could be difficult to achieve in mechanically based approaches such as spinning mirrors or frustrated total internal reflection. Previous advances with EO Q-switched 3 µm Er³⁺ systems were mainly based on LiNbO₃ crystals featuring a low optical damage threshold [2]. Recently, the langasite La₃Ga₅SiO₁₄ (LGS) crystal was suggested as a promising alternative for EO Q-switched 2.79 µm Er:Cr:YSGG lasers [5,6]. LGS crystals feature a high optical damage threshold (750 MW/cm²), small absorption at 2.79 µm, and, as EO Q-switch, can operate in the pulse-off mode at voltages below 5kV (EO coefficient γ₁=2.3 pm/V). The oscillation of Cr:Er:YSGG laser with an LGS EO Q-switch was reported with the output energy of 216 mJ in 14.4 ns pulses under flashlamp pumping with the energy of 150J [5]. This pump energy level requires using an intracavity quarter-wave plate to compensate thermally induce birefringence in Cr:Er:YSGG crystals. In this paper, we report on developing a 300 mJ Q-switched Cr:Er:YSGG laser using an optimized flashlamp chamber that reduces pump energy below 52 J and significantly reduces thermal birefringence in Cr:Er:YSGG crystals.

2. Experimental Results and Discussion

The experimental setup is depicted in Fig.1. The plane-plane cavity of a 36 cm length was formed by the high reflector (HR), 40% reflective output coupler (OC), and AR coated Cr:Er:YSGG rod (d4x100mm, DIEN Tech, PRC) doped with 3 at% Cr³⁺ and 30 at% Er³⁺ which was mounted in the MegaWatt Lasers commercial pump chamber model 4X100C2. This pump chamber utilizes a close-coupled, BaSO₄ diffuse reflector design for pumping uniformity and high efficiency. The flow tube is UV-fused silica, and the rod to flashlamp centerline spacing is 7.5 mm. The flashlamp...
is a M201 model with a 4 mm bore, 90 mm arclength, and 450 torr Xenon fill. A z-cut LGS EO Q-switch (6x6x45 mm, DIAN Tech, PRC) operated in a pulse-off mode, and the applied voltage was ~5kV (smaller than -6kV quarter-wave voltage). Three 1-mm-thick Al₂O₃ plates placed at Brewster angle between the LGS and Cr:Er:YSGG formed a polarizer. The Analog Module flashlamp driver provided pump energy up to 60 J at a pulse duration of 300 µs. The experiments were performed at a 3 Hz repetition rate. Thermal depolarization in the gain medium was compensated by rotation of the LGS EO Q-switch about its axis. A single Q-switch pulse was obtained up to 32.5 J of pumping using three Al₂O₃ plates polarizer. We used an additional 1-mm-thick YAG plate placed between Cr:Er:YSGG and OC to enable a single Q-switch pulse up to maximum pump energy of 52.5 J.

Figure 2A depicts output-input characteristics of Cr:Er:YSGG laser in free-running (blue triangles, curve i) and Q-switched (black triangles curve ii) regimes with Al₂O₃ polarizer and pump energies up to 32.5 J. As one can see, the slope efficiency in the Q-switched regime reached 1.2%, with Q-switched-to-free-running-mode extraction efficiency close to 100%. The maximum energy was 210 mJ at 15 ns pulse duration, corresponding to 14 MW peak power. A further increase of the pump energy resulted in the appearance of a combined Q-switched and free-running spikes regime. To avoid this regime, we added an additional 1-mm-thick YAG plate polarizer near the output coupler. Fig. 2A (curve iii) also shows another output-input characteristic of the Cr:Er:YSGG laser in a Q-switched regime measured up to 52.5 J of pumping. As one can see, due to minor damage to the crystal coating, the slope efficiency decreased to 0.85%. Still, we could pump the crystal up to 52.5 J and obtain output energy of 300 mJ at 15 ns pulse duration and 20 MW peak power without roll-off of the output energy. As shown in Fig.2B (curves iv for three plates polarizer and v for four plates polarizer), the pulse duration decreases with the increase of the pump energy from ~110 ns near the threshold to ~15 ns at 52.5 J of pumping. The insert C in Fig. 2B depicts the spatial profile of the output beam measured at 210 mJ of output energy. As one can see, it has a flat-top profile without hot spots. The insert D in Fig. 2B depicts the spatial profile of the output beam measured at 300 mJ of output energy. As one can see, it has close to a flat-top profile with some hot spots.

Fig. 2: Output energy (A) and pulse width (B) as a function of pump energy. Inserts (C) and (D) are spatial profiles of the output beam at 210 and 300 mJ output energy, respectively.

In conclusion, we demonstrated that LGS enables efficient Q-switch operation of Cr:Er:YSGG lasers at 2.79 µm. We report 300 mJ output energy at 15 ns pulse duration at a 3 Hz repetition rate, which is, to the best of our knowledge, the record result documented to date at 2.79 µm. Further improvement of the AR coating of the gain element, efficiency of the pump chamber, and laser performance over a wide range of repetition rates is planned in the near future.

References: