HIGH EFFICIENT 12W DIODE-PUMPED ACTIVELY Q-SWITCHED YB:KGD$(WO_4)_2$ LASER

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Abstract: Compact diode-pumped actively Q-switched Yb:KGW laser is demonstrated with optical-to-optical efficiency of 50%. In a Z-shaped laser cavity configuration output power of 12.2 W with repetition rate up to 50 kHz and pulse duration of 10-24 ns was obtained. The maximum pulse peak power of 70 kW was achieved. The laser output beam profile was Gaussian up to maximum pump powers with M^2 factor lower than 1.2.

Compact diode-pumped Q-switched lasers with pulse repetition rate of tens kHz are of practical importance for diverse materials processing applications. Currently the most popular active media for such commercial systems are Nd^{3+}-doped crystals (YAG, YVO_4 or YLF). Neodymium doped media have a number of advantages like 4-level laser scheme and high stimulated emission (SE) cross section (~10^{-19}cm^2) that allow efficient laser action with comparatively low pump and laser beam intensities. These systems can provide high single pulse energy without damage of the intracavity optics but high quantum defect of Nd^{3+} ions leads to significant thermo-optic aberrations that restrict the possibilities of power scaling, especially at high repetition rates. In order to obtain relatively high output powers, sophisticated cooling systems and powerful 808 nm AlGaAs diodes are used, which results in the drop of the cost efficiency. In contrast, Yb^{3+}-based laser system have 3-level laser scheme and lower SE cross section that result in a comparatively high pump and intracavity laser beam intensities for efficient laser operation. But this disadvantage almost zeroing when we operate with high PRR and thus with reduced single pulse energy. Moreover, the utilization of Yb-doped material could improve the performance and cost of Q-switched laser system because of the substantial reduction of the thermal effects due to low quantum defect and high availability of InGaAs diodes.

Among the Yb-doped materials, monoclinic potassium rare-earth double tungstates (KGd$(WO_4)_2$, KY$(WO_4)_2$) attract attention due to high available doping levels without luminescence quenching and lattice distortion (up to 100at.% reaching the stoichiometric structure of KYbW), high polarized absorption and emission cross-sections ($\sigma_{abs}=12\times10^{-20}$ cm^2 at 981 nm and $\sigma_{em}=3.2\times10^{-20}$ cm^2 at 1025 nm for $\boldsymbol{E} \parallel N_m$), relatively wide spectral bands (allowing efficient diode-pumping and short pulses generation) and moderate value of thermal conductivity (3 W/mK, which is three times higher than that of glasses). This results in multi-watt femtoscond systems, powerful cw and Q-switched lasers with high average output power in the spectral region of 1 μm [1-5].

Here we present the results of experimental study of Yb:KGW diode-pumped actively Q-switched laser.

A standard Z-shaped laser cavity (Fig. 1) was used for *cw* laser experiments, that was formed by two concave folding mirrors (M2, M3), flat back mirror (M1) and flat output coupler (M4). 5mm-long N_g-cut Yb(1.6at.%):$KGd(WO_4)_2$ crystal was used as a gain medium. The laser crystal was pumped through one of the folding mirrors by using 980nm fiber-coupled (Ø105μm, NA=0.22) laser diode with maximum power of 25 W. The crystal was kept at 20˚C by means of thermoelectrical cooling with forced air-cooled heatsink.

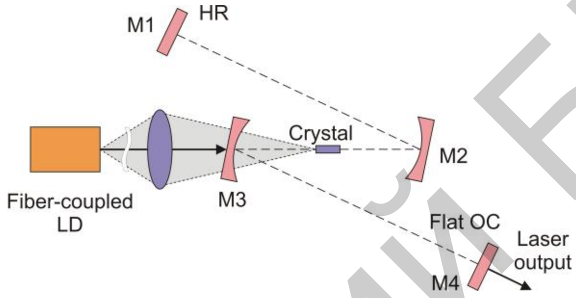

Fig. 1. Schematic of CW Yb:KGW laser

The average output power versus incident pump power for cw mode of operation is shown in Fig. 2. Maximum output power of 13.6 W was obtained for OC transmittance of 20% with optical-to-optical efficiency of about 56%. Slightly lower parameters were demonstrated for OC transmittances of 10 and 30% (fig.2).

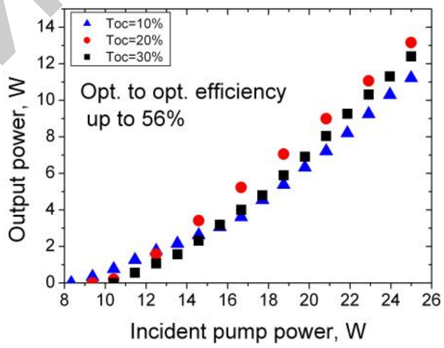

Fig. 2. Average output power versus incident pump power for cw mode of operation

During the CW operation we estimated the focal length of the thermal lens for different pump intensities inside the gain crystal and design the Q-switch cavity to work with TEM_{00} mod radius in the gain crystal of about 100 microns at the maximum pump power to prevent the optical damage of AR coatings. The dependency of optical power of thermal lens from the beam radius in the gain crystal is shown in Fig. 3.

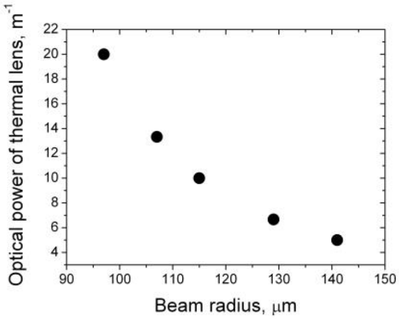

Fig. 3. Beam radius of the TEM_{00} cavity mode in the gain crystal for different optical powers of thermal lens

To reduce the cavity length of Q-switched laser we use 3-mirror laser cavity (Fig. 4). For Q-switching operation in one arm of the cavity TFP and BBO-based electro-optical Q-switch were incorporated.

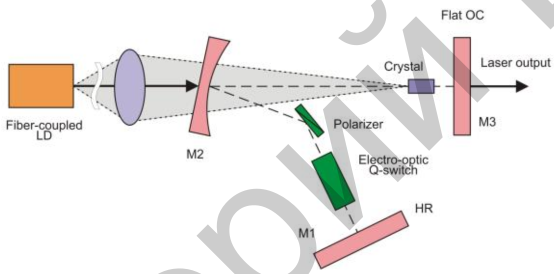

Fig. 4. Schematic of Q-switched laser

The dependency of average output power from the incident pump power for Q-switched laser with 30 kHz pulse repetition frequency (PRF) for output coupler transmittance of 30% is shown in Fig. 5. The optical to optical efficiency reaches 50%.

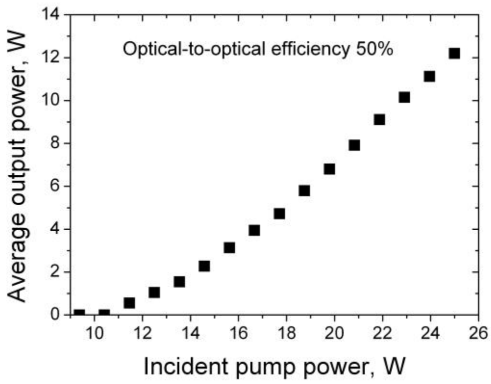

Fig. 5. Average output power versus incident pump power for Q-switched 30 kHz laser

The dependencies of average output power and pulse duration from PRF for Yb:KGW Q-switched laser are presented in Fig. 6.

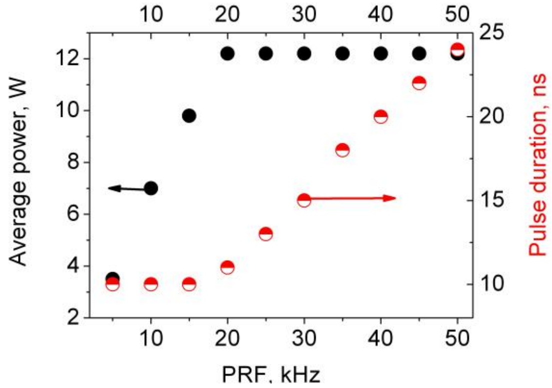

Fig. 6. Average output power and pulse duration versus pulse repetition frequency (PRF)

The maximum average output power of 12.2 W was obtained at a PRF higher than 20 kHz. The corresponding incident pump power was 24.4 W. The optical-to-optical laser efficiency was as high as 50%. Average output power at a lower PRF was limited by the optical damage of the dielectric coatings of output mirror M3. With increasing of PRR from 5 kHz to 50 kHz the pulse duration was increased from 10 ns to 24 ns.

The dependency of output pulse energy from the PRF for Q-switched laser is shown in Fig. 7. Pulse energy of 0.7 mJ was obtained at PRF up to 10 kHz. At the pulse repetition frequrncy of 50 kHz pulse energy reaches 0.244 mJ. The maximum pulse peak power of 70 kW was obtained.

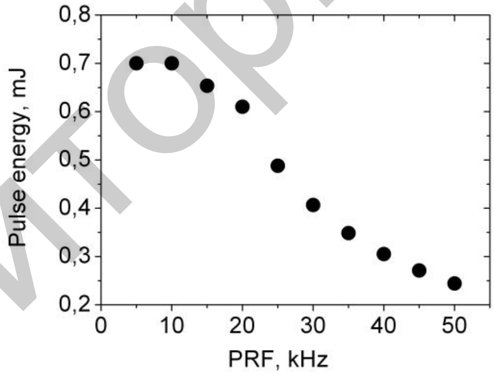

Fig. 7. Pulse energy versus PRF for Q-switched laser

The typical pulse train of the Q-switched laser at PRF of 20 kHz and temporal pulse envelope are shown in the fig. 8 and fig 9 correspondingly.

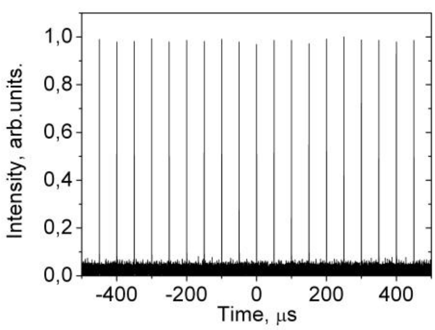

Fig. 8. Pulse train of the Q-switced laser at 20 kHz PRF

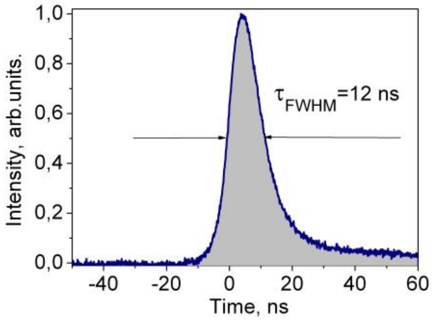

Fig. 9. Temporal pulse envelope of the Q-switched laser

Pulse to pulse intensity instabilities were less than few percent. The laser output beam profile (Fig. 10) was Gaussian up to maximum pump powers with M^2 factor lower than 1.2 thus indicating negligible thermo-optical aberrations.

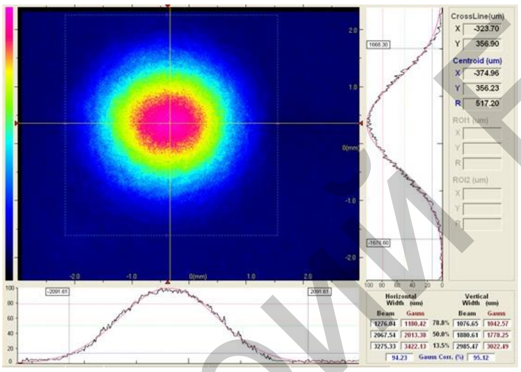

Fig. 10. Laser output beam profile

In conclusion, highly-efficient diode-pumped actively Q-switched Yb:KGW laser is demonstrated for the first time to our knowledge.

References

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