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Nanosecond Compact Eye-Safe Erbium Lasers with 190 kW Peak Power

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Spinel (MgAl_2O_4) single crystals doped with cobalt ions (Co^{2+}) are known as efficient saturable absorbers (SAs) of eye-safe erbium (Er) laser emitting at 1.5–1.7 μm . Their saturable absorption originates from the $^4\text{A}_2(^4\text{F}) \rightarrow ^4\text{T}_1(^4\text{F})$ transition of Co^{2+} ions located in tetrahedral (T_d) sites. Recently, Co^{2+} -doped spinel transparent polycrystalline ceramics and transparent nanophase glass-ceramics (GCs) were proposed as competitive materials for the single-crystal technology [1,2]. Among them, transparent GCs feature high laser induced damage thresholds ($\sim 20 \text{ J/cm}^2$) and the possibility to modify the composition of spinel nanophase [1]. We report on a compact passively-cooled eye-safe Er laser passively Q-switched (PQS) by GC-based SAs suitable for compact range-finders.

The scheme of the laser is shown in Fig. 1(a). The cavity is formed by a concave (RoC = -1.5 m) HR end mirror and a flat output coupler (OC, $T_{\text{OC}} = 13\%$). The rod-shaped laser element ($\Phi 1.0 \text{ mm} \times 10 \text{ mm}$) made of Er,Yb:glass is side-pumped by a laser diode array at 940 nm. The passively-cooled laser is housed by a ZrO_2 -coated glass pump chamber with dimensions of only $\Phi 15 \text{ mm} \times 25 \text{ mm}$. In the free-running regime, Fig. 1(b,c), the laser generates $\sim 3.8 \text{ ms}$ long pulses with a maximum energy of 40 mJ and a slope efficiency of 17.7%. As SA materials, two transparent GCs based on gallium-containing spinel phases ($\text{Mg}(\text{Al,Ga})_2\text{O}_4$ and $\gamma\text{-Ga}_2\text{O}_3$) were selected. They exhibit high GSA cross-sections at $\sim 1.54 \mu\text{m}$, Fig. 1(d), determined from the absorption saturation experiments. The uncoated SA is inserted at the Brewster angle between the laser rod and the OC. The initial transmission of the SAs T_{SA} was varied by the heat-treatment regime of the initial glass and by its thickness.

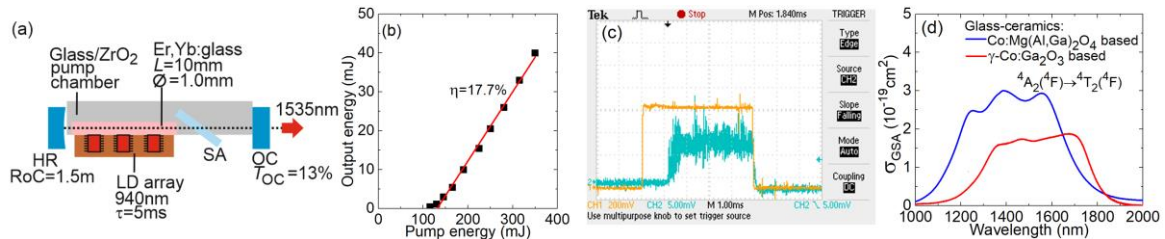


Fig. 1 Diode-side-pumped passively Q-switched compact Er,Yb:glass laser: (a) scheme of the laser, LD – laser diode, HR – highly-reflective mirror, OC – output coupler, SA – saturable absorber; (b) free-running laser performance; (c) oscilloscope traces of the pump and laser pulses in the free-running regime; (d) ground-state absorption (GSA), σ_{GSA} , cross-sections for the $^4\text{A}_2(^4\text{F}) \rightarrow ^4\text{T}_1(^4\text{F})$ Co^{2+} transition in T_d sites in $\text{Mg}(\text{Al,Ga})_2\text{O}_4$ and $\gamma\text{-Ga}_2\text{O}_3$ based transparent GCs.

After inserting the SA, very stable passive Q-switching was achieved. The laser generated a single giant pulse per each pump pulse (pulse repetition rate: 1 – 5 Hz), Fig. 2(a). Using a $\gamma\text{-Co:Ga}_2\text{O}_3$ based GC saturable absorber with $T_{\text{SA}} = 85.4\%$, the pulse duration (FWHM) of 7.2 ns was obtained corresponding to a pulse energy of 1.39 mJ. The peak power thus reached 193 kW. The effect of the small-signal SA transmission on the pulse characteristics was systematically studied, Fig. 2(b,c). The PQS laser exhibited excellent long-term stability (studying >100 repetitive pulses): $\pm 0.02 \text{ mJ}$, $\pm 0.2 \text{ ns}$. No optical damage of the optical elements nor the SAs was observed. The laser wavelength was 1535.2 nm. The measured divergence of the laser beam was $\Theta_{x,y} = 3.83$ and 4.60 mrad, close to the diffraction limit. The developed laser design is suitable for compact range-finders.

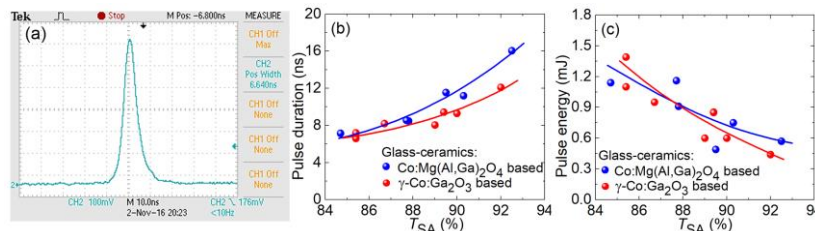


Fig. 2 Pulse characteristics of the passively Q-switched compact Er,Yb:glass laser: (a) oscilloscope trace of a single Q-switched pulse, $\gamma\text{-Co:Ga}_2\text{O}_3$ based GC saturable absorber; (b) pulse duration and (c) pulse energy as a function of the initial transmission T_{SA} of GC-based SAs.

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