Passively Q-Switched Tm^{3+}:$LiGdF_4$ Laser Using Cr^{2+}:ZnSe as Saturable Absorber

Bozhidar Oreshkov[1,4], Stefano Veronesi[2], Mauro Tonelli[2,3], Alberto di Lieto[2,3], Valentin Petrov[1], Uwe Griebner,[1] Xavier Mateos[5], Ivan Buchvarov[4]

1. Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born Strasse 2A, 12489 Berlin, Germany
2. NEST Istituto Nanoscienze - CNR, piazza S. Silvestro 12, 56127 Pisa, Italy
3. Dipartimento di Fisica dell'Università di Pisa, Largo B. Pontecorvo 3, 56127 Pisa, Italy
4. Faculty of Physics, Sofia University, 5 James Bourchier Blvd., BG-1164 Sofia, Bulgaria
5. Física i Cristallografia de Materials i Nanomaterials (FiCMA-FiCNA), Universitat Rovira i Virgili (URV), Campus Sescelades, c/ Marcel·lí Domingo, s/n., Tarragona, Spain E-43007

Lasers based on the Tm^{3+}-ion (Tm) emission near 1.9 µm are interesting for many medical applications [1], remote sensing (LIDAR), as well as for pumping optical parametric oscillators (OPOs) aimed at frequency down-conversion into the mid-IR. High pulse energy and peak power are advantageous for these applications since they can be achieved at relatively low average power if compared to the CW regime. While high energies have been demonstrated by active Q-switching, passive Q-switching (PQS) is much simpler and cheaper to realize and more importantly, shorter pulses are generated with higher peak power. In recent years, PQS of diode-pumped solid-state (DPSS) lasers by the use of intracavity saturable absorbers (SA), was successfully demonstrated in several CW-pumped, bulk Tm-doped materials. The best results so far, for any DPSS PQS Tm-doped laser, have been achieved, using fluoride hosts - Tm:YLF and Tm:LLF [2], combined with Cr:ZnS SAs. In the present work we investigate the PQS performance of Tm-doped $LiGdF_4$ (GLF). This is a relatively new laser crystal isomorphous to the well-known YLF and LLF, in which the dopant substitutes Gd^{3+} host ions. Whilst CW and mode-locked operation of Tm:GLF were previously studied, to the best of our knowledge, this is the first report of Q-switching of this laser medium.

For our experiments an L-shape hemispherical resonator and polycrystalline Cr^{2+}:ZnSe as SA, exhibiting 82% transmission at 1880 nm, were employed. The pump source was a fiber-coupled (NA=0.15, 105 µm core diameter) AlGaAs diode laser, delivering up to 1.9 W at 792.4 nm. The performance of the Tm:GLF laser was first studied in CW regime and after that in PQS, with absorbed pump power up to ~1.0 W. The crystal absorption was measured to be on average 57.0%. Using an output coupler with 20% transmission for the laser wavelength we were able to achieve up to 358 mW output power (50.8% slope efficiency) in the CW regime, and up to 152 mW average power (29.8% slope efficiency) in PQS (Fig.1 a). This corresponds to 42.5% of Q-switching to CW extraction efficiency at maximum power. Pulse durations as short as 13 ns, with moderate pulse energy of 467 µJ and high peak power, 37 kW, were achieved (Fig.1 b,c). The repetition rate increases from 30 to 350 Hz with pump power. The output radiation in both CW and PQS regimes was π-polarized, with a central wavelength of 1878 nm in CW and 1876 nm in PQS regime.

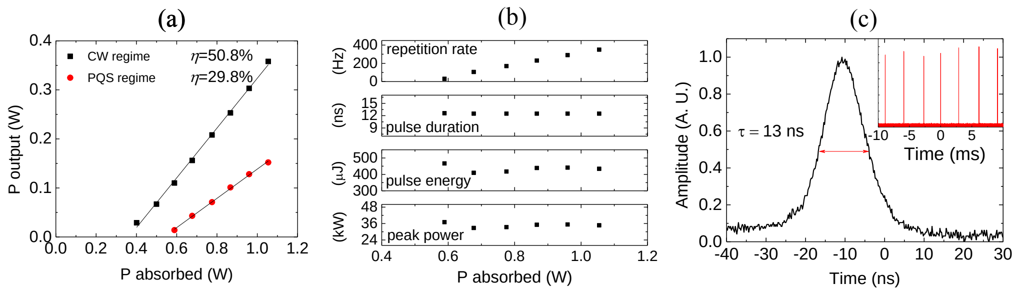

Fig. 1 Cr:ZnSe Q-switched Tm:GLF laser: (a) output power in CW and PQS regimes vs. absorbed pump power (symbols) and linear fits (lines), (b) pulse characteristics in the PQS regime vs. absorbed pump power, and (c) Q-switched pulse shape recorded at maximum pump power; the inset shows the pulse train.

In conclusion, we demonstrated PQS of a DPSS Tm:GLF laser for the first time. The initial results are better compared to other Tm hosts such as garnets and double tungstates. However, they are still inferior compared to the other two fluoride isomorphs (Tm:YLF and Tm:LLF). We attribute this to the inferior quality of the available Tm:GLF crystal sample. We believe that with better optical quality samples, higher energies and shorter pulse durations could be achieved with this promising new material. The advantage in comparison to the other fluoride materials is the stable intrinsic polarization selection which also supports a different oscillation wavelength.

References

[1] K. Scholle, S. Lamrini, P. Koopmann, and P. Fuhrberg, "2 µm laser sources and their possible applications," in *Frontiers in Guided Wave Optics and Optoelectronics*, B. Pal, Ed., Intech, Vukovar, Croatia, pp. 471–500, (2010).
[2] H. Yu, V. Petrov, U. Griebner, D. Parisi, S. Veronesi, and M. Tonelli, "Compact passively Q-switched diode-pumped $Tm:LiLuF_4$ laser with 1.26 mJ output energy", Opt. Lett. **37**, 2544-2546 (2012).

978-1-4673-7475-0/15/$31.00 ©2015 European Union