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Passively Q-switched Pr:YLF laser

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Abstract: We report passively Q-switched operation of a diode-pumped Pr:YLF laser using an AlInGaP on GaAs SEmiconductor Saturable Absorber Mirror. Q-switched pulses with 145ns duration and 23mW average output power at 639.5nm are obtained.

OCIS codes: 140.7300 visible lasers, 140.3540 Lasers, Q-switched

1. Introduction

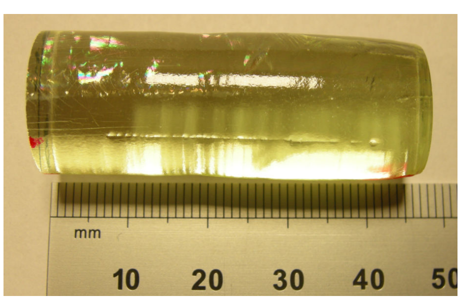
Solid-state lasers with direct emission in the visible have attracted a lot of attention in recent years for their potential applications as emitters for projection/display purposes, bio-photonics or medical use [1-6]. Among these sources, praseodymium-doped fluoride lasers are of particular interest since they can be pumped using commercially available GaN laser diodes and offer laser emission in the red, green and blue parts of the optical spectrum [3-5]. To-date, these sources have mainly been operated in continuous- /quasi-continuous-wave regime. Interests in direct visible pulsed sources has however led to the recent study of active Q-switching of a Pr:YLF laser [7].

In this paper, we extend this work and report investigations of AlInGaP on GaAs SEmiconductor Saturable Absorber Mirrors (SESAMs) as pulse trigger and stabilisation elements to induce passively Q-switched operation of a diode pumped Pr:YLF laser operating at 639.5nm.

2. Components description

A <100>-oriented 15mm-diameter and 45mm-long boule of Pr:YLF (see Fig. 1.a) with ~0.6 atomic percent doping was grown by the Czochralski method under an Ar and CF_4 atmosphere, with a growth rate of 1.0 mm/h and a rotation rate of 15 rpm. It used rare earth fluorides that were prepared from pure oxide powders (99.99%) by hydro-fluorination at high temperature in HF atmosphere. The LiF-LnF_3 (Ln=Y and Pr) mixture was melted in the same conditions, with a composition of 1.02 LiF: 1 LnF_3. A 4*4mm-cross section and 7mm-long crystal was cut from this boule for light propagation along the *a*-axis.

The SESAMs under investigation consist of a 45.5-pair AlAs/$Al_{0.55}Ga_{0.45}As$ Distributed Bragg Reflector mirror on top of which is a 3λ/4-thick $(Al_{0.3}Ga_{0.7})_{0.51}In_{0.49}P$ layer capped by 10nm of $In_{0.49}Ga_{0.51}P$. The saturable absorber is a single 8nm-thick $In_{0.49}Ga_{0.51}P$ quantum-well positioned at the antinode of the electric field pattern in the $(Al_{0.3}Ga_{0.7})_{0.51}In_{0.49}P$ layer. The structures were grown by Metal Organic Vapour Phase Epitaxy on a 2-inch (100) GaAs substrate. A reflectivity measurement is shown in Fig. 1.b.



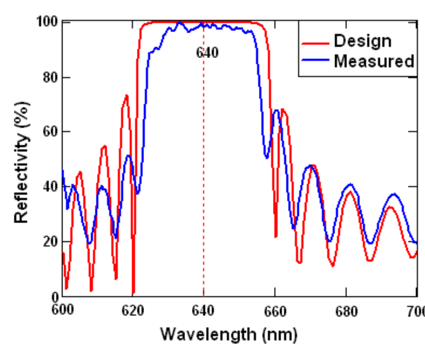


Fig. 1. a) Produced boule of Pr:YLF. b) SESAM Reflectivity spectrum

3. Results and Discussion

The crystal was pumped using a commercially-sourced GaN diode laser delivering up to 409 mW at 444 nm with its polarisation aligned for maximum absorption in the Pr:YLF crystal (i.e. along the *c*–axis [8]).

Continuous-wave operation in a simple plano-concave cavity with a 1% output coupling mirror produced up to 72mW of output at 639.5nm with a threshold of ~120mW and a slope efficiency of 31% with respect to the absorbed pump power (Fig. 3 (a), triangles), a result on a par with state-of-the-art performance [3-4]. The emission was polarised perpendicular to the *c*-axis as expected from polarised emission spectra of the material [8].

To achieve passively Q-switched operation, the laser setup was modified to form the three-mirror cavity as represented in Fig. 2 (a), with an estimated mode size of ~180µm in diameter inside the laser crystal and ~230µm in diameter on the SESAM. The minimum pulse duration produced by the laser was 145±15 ns (Fig. 3 (b)) at the repetition rate of 105±40 kHz and average output power of 23 mW (Fig. 3). The slope efficiency of the Q-switched Pr:YLF laser was estimated to be 11%. By replacing the SESAM with a high reflectivity mirror, the laser produced 39mW of maximum power with a slope efficiency of 17 % (Fig. 3 (a), open circles).

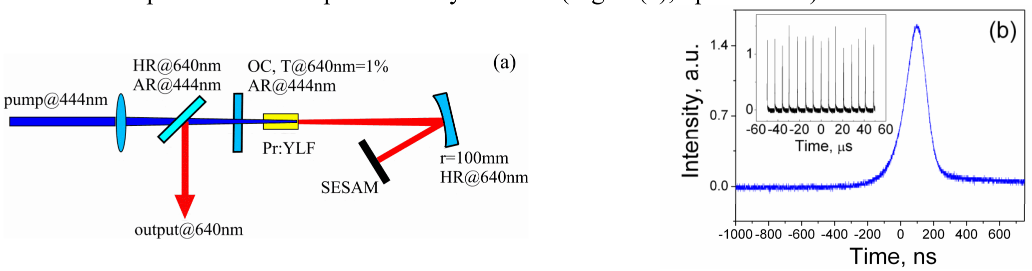


Fig. 2. a) 3-mirror laser setup b) The Q-switched pulse with the FWHM duration of 145ns, inset – typical pulse train

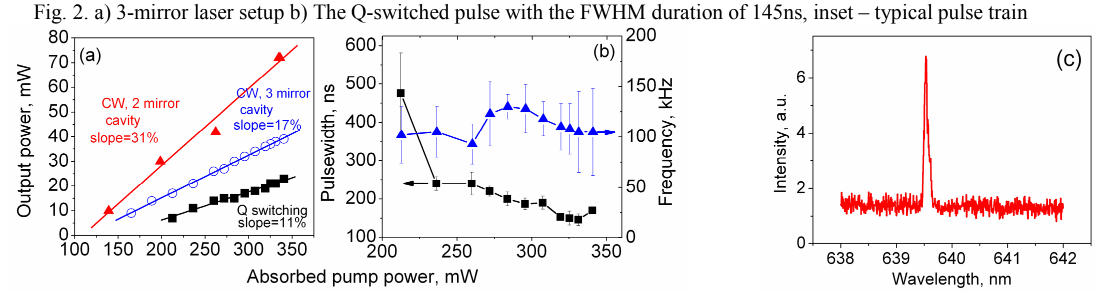


Fig. 3. a) Power transfers b) Pulse width and repetition-rate evolution c) Emission spectrum of the passively Q-switched Pr:YLF laser

Threshold analysis of this four-level transition laser reveals SESAM non-saturable round-trip losses of 4%. Following the approach of reference [9], using the latter non-saturable loss value together with the achieved pulse duration and energy, the saturable loss parameter is estimated to be 0.7%.

4. Conclusion

We have demonstrated the first, to our knowledge, passively Q-switched Pr:YLF laser operating at 640nm. The minimum pulse duration of 145 ns was obtained at the output power of 23 mW (slope efficiency of 11%) and repetition rate of ~100 kHz. Improvements in performance are expected through the use of more optimised SESAMs with higher saturable losses and potentially reduced non-saturable losses.

5. References

[1] J.E. Hastie, S. Calvez, M.D. Dawson, T. Leinonen, A. Laakso, J. Lyytikainen, and M. Pessa, "High power CW red VECSEL with linearly polarized TEM00 output beam", Opt. Express **13**, 77-81 (2005).

[2] A. Smith, J.E. Hastie, H.D. Foreman, T. Leinonen, M. Guina and M.D. Dawson, "GaN diode-pumping of red semiconductor disk laser", *Electron. Lett.* **44**, 1195-1196 (2008).

[3] A. Richter, E. Heumann, G. Huber, V. Oustroumov, and W. Seelert, "Power scaling of semiconductor laser pumped praseodymium lasers", *Opt. Express* **15**, 5172-5178 (2007).

[4] K. Hashimoto and F. Kannari, "High-power GaN diode-pumped continuous wave Pr^{3+}-doped $LiYF_4$ laser", *Opt. Lett.* **32**, 2493-2495 (2007).

[5] J. Nakanishi, T. Yamada, Y. Fujimoto, O. Ishii and M. Yamazaki, "High-power red laser oscillation of 311.4mW in Pr^{3+}-doped waterproof fluoro-aluminate glass fibre excited by GaN laser diode" , *Electron. Lett* **46**, 1285-1286 (2010).

[6] Y. Fujimoto, O. Ishii and M. Yamazaki, "Yeloow laser oscillation in Dy^{3+}-doped waterproof fluoro-aluminate glass fibre pumped by 398.8nm GaN lase diodes", *Electron. Lett.* **46**, 575-576 (2010).

[7] J. Kojou, Y. Watanabe, Y. Kojima, P. Agrawal, and F. Kannari, "Q-Switching of Pr^{3+}-Doped $LiYF_4$ Visible Lasers Pumped by a High-Power GaN Diode Laser," in *Conference on Lasers and Electro-Optics*, OSA Technical Digest (CD) (Optical Society of America, 2010), paper JTuD116 (2010).

[8] S. Khiari, M. Velazquez, R. Moncorg´e, J.L. Doualan, P. Camy, A. Ferrier, M. Diaf, "Red-luminescence analysis of Pr3+ doped fluoride crystals," *J. Alloys and Compounds* **451**, 128-131 (2008).

[9] G.J. Spuhler, R. Paschotta, R. Fluck, B. Braun, M. Moser, G. Zhang, E. Gini and U. Keller, "Experimentally confirmed design guidelines for passively Q-switched microchip lasers using semiconductor saturable absorbers", *JOSA B* **16**, 376-388 (1999).