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# Mechanically Q-switched codoped Er-Yb glass laser under Ti:sapphire and laser diode pumping

E. Tanguy, J.P. Pocholle, G. Feugnet, C. Larat, M. Schwarz, A. Brun and P. Georges

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A simple Q-switched TEM<sub>00</sub> Er<sup>3+</sup>, Yb<sup>3+</sup>:glass laser end-pumped by a Ti:Al<sub>2</sub>O<sub>3</sub> laser or by a broad-area high-power laser diode is demonstrated. In both cases the FWHM pulse duration is ~50ns and the peak power is > 100W

A compact laser emitting in the 1.5 μm eye-safe wavelength range finds very interesting applications in the fields of telemetry or optical communications [1]. Codoped Er<sup>3+</sup>, Yb<sup>3+</sup> phosphate glass [2], and a pumped laser diode lead to a low-cost, compact microlaser emitting at this wavelength [3].

In this Letter an Er<sup>3+</sup>:Yb<sup>3+</sup> microlaser pumped by a Ti:Al<sub>2</sub>O<sub>3</sub> laser and a broad-area laser diode are presented. Continuous and Q-switched operations were performed. The laser cavity shown in Fig. 1 is made of a 2 mm-thick KIGRE QX/ER Er<sup>3+</sup>:Yb<sup>3+</sup> phosphate glass disc and a plane output mirror. One face of the disc is high-reflectivity-coated at 1540nm ( $R > 99.9\%$ ) and the transmission at 980nm is about 95%. The other disc face is antireflection-coated at 1540nm ( $R < 0.03\%$ ). The output mirror reflection is estimated to be ~99% at 1535nm. The overall cavity length is 2.5 to 3mm.

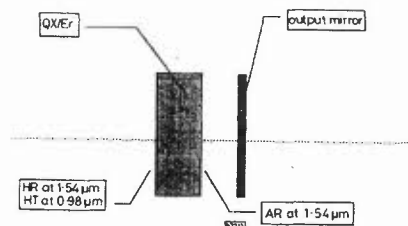


Fig. 1 Longitudinal pumping scheme

A 200mm lens focuses the Ti:Al<sub>2</sub>O<sub>3</sub> laser operating at  $\lambda = 980\text{nm}$  leading to a measured spot radius within the disc of ~100μm. The Rayleigh range of the pump beam is about 2cm. Thus the spot size can be considered constant into the active material. The output power from the Er<sup>3+</sup>:Yb<sup>3+</sup>:glass laser is shown in Fig. 2 as a function of the pump power.

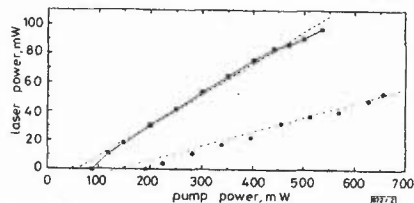


Fig. 2 Output power against pump power

Titanium-sapphire pumped Er:Glass laser:  
 —■— measured data  
 —○— rate equation analysis calculated data  
 Laser-diode-pumped Er:Glass laser:  
 - - -●- - - measured data  
 - - -○- - - rate equation analysis calculated data

The power was measured by a thermopile power meter. A semiconductor filter rejects the unabsorbed pump power. The maximum output power obtained is 100mW at a 540mW pump power

level. The optical-optical efficiency is 18.5%, the laser threshold is 90mW and the slope efficiency is 22%. The measured output beam was almost diffraction-limited ( $M^2 = 1.3$ ) with a 7mrad angular divergence leading to an intracavity beam radius of ~90μm. As expected in a plano-plano cavity, the intracavity and the pump beam have almost the same dimension.

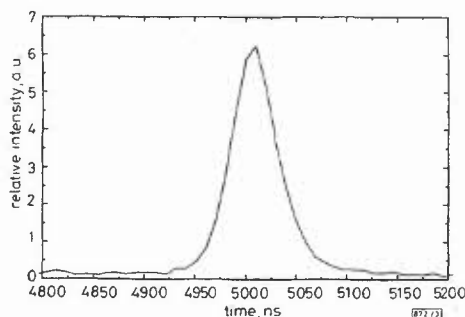


Fig. 3 Temporal pulse shape

FWHM = 48ns, energy = 9μJ, peak power = 180W

A one-slit (~1mm-width) mechanical chopper is inserted into the cavity between the active material and the output mirror (cavity length = 8mm). With this cavity length the laser is less efficient. The CW output power is about 30mW for a 360mW pump level used. Q-switch operation was observed at 140Hz repetition rate. The FWHM pulse duration is 48ns as shown in Fig. 3, and the pulse energy is 8.6μJ (measured with a pyroelectric joulemeter). Thus the peak power was estimated to be 180W. The Q-switch mode average power is 1.2mW. The average power should be the same order of magnitude as that in CW-mode operation. A possible explanation is that the Q-switch rise time is not fast enough (~5μs) to release the stored energy completely.

The same cavity laser configuration was pumped by a broad-area high-power fibre pigtailed laser diode emitting at ~980nm ( $\Phi = 200\mu\text{m}$ ). The pump beam angular divergence at the output of the fibre FWHM is 15°. The optical fibre was in contact with the active material. An optical-optical efficiency of 8% is obtained (see Fig. 2). The laser threshold is 190mW and the slope efficiency is 11%. The beam profiles are almost Gaussian but an  $M^2$  measurement was not performed.

In the laser-diode-pumped configuration, the threshold power is twice as high and the slope efficiency is twice as small as in the titanium-sapphire pumped configuration. A possible explanation is that the laser-diode beam is divergent whereas the titanium-sapphire beam is almost collimated in the active material.

In the Q-switched regime, 52ns FWHM pulses are obtained. In that case, the chopper disc presents three 0.5mm-width slits. The measured energy per pulse is 6.2μJ. Thus the peak power is 120W for a 650mW pump power level.

As shown in Fig. 2, the experimental data are well fitted in both cases by a rate equation analysis. This one differs from the model published by Laporta *et al.* [4] because it takes into account the nonconstant energy transfer between Er<sup>3+</sup> and Yb<sup>3+</sup>. As no shortening of the erbium <sup>4</sup>I<sub>13/2</sub> level lifetime was observed, the 'up-conversion' phenomenon is not considered in this model.

The thresholds are high because of the large intracavity spot size. The plano-plano cavity is only stabilised by the gain-guiding and/or the thermal lens. A planoconcave cavity with an appropriate radius of curvature might have a smaller spot size and lead to a smaller threshold [5]. However, this cavity configuration was not studied because a goal of this work is to make a microchip, and it is more difficult to make it with a planoconcave cavity configuration.

In conclusion, we have demonstrated a simple, efficient and compact Q-switched TEM<sub>00</sub> Er<sup>3+</sup>:Yb<sup>3+</sup> laser end pumped by a Ti:Al<sub>2</sub>O<sub>3</sub> laser and by a broad-area high-power laser diode. In both cases, the FWHM pulse duration is ~50ns and the peak power is > 100W.

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