Mechanically Q-switched co-doped Er-Yb glass laser under Ti:Sapphire and laser diode pumping

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A simple Q-switched TEM_{00} Er^{3+}, Yb^{3+}:glass laser end-pumped by a $Ti:Al_2O_3$ 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^{3+}, Yb^{3+} 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^{3+}:Yb^{3+} microlaser pumped by a $Ti:Al_2O_3$ 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^{3+} : Yb^{3+} : 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.

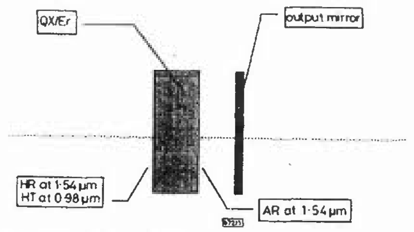

Fig. 1 *Longitudinal pumping scheme*

A 200mm lens focuses the $Ti:Al_2O_3$ laser operating at λ = 980nm 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^{3+},Yb^{3+}:glass laser is shown in Fig. 2 as a function of the pump power.

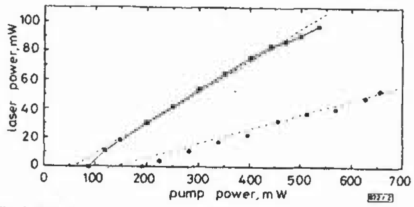

Fig. 2 *Output power against pump power*

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.

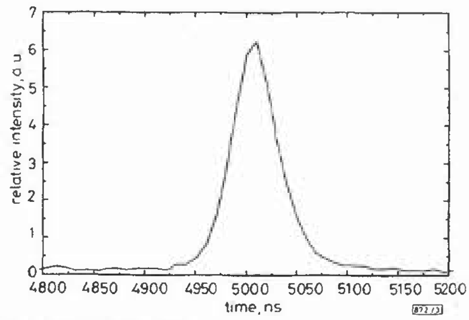

Fig. 3 *Temporal pulse shape*

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 be180 W. 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 (Φ = 200µm). 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^{3+} and Yb^{3+}. As no shortering of the erbium $^4I_{13/2}$ 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_{00} Er^{3+} : Yb^{3+} laser end pumped by a $Ti:Al_2O_3$ 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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