

# High power in-band pumped Er:YAG laser at 1617 nm

J. W. Kim, J. K. Sahu, W. A. Clarkson

Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK

Laser sources operating in the eyesafe wavelength regime around 1.5-1.6  $\mu\text{m}$  have applications in a number of areas including, remote sensing, ranging and free-space communications. For many of these applications, the requirement for high output power is often supplemented by the need for high efficiency and good beam quality. This combination of operating characteristics is very difficult to achieve in conventional diode-pumped solid-state lasers based on erbium doped crystals (sensitised with Yb) owing to the relatively high fractional heat loading which results from the large quantum defect ( $\sim 40\%$ ) and energy-transfer-upconversion. To alleviate this problem, attention has recently turned to singly-doped crystals (e.g. Er:YAG) and in-band pumping using an Er,Yb fibre laser. This approach has the advantage that most of the waste heat is generated in the fibre, which is largely immune to thermal effects, and quantum defect heating in the Er-doped crystal is very small ( $\sim 7\%$ ). Using this hybrid laser scheme, we have demonstrated  $\sim 60$  W of continuous-wave output from an Er:YAG laser at 1645 nm with a slope efficiency of 80 %<sup>1</sup>. However, for some remote sensing applications this operating wavelength is a little inconvenient, since there are atmospheric absorption lines due to methane which are in very close proximity necessitating careful selection and control of the lasing wavelength. Er:YAG also has a transition from the same upper level manifold ( $^4I_{13/2}$ ) at 1617 nm, which lies in a region of the spectrum where there are no atmospheric absorption lines. However, this transition has a much more pronounced three-level character and hence a much higher threshold pump power, so it has received little attention in spite of its obvious advantages for certain applications. Here, we report preliminary results for power scaling of an Er:YAG laser at 1617 nm in-band pumped by a high-power cladding-pumped Er,Yb fibre laser.

The Er,Yb fibre pump laser was constructed in-house with wavelength selection provided by an external cavity containing a diffraction grating in the Littrow configuration. The Er,Yb fibre laser was pumped by two 9-bar pump modules at 975 nm and produced up to 120 W of output in a beam with  $M^2 \approx 5$ . For efficient pumping of Er:YAG, the Er,Yb fibre laser operating wavelength was tuned to the absorption peak at 1532 nm. In this preliminary study, a simple four-mirror folded cavity was employed for the Er:YAG laser comprising a 29 mm long Er:YAG rod with 0.5 at.%  $\text{Er}^{3+}$  concentration mounted in a water-cooled aluminium heat-sink, a plane pump in-coupling mirror with high reflectivity at 1617 nm and high transmission at 1532 nm, two concave mirrors of 100 mm radius of curvature and high reflectivity at 1617 nm, a plane output coupler of transmission, 30% at 1617 nm, and a 100  $\mu\text{m}$  thick fused silica etalon. The latter was used to select the 1617 nm line and suppress oscillation on the higher gain 1645 nm line. Figure 1 shows the Er:YAG output power at 1617 nm as a function of pump power. The Er:YAG laser yielded a maximum output power of 23 W for 68 W of pump power from the Er,Yb fibre laser. The threshold pump power was 1.9 W and the slope efficiency with respect to incident pump power was 38%. To the best of our knowledge, this result represents the highest output power so far demonstrated from an Er:YAG laser at 1617 nm. Nevertheless, the performance is somewhat poorer than has been achieved at 1645 nm, and in Fig. 1 it can clearly be seen that the power is rolling over at pump powers over 60 W. This is probably due to increased re-absorption loss at higher pump power due to an increase in temperature. The use of an improved heat sinking-arrangement for the laser rod and a lower  $\text{Er}^{3+}$  concentration should alleviate this problem and open up the prospect of performance comparable to that at 1645 nm.

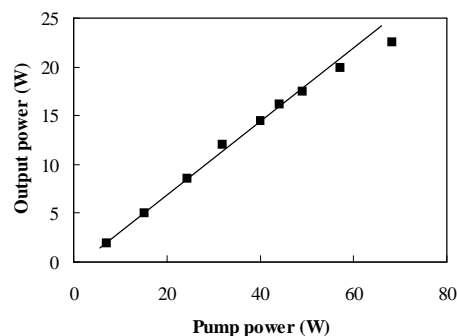


Fig.1: Er:YAG output power at 1617 nm versus pump power.

## References:

1. D. Y. Shen, J. K. Sahu, and W. A. Clarkson, "Highly efficient in-band pumped Er:YAG laser with 60 W of output at 1645 nm", *Opt. Lett.*, **31**, pp.754-757, 2006.