

## Q-SWITCHED AND SINGLE POLARISATION DIODE PUMPED Nd<sup>3+</sup> DOPED FIBRE LASERS

W.L.BARNES, J.T.LIN, L.REEKIE, D.J.TAYLOR,  
I.M.JAUNCEY, S.B.POOLE AND D.N.PAYNE.

### INTRODUCTION

Fibre lasers are attractive candidates as sources for fibre devices. Certain applications, such as distributed sensing, require short duration pulses of reasonable energy  $\sim 1\mu\text{J}$ : other applications, for example current monitors, require single polarisation operation. The work reported here demonstrates that both requirements can be met by diode pumped fibre lasers. Results are presented for Nd<sup>3+</sup> doped silica fibres, fabricated by the solution doping technique <sup>1</sup>.

### HIGH POWER Q-SWITCHED OPERATION

The experimental configuration is shown in Fig 1. The output mirror provides feedback and lasing action occurs when the acousto-optic deflector (AOD) is off: this is known as zero-order Q-switching.

~~Early results obtained using this method <sup>2</sup> were limited by CW~~ lasing action, which occurred when the AOD was in the on (ie, low Q) state, due to the low diffraction efficiency of the AOD used. An improvement in output power was obtained by moving to 1st order Q-switching. Here the output mirror is placed so as to feed back the 1st order deflected light, and laser output is taken from the un-diffracted beam. There can therefore be no CW lasing in the low Q state. This technique was used to produce pulses of 13.3 W and 120 ns <sup>3</sup>; the absorbed power was 15 mW at 825 nm, in 2.5m of fibre.

The lack of CW lasing in the 1st order configuration is bought at the expense of significantly increased intracavity loss. Higher powers using similar fibre can only be obtained by improving the diffraction efficiency of the AOD in the zero order configuration. Use of a more efficient modulator has recently allowed us to produce pulses of 21.4 W and 53 ns in zero order. A fibre length of 1.0 m was used, 8mW of 825 nm pump power being absorbed in the fibre. Further reductions in pulse width require the turn on time of the modulator to be reduced, and for the lasing cavity to be made shorter. The results mentioned so far were made on fibres with dopant concentrations of order 200 ppm, much above this clustering occurs.

To overcome these problems we co-doped the Nd<sup>3+</sup> with Al<sub>2</sub>O<sub>3</sub> allowing the fabrication of single mode fibre with 0.9 % wt concentration of Nd<sub>2</sub>O<sub>3</sub> in the core. This allows us to use a shorter length of fibre, since the absorption at the pump wavelength is much increased (72dB/m vs 6dB/m). The fibre still has a relatively low loss at the lasing wavelength (1063nm) of approx 0.3dB/m. The output lens of fig 1 was replaced with a grin-rod, thus reducing the beam diameter and hence the turn on time of the modulator. The diffraction efficiency of the AOD was measured in the cavity to be 55%. The output mirror had a reflectivity of 50% and 0.17m of fibre

The authors are with the Optical Fibre Group, Department of Electronics and Computer Science, The University, Southampton.

was used, the open part of the cavity being 0.2m. An index guided, single stripe laser diode (Sony SLD 204V) allowed 11mW of pump power to be absorbed in the fibre at 826 nm. Such a set up produced pulses (fig 2) of 110 W peak power and 15.5 ns duration: the repetition rate was 800 Hz.

#### SINGLE POLARISATION OPERATION

It has recently become possible to incorporate integral, low-loss, fibre polarisers into fibre lasers <sup>4</sup>. Such polarisers poses low insertion loss and a high polarisation extinction ratio. A fibre laser with an integral polariser has only one polarisation eigen-axis, there being too much loss on the orthogonal axis to allow lasing. Results of both CW and Q-switched operation are presented here, for a diode pumped fibre laser. The experimental configuration used was similar to that of fig 1, the AOD being removed for CW measurements. In addition a half wave plate was used to control the polarisation of the launched pump light and a polarizer was placed in front of the detector. With the launched pump light polarised parallel to the eigen-axis an extinction ratio of 20 dB was measured for the fibre laser, the emission also being polarised parallel to the eigen-axis; emission perpendicular to the eigen-axis contained only fluorescence. This extinction ratio was obtained with the fibre laser well above threshold.

---

Insertion of an AOD into the cavity allows Q-switching of the fibre laser to be performed. With the pump light polarised parallel to the eigen-axis, an extinction ratio of 29.3 dB was measured. This improvement in extinction ratio over the CW case arises because of the increased power of the laser light in Q-switched operation, whilst there is still only fluorescence on the perpendicular axis. Pumped on axis a peak power of 3.9 W and a duration of 150 ns were obtained. It is anticipated that use of the higher doped fibre and improved experimental configuration (as detailed in the previous section) should allow significant improvements in the single polarisation Q-switched operation.

#### CONCLUSION

Optimisation of the laser cavity and improvements in fibre fabrication have allowed for the production of high power, short duration pulses from a diode laser pumped fibre laser. In addition we have shown that such lasers may be operated as single polarisation devices. The results demonstrate the viability of Q-switched, diode laser pumped fibre lasers as sources for both sensors and nonlinear optics.

#### ACKNOWLEDGEMENTS

This work was carried out with the assistance of funding from Amoco Research whose support is gratefully acknowledged.

## REFERENCES

1. J.E.Townsend, S.B.Poole and D.N.Payne:  
"Solution doping technique for the fabrication of rare-earth doped fibres",  
Electron. Lett. 23, 1987, pp 329-333
2. I.M.Jauncey, J.T.Lin, L.Reekie and R.J.Mears:  
"Efficient diode-pumped CW and Q-Switched single-mode fibre laser",  
Electron. Lett. 22, 1986, pp 198-199
3. L.Reekie, I.M.Jauncey and D.N.Payne:  
"Near optimum operation of a diode pumped fibre laser",  
ECOC Tech Digest Vol 1, 1987, pp 105-108
4. J.T.Lin, L.Reekie and L.Li  
"Single polarization operation of a Nd<sup>3+</sup>-doped single mode fibre laser",  
CLEO Technical proceedings, 1987, pp 358-360

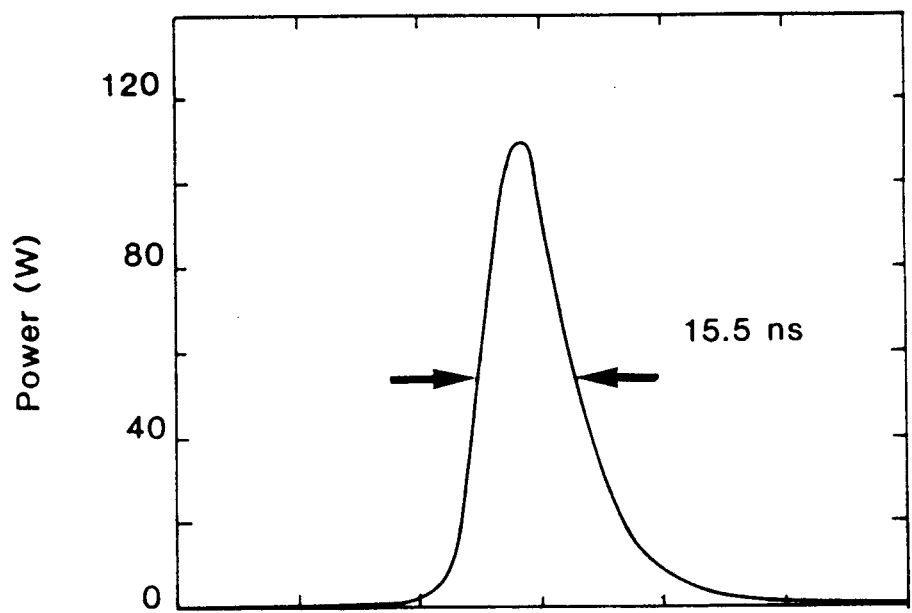
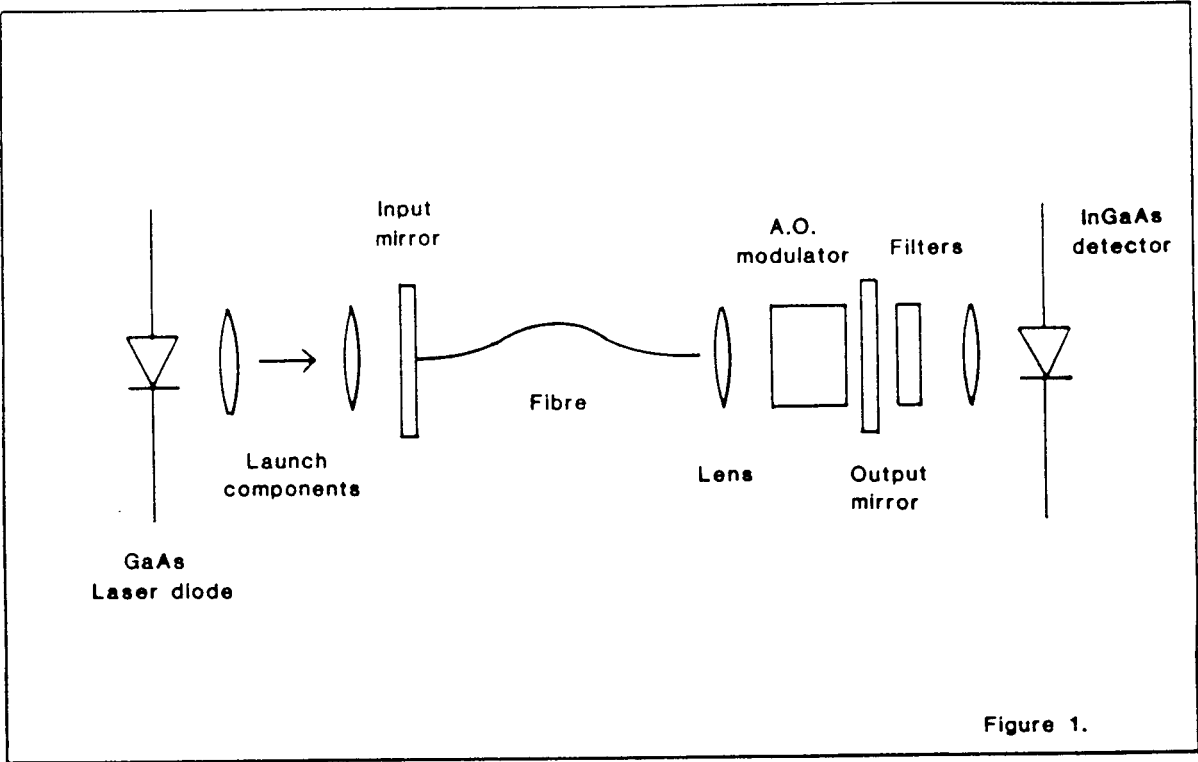


Figure 2