IEE Colloq. 1986

A DIODE PUMPED SINGLE-MODE FIBRE LASER.

I.M. Jauncey, J.T. Lin, L. Reekie, R.J. Mears and D.N. Payne.

Fibre lasers present numerous advantages over other lasers not only in terms of low threshold, efficiency and low operating power but also with respect to their compatibility with standard single-mode fibres. Lasing action has been demonstrated in rare-earth doped silica single-mode fibres[1] with both semiconductor laser[2] and argon ion/dye laser[3,4] pump sources.

Semiconductor laser-diode pumping is highly convenient both in terms of cost and operational requirements. We describe here the characteristics of a single-mode Nd^{3+}-doped fibre laser operating at 1.088μm.In particular results are presented for CW, Q-switched and mode-locked operation.

Experiment.

In any laser configuration it is necessary to minimise non-useful cavity losses and for CW action this is done by using the butted arrangement shown in Fig. 1. The fibre used had negligible loss at the lasing wavelength and so the cavity length was chosen to absorb most (>95%) of the pump energy. For the fibre used (3.5μm core diameter, dopant concentration 330ppm) this corresponded to a length of about 3m. The fibre ends were cleaved and butted to dielectric mirrors. The input mirror was chosen to have a high transmission (T=85%) at the pump wavelength and a high reflectivity (R=99%) at the lasing wavelength. The gain of the fibre was such that, of the mirrors available, a mirror having a transmission of 65% coupled out maximum power.

A single-mode GaAlAs laser (Hitachi HLP 1400) with a maximum power of 20mW was used as the pump source and, using microscope objectives, about 6mW could be launched into the fibre. The pump wavelength was 826nm corresponding to an absorption band in Nd^{3+}ions in glass. The lasing characteristic is shown in Fig. 2. The threshold for lasing action was 2.6mW absorbed and a slope efficiency of 33% was obtained.

Q-Switched Operation.

For both Q-switched and mode-locked operation it was necessary to modulate the cavity finesse and this was achieved[6] by adopting the arrangement outlined in Fig. 3. The presence of intra-cavity components inevitably increased the cavity loss (the greater part of the CW loss arising from the microscpe objective rather than the acousto-optic deflector), yet the CW threshold was only slightly higher at 3.7mW absorbed. For Q-swtching the acousto-optic deflector was used in zero-order mode, the high-Q state being achieved by electronically removing the applied RF with 2μs duration pulses.

The authors are with the Optical Fibre Group, Dept of Electronics, The Univeristy, Southampton, SO9 5NH.

A typical Q-switched pulse, obtained using an output mirror of 12% transmission at the lasing wavelength, is shown in Fig. 4. The absorbed pump power was 5.6mW. There was no change in peak output power or pulse duration when the pulse repetition rate was varied form single-shot to 4kHz. The maximum peak power was limited by residual CW action, caused by the failure of the deflector to hold off lasing action even during the low-Q ("off") states.

A mechanical chopper having a mark-space ratio of 1:300 in place of the acousto-optic deflector provided an alternative method of Q-switching. Using an output mirror with a transmission of 65% at the lasing wavelength, output pulses of peak power greater than 300mW and FWHM of 500nS at a repetition rate of 400Hz were then obtained.

Mode-Locking.

Using an acousto-optic mode-locker operating at 49.9MHz allowed some mode-locking of the laser to be obtained. The output mirror was placed on a translation stage to provide convenient adjustment of the cavity length and hence bring the inter-modal frequency into resonance with the mode-locker. The mode-locker frequency limited the maximum length of fibre within the cavity to about 87cm, which absorbed 50% of the pump light. In order to obtain greater gain it was necessary to use a fibre of length 2.0m, absorbing some 90% of the pump energy. This corresponded to mode-locker interaction between adjacent but one modes. Some typical, partially mode-locked, pulses are shown in Fig 5. The maximum peak power was about 9mW with a 2nS FWHM. This peak power and FWHM are not characteristic of other solid-state laser mode-locked pulses and indicate that more study of this device is required.

Conclusions.

Efficient laser action in a single-mode Nd^{3+}-doped fibre laser using a GaAlAs diode source has been demonstrated. An output power in excess of 1mW for 5.6mW pump absorbed was obtained. Insertion of an acousto-optic device in the cavity allows for Q-Switched and mode-locked operation. Pulses of over 300mW peak power with a FWHM of 500nS were produced in Q-switched operation while mode-locking gave pulses of about 10mW peak power and 2nS FWHM, uncharacteristic of other solid state lasers.

Acknowledgements

We would like to thank S.B. Poole for supplying the Nd^{3+}-doped fibre. A CASE studentship (IMJ) was provided by Plessey Research (Caswell) Ltd. The work was supported by the Science and Engineering Research Council under the JOERS programme.

References

1. Poole, S.B., Payne, D.N. and Fermann, M.E.:"Fabrication of low-loss optical fibres containing rare-earth ions", Electron. Lett., 1985, 21, pp 737-738.

2. Mears, R.J., Reekie, L., Poole, S.B. and Payne, D.N.:"Neodymium-doped silica single-mode fibre lasers", Electron. Lett., 1985, 21, pp 738-740.

3. Mears, R.J., Reekie, L., Poole, S.B. and Payne, D.N.:"A low-threshold tunable CW and Q-switched fibre laser operating at 1.55um", Electron. Lett., 1986, 22, pp 159-160.

4. Reekie, L., Mears, R.J., Poole, S.B. and Payne, D.N.:"Tunable single-mode fibre lasers", submitted to IEEE Journal of Lightwave Technology.

5. Alcock, I., Tropper, A., Ferguson, A.I. and Hanna, D.C.:"Q-switched operation of a neodymium-doped fibre laser", Electron. Lett., 1986, 22, pp 84-85.

6. Jauncey, I.M., Lin, J.T., Reekie, L. and Mears, R.J.:"Efficient diode-pumped CW and Q-switched single-mode fibre laser",Electron. Lett., 1986, 22, pp 198-199.

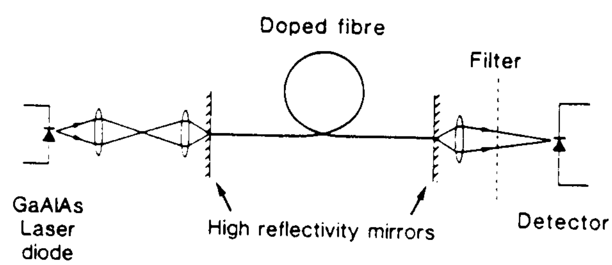
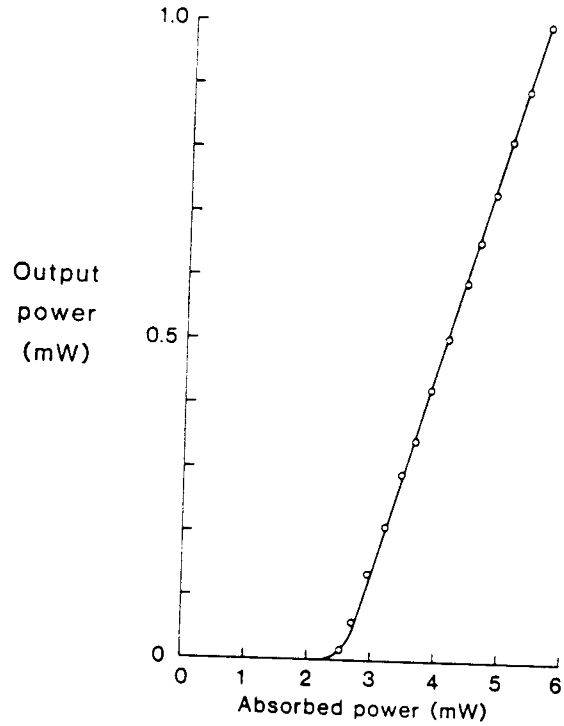


Fig. 1. CW experimental Arrangement.

Fig. 2.
CW characteristic.



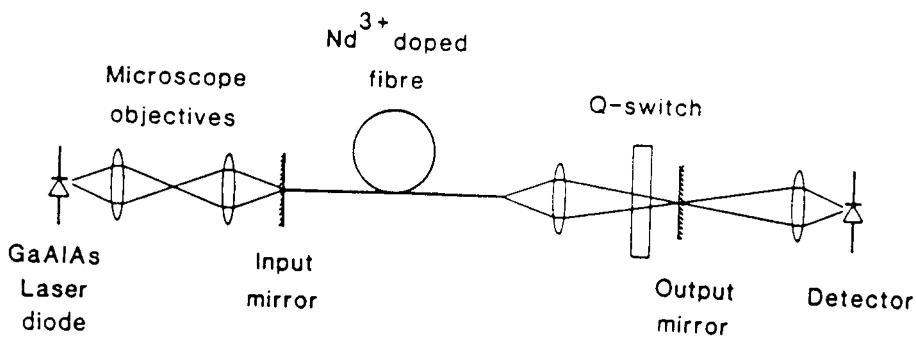


Fig. 3. Q-switched experimental arrangement.

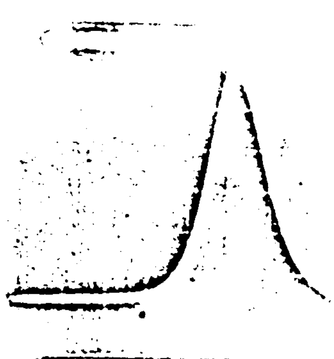


Fig. 4.
Typical Q-switched pulse.

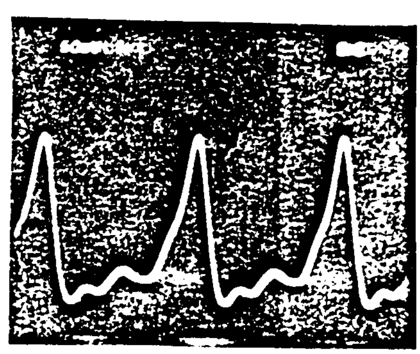


Fig. 5.
Typical mode-locked pulses.