9:30 am

CWE7 Very low threshold laser operation of an epitaxially grown Nd:YAG waveguide

D. P. Shepherd, S. J. Field, D. C. Hanna, A. C. Large, A. C. Tropper, I. Chartier,* B. Ferrand,* D. Pelenc,* *Department of Physics and Optoelectronics Research Centre, University of Southampton, Southampton S09 5NH, U.K.*

The use of optical waveguide geometries to maintain small spot sizes/high intensities over relatively long lengths can lead to high amplifications per unit pump power and low laser thresholds in laser-ion-doped materials. This has been successfully demonstrated in glass optical fibres,[1] and recently much work has been carried out on crystal host waveguides.[2,3] Here we report the fabrication and low threshold laser operation of a very low loss Nd:YAG planar waveguide grown by liquid phase epitaxy.[4]

A 38-μm deep layer of 1.5 at.% Nd^{3+}-doped YAG was grown on an undoped YAG substrate cut into 6-mm long pieces. The index difference between the (higher index) doped and undoped YAG is sufficient to form a planar optical waveguide. The laser cavity was formed by butting plane dielectric mirrors directly onto the polished end-faces of the waveguide. These lightweight mirrors were held in place by the surface tension of a drop of fluorinated liquid. Initial tests were carried out using an R6G dye laser as the pump source, tuned to the strong Nd^{3+} absorption around 590 nm. Using high reflectivity mirrors an end launched threshold pump power of 0.67 mW was obtained (assuming 100% launch efficiency). The 6-mm long waveguide absorbs virtually all this light.

The output was in the fundamental mode of this multimode guide, with a 14-μm spot size ($1/e^2$ half width of intensity) measured perpendicular to the guiding layer. This is in fair agreement with a calculated value of 16.5 μm in which we assumed an index difference of 0.06%, which is the quoted value,[5] for 1 at.% Nd^{3+}-doped YAG. From the observed laser threshold and the measured pump and signal spot sizes, we can put an upper limit on the propagation loss of 0.05 dB/cm. This is less than the best losses reported for Nd:YAG crystal fibers,[3] and approaches that of bulk Nd:YAG.[6]

Diode-pumped operation has also been demonstrated using a single-mode 100-mW GaAAs diode laser (SDL-5412-H1). Using a nominally 83% reflectivity output coupler we obtained the results shown in Fig. 1. A best fit to the experimental points gives a slope efficiency with respect to launched power (assuming 100% launch efficiency) of 40±3%. The threshold is consistent with the losses being dominated by the mirror transmission.

Directly coating the end-faces and optimization of the guide depth and index difference should further improve upon the waveguide laser performance we have obtained to date. Production of channel waveguides, possibly by etching techniques, could also give considerable improvement if the low loss can be maintained. As there are many alternative laser transitions for YAG doped with Nd^{3+} and many alternative dopants, such as Er^{3+}, Tm^{3+}, Cr^{4+}, etc., it is clear that potentially a wide range of different lasers could benefit from this epitaxial waveguiding arrangement. Since the epitaxial growth technique should be applicable to other host crystals, the scope for development is extremely wide indeed.

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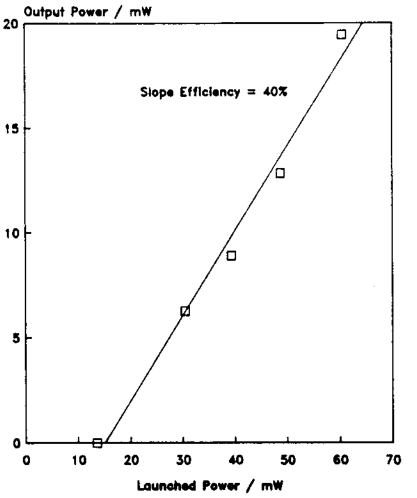
1. P. W. France, (Ed.). *Optical Fibre Lasers and Amplifiers* (Blackie, London, 1991).
2. S. J. Field, D. C. Hanna, A. C. Large, D. P. Shepherd, A. C. Tropper, P. J. Chandler, P. D. Townsend, and L. Zhang, "An ion-implanted Nd:GGG channel waveguide laser," to be published, Opt. Lett.; S. J. Field, D. C. Hanna, A. C. Large, D. P. Shepherd, A. C. Tropper, P. J. Chandler, P. D. Townsend, and L. Zhang, "A low threshold ion-implanted Nd:YAG channel waveguide laser," to be published, Electron. Lett.; E. Lallier, J. P. Pochelle, M. Papuchon, M. de Micheli, M. J. Li, Q. He, D. B. Ostrowsky, C. Grezes-Besset, and E. Pelletier, IEEE J. Quantum Electron. **QE-27**, 618 (1991); R. Brinkmann, W. Sohler, and H. Suche, Electron. Lett. **25**, 985 (1989).
3. M. J. F. Digonnet, C. J. Gaeta, D. O'Meara, and H. J. Shaw, J. Lightwave Technol. **LT-4**, 642 (1987).
4. D. Pelenc, B. Chambaz, I. Chartier, B. Ferrand, J. C. Vial, paper E40, Laser M2P Conference, Grenoble, 1991.
5. A. A. Kaminskii, *Laser Crystals* (Springer-Verlag, New York, 1981), Vol. 14, pp. 321.
6. T. Nishimura and T. Omi, Jap. Jnl. Appl. Phys. **14**, 1011 (1975).



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