SINGLE–POLARISATION FIBRE LASER INCORPORATING AN IN–LINE METAL–PLATED POLARISER

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For many applications the realisation of a practical single–polarisation single–mode (SPSM) fibre laser is of considerable interest. In this paper we report an in–line metal–plated fibre polariser technique for making SPSM fibre lasers. The corresponding theory, design method and experimental results are also presented.

Theory

Based on existing laser theory and a knowledge of the polarisation anisotropy of rare–earth ions in a glass matrix, a theoretical model analysing the polarisation effects in fibre lasers has been developed[1,2].

Experimentally we have found that the polarisation state of a fibre laser output depends strongly on the orientation of the (linearly–polarised) pump source, an unexpected result. Since a fibre laser can have two orthogonally–polarised eigenmodes[1], we define the polarisation efficiency η, as:

$$\eta = \frac{p^x}{p_{ab}} \tag{1}$$

where p_{ab} is the total absorbed pump power, and p^x is the fraction of p_{ab} which contributes to the operating polarisation mode, say the x–mode. The efficiency η is a function of the polarisation anisotropy of the active ions, as well as the launching orientation angle α of the linearly–polarised pump light to the birefringent axes of the single–mode fibre cavity. Figure 1 theoretically compares the polarisation efficiency of Nd^{3+} and Er^{3+} –doped SPSM fibre lasers having intra–cavity polarisers with a fibre laser having a polariser located outside the cavity. The experimental results for a Nd^{3+} –fibre laser are also shown. It can clearly be seen that the SPSM fibre laser offers a much higher polarisation efficiency. This is because a higher proportion of the total population inversion of excited ions has contributed to the operating polarisation if the undesired polarisation component has been suppressed within the resonator.

Construction

The doped fibre is polished on a motor–driven polishing wheel impregnated with diamond particles until access to the evanescent field has been achieved[3]. After further polishing in a cerium oxide suspension to eliminate surface roughness an optically thick aluminium coating, (approximately 300 nm), is evaporated to form the polariser.

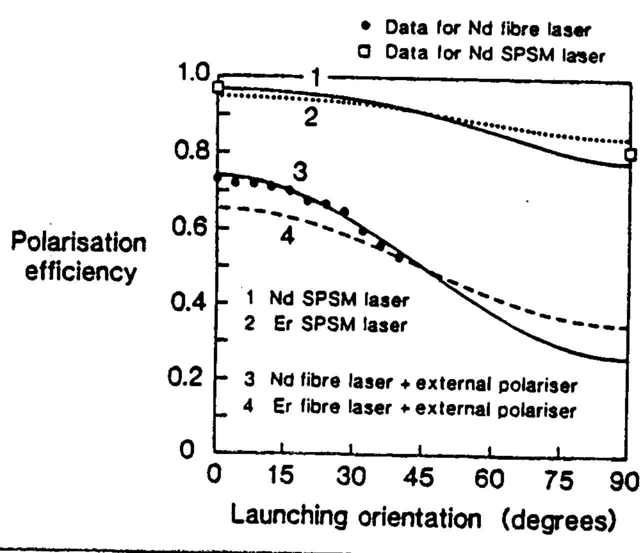

Fig.1 Polarisation efficiency as a function of pump launching orientation, showing a higher polarisation efficiency for SPSM fibre lasers.

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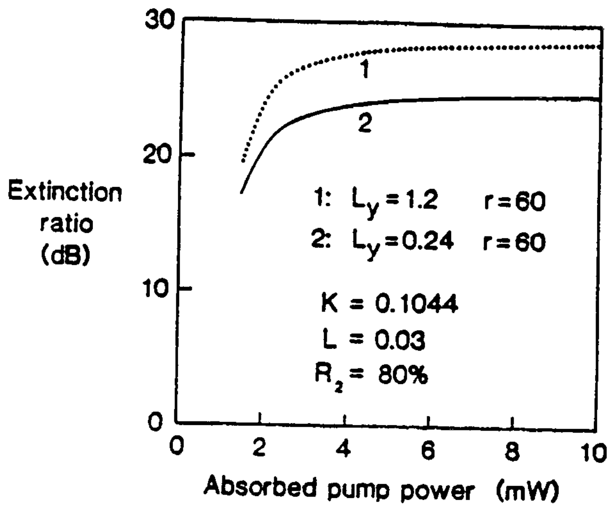

Fig.2 Theoretical curves of extinction ratio as a function of absorbed pump power for two sets of integral polariser parameter.

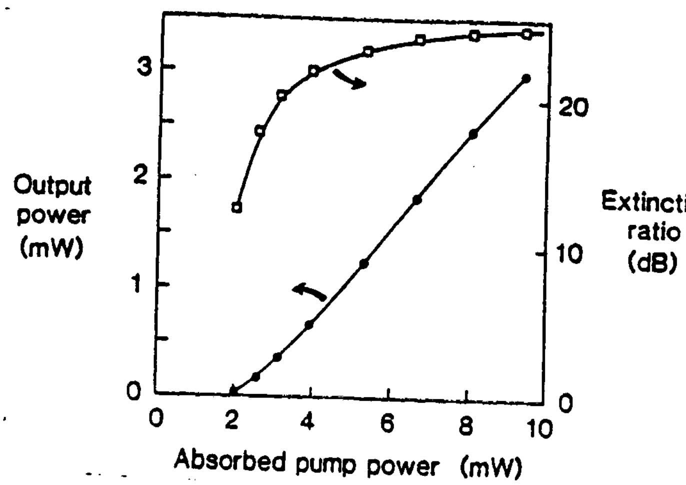

Fig.3 Experimental characteristics of a LD-pumped Nd^{3+} -doped fibre laser using an Al-plated integral polariser.

Previous reports of SPSM fibre lasers have employed special D–shaped doped fibres or doped fibres with hollow sectors closed to the core[1]. Such fibres are very difficult to cleave. The above approach is believed to be superior since it employs fibres of conventional design leaving the fibre ends unaffected thus alleviating the problem of cleaving.

Design

The performance of the fibre polariser is described by the insertion loss of the undesired y–mode L_y, and the attenuated ratio r of the y– and x–modes, $r = L_y/L_x$, which is a function of the metal used. L_y is proportional to the metal length and depends on the normalised separation d/a, where a is the core radius and d is the distance between the metal surface and the core centre. The minimum L_y required for a given absorbed pump power is given by

$$L_y \geq 2KP^y - L + \ln R_2 \tag{2}$$

where p^y is the effective absorbed pump power[2] for the y–mode, L is the intrinsic cavity loss, which is identical for both x and y–mode, R_2 is the reflectivity of the output mirror, K is the laser parameter[4] related to pumping efficiency, saturation density and the cross–sectional area of the fibre cavity. Both L and K can be determined experimentally[4].

In practice, the extinction ratio of the output from a SPSM fibre laser is limited by the superfluorescence of the unwanted polarised mode. Increasing L_y leads to a higher extinction ratio, at the expense of less output power. Figure 2 shows calculated curves for a LD–pumped SPSM laser for two different L_y.

Results

A laser–diode pumped SPSM fibre laser incorporating an aluminium plated in–line polariser has been realised. The pump source was a GaAlAs LD operating at 825 nm. The laser cavity was formed by 26 cm Nd^{3+} doped single–mode fibre. The output mirror had an 80% reflectivity at the lasing wavelength of 1.088 μm. The effective interaction length of the metal–plated polariser was 15 mm. At a 10 mW level of absorbed pump power a CW output of 3 mW, a 25 dB polarisation extinction ratio and a 37% slope efficiency have been obtained, as shown in Figure 3.

References

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