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CONTINUOUS-WAVE OSCILLATION OF A MONOMODE YTTERBIUM-DOPED FIBRE LASER

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INTRODUCTION

The last few years have seen intense interest and activity in the field of rare earth doped monomode fibre lasers and amplifiers [1,2],since these components could be used in fields as diverse as medicine and communications. Furthermore their small active volume offers a number of important advantages over conventional bulk glass lasers.

We have chosen to investigate ytterbium doped fibre as it provides a very "clean" system (*ie* free from excited state absorption. Apart from the energy levels around 11,000cm^{-1} there are no other levels until the ultra-violet). The ytterbium fibre laser should therefore offer a good system on which to test some of the basic physics of fibre lasers. In addition it offers 3-level, 4-level and quasi 3-level laser transtions. Published work on ytterbium doped glass lasers in bulk form has been sparse with the main publication being that of Snitzer [3].

In this paper we describe the characteristics of an ytterbium-doped, silica based, monomode fibre laser operating at discrete wavelengths in the range 1035nm to 1076nm.

EXPERIMENTAL

The experimental arrangement used for these measurements is illustrated in figure 1. The pump source was provided by a cw Styryl 9M dye laser operating at around 840nm. Longer pump wavelengths would be more suitable, but since our intention was to simulate the performance achieveable using diode lasers we chose 840nm as this is the longest wavelength commercially available from GaAlAs diode lasers.

A three mirror cavity was used in which optimum pump launch was achieved through the use of an extra-cavity lens (f = 50cm) and an intra-cavity gradient index (GRIN) lens. Due to chromatic aberration in the GRIN lens the fluorescence wavelengths would not be relaunched unless a third mirror was included at the approximate location of the beam waist to correct for this. The input mirror had a transmission of 93% for the pump band, and a reflectivity of 99% for the lasing wavelength. The output coupler and third mirror had transmissions of 20% and <1% respectively for the laser, and >80% for the pump.

The fibre used in these experiments was fabricated using a solution doping technique [4], allowing a relatively high dopant concentration of 2500ppm. The fibre had a numerical aperture of 0.16 and a cut-off wavelength of 780nm, which implies a core diameter of around 4μm. The ends of the fibre were prepared by several different methods with the best results coming from the use of a mechanical cleaver.

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Figure 2 shows the approximate mean energies of the inhomogeneously broadened Stark levels of the $^2F_{5/2}$ and $^2F_{7/2}$ multiplets of ytterbium in fused silica. At room temperature around 1% of the ytterbium ions will occupy the thermally excited 830cm^{-1} Stark level. This population causes a significant reabsorption loss which limits the length of fibre that can be used. Most of these experiments used a 2.8m length of doped fibre on the basis of a calculation of the length needed to optimize the gain produced from the available pump power.

RESULTS

Laser action has been observed at a range of wavelengths from 1035nm to 1084nm. The present cavity has no intentionally wavelength selective elements, so emission is generally on a discrete line, or sometimes more than one line, at a wavelength determined by the focusing of the optical cavity, the length of the fibre, and the spectral reflectivity of the output coupler. Between 1044nm and 1076nm the output wavelength can be "tuned" in a stepwise fashion by adjusting either the input or output focus conditions, exploiting the chromatic aberration of the intra-cavity GRIN lenses. Operation at shorter wavelengths was obtained using an output coupler with a higher transmission at wavelengths longer than 1044nm, and a reduced fibre length of approximately 0.3m. Emission at 1084nm was observed with the pump tuned around 850nm, but with the main emission still centred at 1076nm. These results suggest that inclusion of a suitable tuning element in the cavity would enable continuous tuning to be achieved over a broad range.

The threshold for laser operation at 1076nm was 24mW of absorbed power and a slope efficiency of 4.3% was measured at this wavelength. It should be noted however that the three mirror cavity had a large loss, 54% as measured by a relaxation oscillation method [5]. The merit of this cavity configuration was that it could be used with prototype fibre with ends of unavoidably poor optical quality. As soon as better quality ytterbium fibre becomes available the performance of a more conventional cavity in which the fibre ends are butted to the mirrors will be investigated. Significantly lower threshold, (approximately 1-2mW) and higher slope efficiencies can be expected from such a device.

CONCLUSION

Laser action has been observed in an ytterbium doped fibre at discrete wavelengths over a 50nm range, indicating that a broad band tunable laser device may be based on this system. The results show that it should be possible to pump ytterbium doped fibre with a diode laser, and future work will attempt to demonstrate this experimentally.

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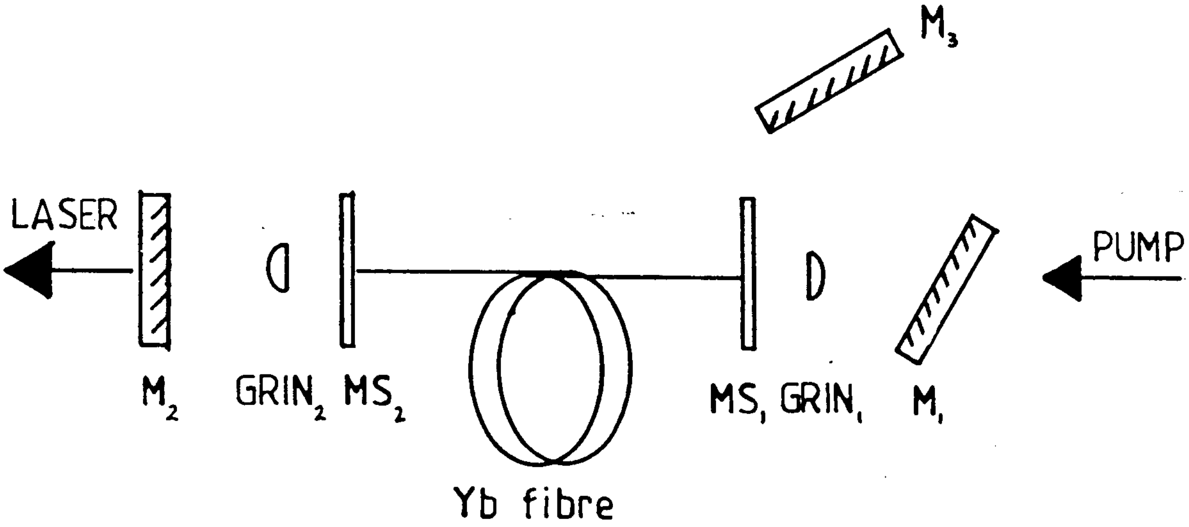

Fig.1 Experimental arrangement for the Yb fibre laser

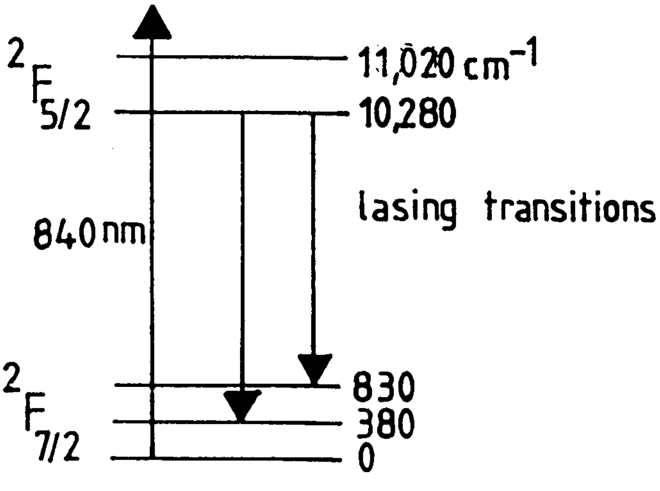

Fig.2 Energy level diagram for Yb in a silica host