H283

ERBIUM-DOPED FIBRE SUPERFLUORESCENT SOURCE FOR THE FIBRE GYROSCOPE.

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ABSTRACT

The operation of an erbium-doped silica fibre as a superfluorescent source at 1.535μm pumped at 980nm is reported. The variation of superfluorescent output power with pump power and fibre length is characterised. The spectrum of the superfluorescent emission is seen to be dependent on fibre length , pump power and fibre temperature. However, under certain operating conditions, good spectral stability with pump power and fibre temperature can be obtained.

INTRODUCTION

A broadband optical source capable of providing several milliwatts of power in a single transverse mode is of interest for a number of optical sensor applications, in particular for the fibre-optic gyroscope (FOG). In the gyro application, use of a broadband source is a well-known means of reducing gyro bias introduced by coherent backscatter and the optical Kerr effect[1]. Superfluorescent emission from neodymium-doped silica fibres and its potential for a gyro source has been previously investigated[2,3]. As well as increased power, the advantage of using rare-earth doped fibres over semiconductor superluminescent diodes rests primarily in greater spectral stability with respect to temperature[3]. This factor directly determines gyro scale-factor stability (defined as output over rotation rate) and is a critical performance criterion for the FOG. Potential advantages of the erbium system over neodymium include increased gain and hence higher output powers for a given pump power, and operation at a wavelength more compatible with telecommunications technology. In addition, the 1.54μm wavelength has advantages of decreased sensitivity to irradiation of the fibre, lower fibre/integrated optics loss and a higher integrated optics damage threshold. Coherent Rayleigh backscatter is also considerably reduced at the 1.54μm wavelength compared to 1.06μm, and the photon energy is lower so improving the shot noise limit.

A qualitative investigation of the amplified spontaneous emission (ASE) spectrum as a function of pump power and fibre length has previously been reported by Desuvire et al[4]. This work showed that the difference in absorption and emission spectra inherent in the 3-level erbium system gives rise to variations in emission spectra with fibre length and pump power. The latter effect suggests poor spectral stability and that the erbium-doped fibre superfluorescent source is poorly suited to the FOG.

In this paper we investigate the practicality of erbium doped fibres as a superfluorescent sources when pumped at 980nm. Particular attention is applied to spectral stability with pump power and temperature in order to determine whether a spectrally-stable device can be fabricated. Surprisingly, it is found that under certain operating conditions the source has excellent wavelength stability.

EXPERIMENTAL

Fig. 1 shows the experimental set-up used. A 10m length of Er^{3+} doped germano silicate fibre (NA 0.17, cutoff 925nm, Er^{3+} dopant concentration 60 ppm) was butted up to a dielectric mirror which had greater than 99% reflectivity at 1.55μm, but transmitted 85% at 980nm. The other end of the fibre was carefully terminated in an index-matching cell in order to prevent laser oscillation in the fibre. The fibre was successively cut back and at each length the variation of output power with pump power at both room and liquid nitrogen fibre temperatures was recorded using a germanium PIN detector. It was found necessary to slightly angle the detector in order to prevent feedback and laser oscillation from the detector surface under conditions of heavy pumping. In addition, emission spectra were recorded using an Anritsu optical spectrum analyser at resolutions down to 0.1nm and the data stored on computer for processing. The pump source used in the experiments was a Styrl-13 dye laser tuned to 980nm pumped with a 6W argon-ion laser. Using this set up a maximum of approximately 35mW could be coupled into the fibre. The emission spectra were numerically integrated to give a value for the weighted mean wavelength according to the relation:

$$\bar{\lambda} = \frac{\int a(\lambda).\lambda \, d\lambda}{\int a(\lambda) \, d\lambda}$$

where $a(\lambda)$ represents the magnitude of the signal at wavelength λ.

RESULTS

Fig. 2 shows the superfluorescent output power as a function of fibre length with the fibre at room temperature for a number of different pump powers. An optimum length for maximum output power clearly exists with the optimum length increasing slightly with pump power. The maximum output power is seen to be in excess of 2mW for 33mW of launched pump power.

For the 6m fibre length, fig. 3 shows the variation of signal output power and optical bandwidth as a function of launched pump power at room temperature. Above 15mW launched pump power the characteristic is seen to saturate from the expected exponential input/output relation and the optical spectrum tends asymptotically to around 2nm. The superfluorescent output of the fibre was observed to be randomly polarised within the limits of experimental error.

Fig. 4 indicates the variation of $\bar{\lambda}$ with pump power for the 6m fibre length. At low levels of pump power, the long wavelength edge of the gain spectrum dominates the ASE spectrum, consistent with quasi 4-level like behaviour[4]. However as the pump power is increased, $\bar{\lambda}$ is seen to tend towards 1.535μm, which corresponds with the peak of the fluorescence emission in this fibre type. Note also that at the lower pump-power levels the spectrum is seen to be significantly different for 77K and room temp. operation, consistent with redistribution of the populations of the Stark components of the energy levels. However, at the higher pump levels, the peak of the gain curve dominates and we may assume that this peak corresponds to only 1 Stark component of the transition. This effect clamps the spectrum at a particular wavelength relatively independent of temperature and pump power.

CONCLUSIONS

The implementation of an erbium doped silica fibre superfluorescent source emitting >2mW @ 1.535μm when pumped at 980 nm has been shown. Examination of the emission spectrum shows a spectral width around 2nm for output powers in excess of approx 100μW, corresponding to one Stark transition. Cooling the fibre to 77K indicates that under high gain operating conditions temperature may only affect the output spectrum by ~10ppm/°C, a figure far superior to that of an ELED (~300 ppm/°C)..

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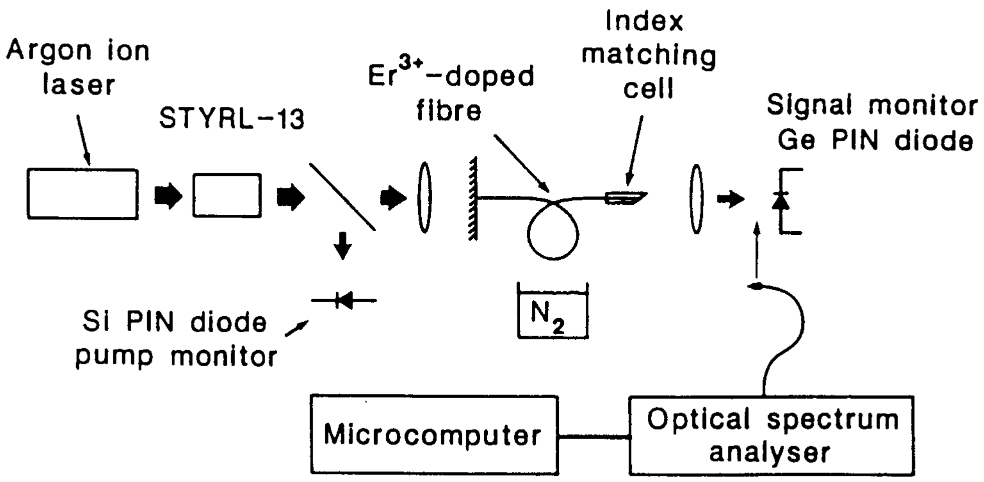

Fig. 1. Experimental set-up.

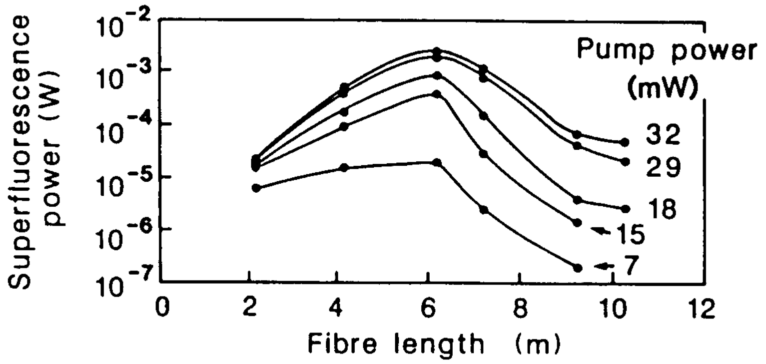

Fig. 2. Superfluorescent output power vs fibre length for a number of pump powers.

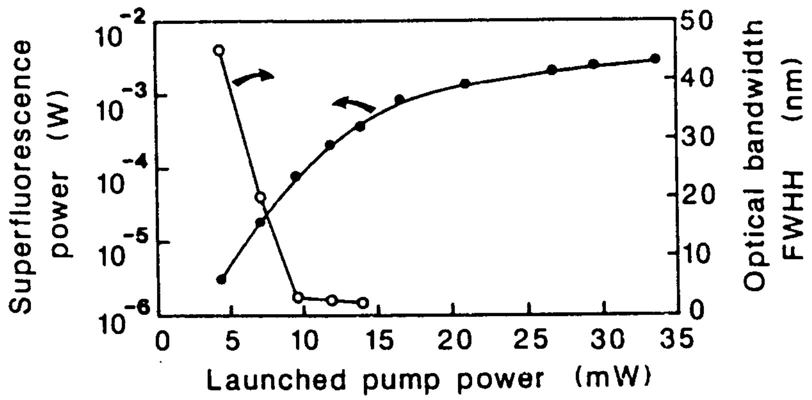

Fig. 3. Superfluorescent output power @ 1.54μm and optical bandwidth vs pump power. 6.2m fibre length.

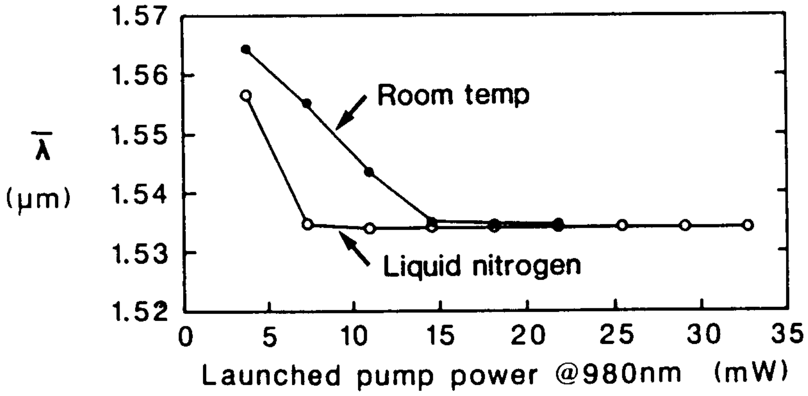

Fig. 4. Weighted mean wavelength vs pump power 6.2m fibre length. Fibre at room temp. & 77K.