NARROW-LINEWIDTH FIBRE LASER WITH INTEGRAL FIBRE GRATING

Indexing terms: Lasers and laser applications, Optical fibres

The fabrication and operation of an Nd^{3+}-doped silica single-mode fibre laser using a distributed fibre grating as the feedback element is reported. The laser had a threshold of less than 2 mW, a slope efficiency of 19% and an output bandwidth at the lasing wavelength of 1·084 μm of 16 GHz, significantly narrower than the conventional cavity design.

Introduction: Rare-earth-doped silica single-mode fibres[1] have been used to construct a number of reliable, solid-state and potentially very cheap laser devices.[2] The small active volume allows for efficient longitudinal pumping, and both semiconductor[2,3] and ion/dye[2,4] laser pump sources have been used. Moreover, room-temperature CW operation of three-level laser systems is possible[4,5] with minimal thermal problems. Consequently, compact, widely tunable fibre laser sources are now available.[6]

A potential advantage of fibre lasers is their compatibility with a wide range of fibre devices, such as filters and polarisers. Until now, however, fibre lasers have all relied on bulk optic components for the high-reflectivity feedback element. In a step towards producing an all-fibre device, we report here the fabrication and characteristics of a single-mode rare-earth-doped fibre laser using a high-reflectivity, integral fibre grating to provide feedback.

Experiment: The fabrication method and the properties of high-efficiency fibre grating reflectors have been described previously.[7] A length of undoped, step-index single-mode fibre of 3·5 μm core and 0·21 NA was cemented into a preformed convex groove in a fused silica block and subsequently polished to within a few micrometres of the core. A periodic surface relief pattern was formed in a photoresist layer deposited on the polished surface of the fibre by standard two-beam interference lithography, and the corrugations transferred into the fibre by reactive ion beam etching. A thin layer ($\leq$90 nm) of aluminium oxide was deposited on to the surface of the grating and overlaid, in turn, with a low refractive index oil.

A number of gratings have been prepared by this method, differing in their peak reflectivities and Bragg reflection bandwidths. The spectral reflection characteristics of a typical grating, similar to the device used in the work described here, was measured using a monochromator with 0·5 nm resolution, and is shown in Fig. 1. The grating was produced with a 400 cm radius of curvature groove and had 70% reflectivity at 1092 nm centre wavelength with FWHM bandwidth 1·9 nm, using an overlayer oil of refractive index 1·420. Other gratings, having up to 95% reflectivity and 0·8 nm FWHM bandwidth, have also been successfully fabricated.

The experimental arrangement is shown in Fig. 2. A single-mode GaAlAs semiconductor laser (Sharp LT015) emitting at 830 nm was used as the pump source. To absorb most of the pump energy at this wavelength, a 6 m length of fibre was used. The input mirror was chosen to have a large reflectivity (99%) at the lasing wavelength and a large transmission (85%) at the pump wavelength in order to couple in maximum pump power while maintaining the cavity finesse.

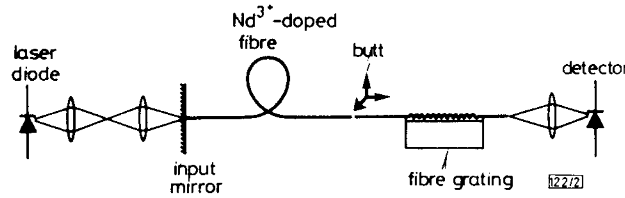

Fig. 2 *Experimental configuration of fibre laser using fibre grating*

The doped fibre (3·5 μm core diameter, 0·21 NA, 330 pm Nd^{3+}) was cleaved and butted at one end to the input mirror and at the other end to the input fibre of the grating. Since, for experimental convenience, the grating fibre was not fusion-spliced to the doped fibre, etalon effects were observed at the butt between the doped fibre and grating fibre ends. These could be eliminated by placing a drop of index-matching oil on the butt.

The output spectrum of the fibre laser was obtained using a Fourier-transform Michelson interferometer. As expected, the lasing wavelength (1084 nm) was coincidental with the peak reflectivity of the fibre grating. In the frequency domain the output was found to have an approximately Gaussian profile,

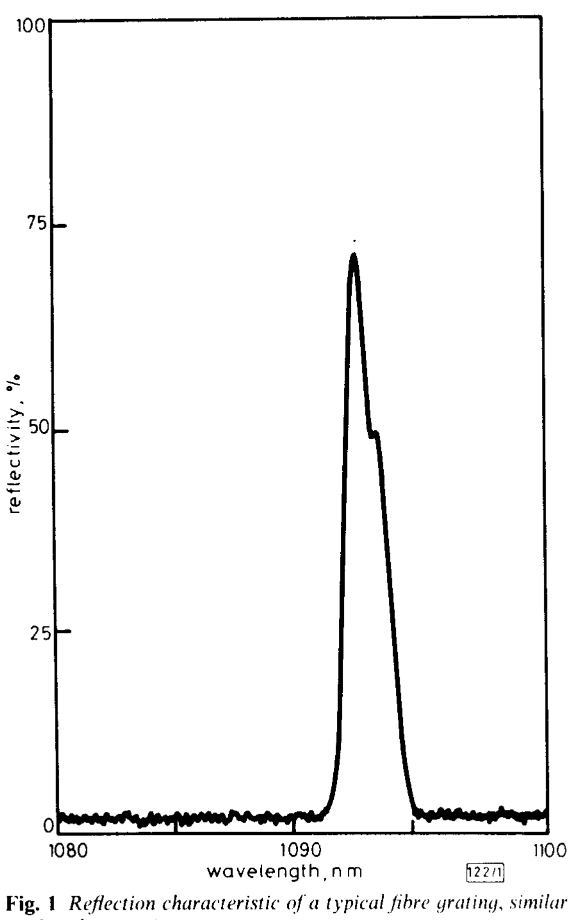

Fig. 1 *Reflection characteristic of a typical fibre grating, similar to that used in the experiment*

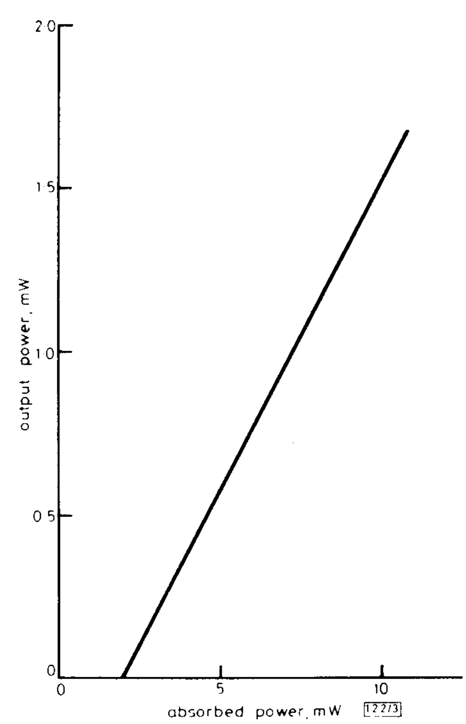

Fig. 3 *Nd^{3+}-doped single-mode fibre laser characteristic using fibre grating and 830 nm diode laser pump*

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centred at 1084 nm with an FWHM of 16 GHz (or 0·6 Å), ±10%. As expected, this width was significantly narrower than the grating bandwidth, due to modal gain competition. The laser output bandwidth can be compared to the corresponding figure of several nanometres for the conventional fibre laser cavity design. It is expected that gratings with narrower feedback bandwidths will produce correspondingly narrower laser outputs.

The lasing characteristic using an oil overlayer of refractive index 1·442 is shown in Fig. 3. A lasing threshold of 1·9 W absorbed and a slope efficiency of 19% were obtained. The slope efficiency was less than that reported previously[3] owing to the butt loss, measured as 1·3 dB. It is expected that reduction of this loss will lead to a significantly more efficient device. As has been demonstrated previously,[6] line-narrowing the laser output does not reduce its efficiency.

Conclusions; The use of a distributed fibre grating as the feedback element in a single-mode fibre laser has been successfully demonstrated. Using an Nd^{3+}-doped silica fibre and a diode laser pump source, a laser characterised by a threshold less than 2 mW, a slope efficiency of 19% and a linewidth of 16 GHz (FWHM) has been constructed.

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I. M. JAUNCEY
L. REEKIE
R. J. MEARS
D. N. PAYNE

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Optical Fibre Group
Department of Electronics
The University, Southampton S09 5NH, United Kingdom

C. J. ROWE
D. C. J. REID
I. BENNION
C. EDGE

Plessey Research (Caswell) Ltd.
Allen Clark Research Centre
Caswell, Towcester, Northants. NN12 8EQ, United Kingdom

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