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Intracavity Pumping for Increased Output Power from a Distributed Feedback Erbium Fibre Laser

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Abstract

Use of an Yb^{3+}-fibre host laser for intracavity pumping a distributed feedback erbium fibre laser is demonstrated. Compared with direct 980 nm pumping of the same DFB laser, a 3-fold increase in output power is obtained.

Fibre grating-based single frequency erbium fibre lasers have considerable potential for use in various telecommunications and sensor applications, as they are compact, simple to fabricate, and fibre-compatible. Both distributed Bragg reflector (DBR) and distributed feedback (DFB) erbium fibre lasers have now been demonstrated by various groups[1-5]. In order to achieve robust single frequency operation, however, the laser cavity lengths have to be kept short, typically to just several cm. For germanosilicate erbium fibres, this results in low pump absorption and hence low output powers (~ 100 μW), since the maximum erbium concentration allowable is limited by concentration quenching effects. One solution is to use Er^{3+}-Yb^{3+} phosphosilicate fibres[6], with a high Yb^{3+} concentration to increase the pump absorption; however, the low photosensitivity of such fibres at present makes the formation of high quality Bragg gratings a difficult problem, particularly for the realisation of DFB lasers. The purpose of this Letter is to point out that intracavity pumping is a feasible option to achieving increased output power from short single frequency erbium fibre lasers.

Fig. 1 shows the experimental configurations for the conventional direct pumping approach and the intracavity pumping scheme. The direct pumping scheme is similar to that previously reported[4]. For intracavity pumping, we use an Yb^{3+}-doped silicate fibre laser as the host laser, operating at 975 nm. The laser was pumped in the 900 nm region where there is an absorption peak[7]. To suppress lasing at longer wavelengths beyond 1 μm, high reflecting 975 nm fibre gratings are used as the cavity end reflectors. The NA of the Yb^{3+}-fibre was 0.17, and the dopant concentration ~550 ppm. The fibre length used in the experiment was 0.45 m.

The 10 cm long DFB laser was written in an Er^{3+}-doped fibre with an NA of 0.17, which matched that of the Yb^{3+}-fibre. The dopant concentration was ~300 ppm, and had a small-signal absorption of 10 dB/m at 980 nm. During fabrication of the grating, the fibre was deliberately twisted to obtain single polarisation state operation[8]. The grating spectrum, scanned with an external cavity laser diode, is shown in Fig. 2. The bandwidth is 0.055 nm and peak reflectivity 99.8%.

The 975 nm fibre gratings were each 3 cm in length, written in the more photosensitive Er^{3+}-doped fibre, and spliced to the Yb^{3+}-fibre where necessary. The grating bandwidths were 0.1 nm, and one of the gratings was mounted on a peltier-controlled heat sink in order to fine-tune its Bragg wavelength to coincide with that of the other grating. As both 975 nm gratings were fabricated from the same uniform phase mask, their Bragg wavelengths were already quite close together and any temperature tuning required was $<5°$ C.

To evaluate the effectiveness of the intracavity pumping scheme, the performance of the DFB laser under direct 980 nm diode pumping is first characterised. Fig. 3 shows the lasing characteristic obtained. The threshold under direct pumping is 5 mW, and the output power increases slowly to 1 mW for a pump power of 110 mW. The laser output was predominantly one-sided, with about 85% of the total power emitting from the end spliced to the WDM. Observation of the lasing spectrum with an optical spectrum analyser and scanning Fabry-Perot interferometer showed that the laser operated stably at 1549 nm on a single mode (and single polarisation state) throughout.

For intracavity pumping, a Ti:Sapphire operating at 924 nm was used. In this case, the DFB laser required 15 mW of pump power to reach threshold, but the output power increased more rapidly, yielding 3 mW for 110 mW of pump power. This represents a 3-fold improvement over direct pumping. A similar improvement in performance was obtained for the pump wavelength at 900 nm. At maximum pump power, the 975 nm output was only in the region of $\sim 10\ \mu W$. Since the 975 nm power must be well over 100 mW inside the laser cavity in order to generate 3 mW from the DFB laser, the 975 nm fibre grating can be inferred to have at least 40 dB of rejection. However, it was observed that single polarisation operation in the DFB laser was maintained only up to an output power of about 2 mW. Above that, the laser reverted to lasing in both polarisation modes. Strong intensity instabilities, such as spiking behaviour, were not observed.

In conclusion, an intracavity approach to achieving higher output power/efficiency from short cavity Er^{3+}-fibre DFB and DBR lasers is described. A 3-fold improvement in output power has been obtained for 100 mW pump power. With better optimisation, further improvements can be expected.

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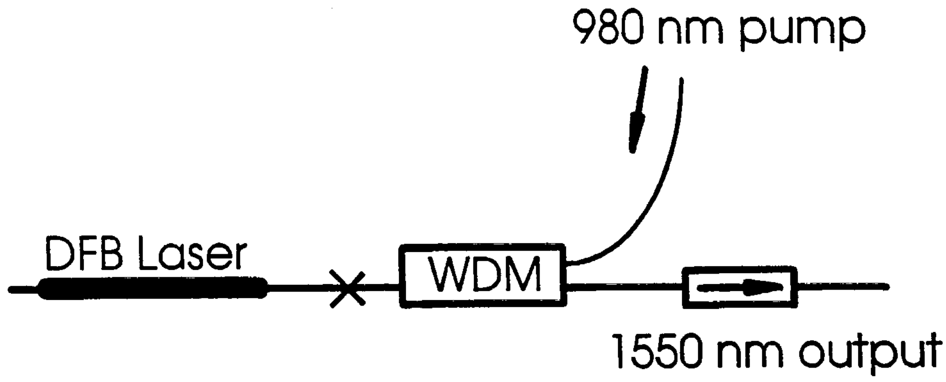
Figure Captions

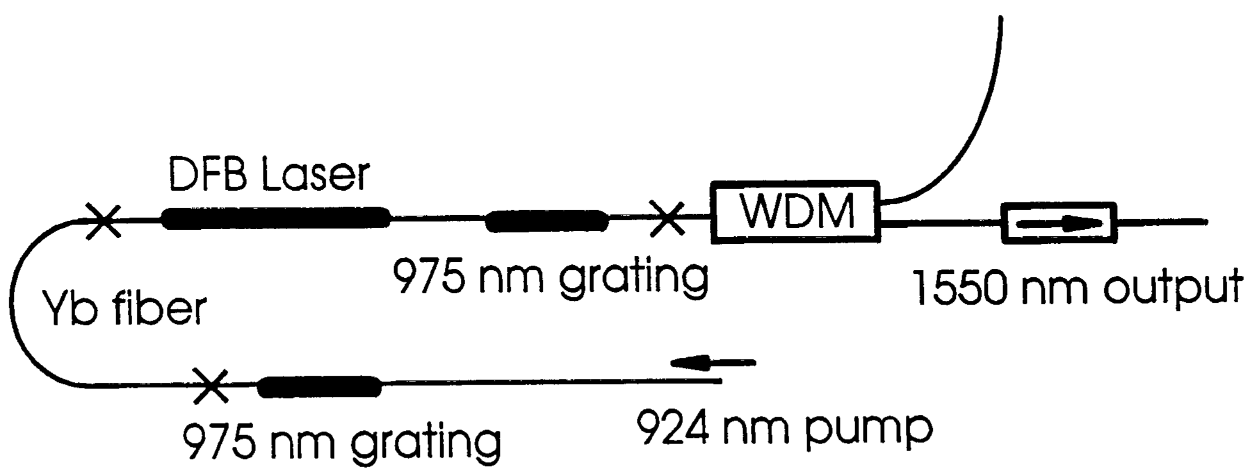
Fig. 1 Experimental configurations for pumping DFB fibre laser. (a) direct 980 nm pumping, (b) intracavity pumping.

Fig. 2 Transmission spectrum of DFB grating.

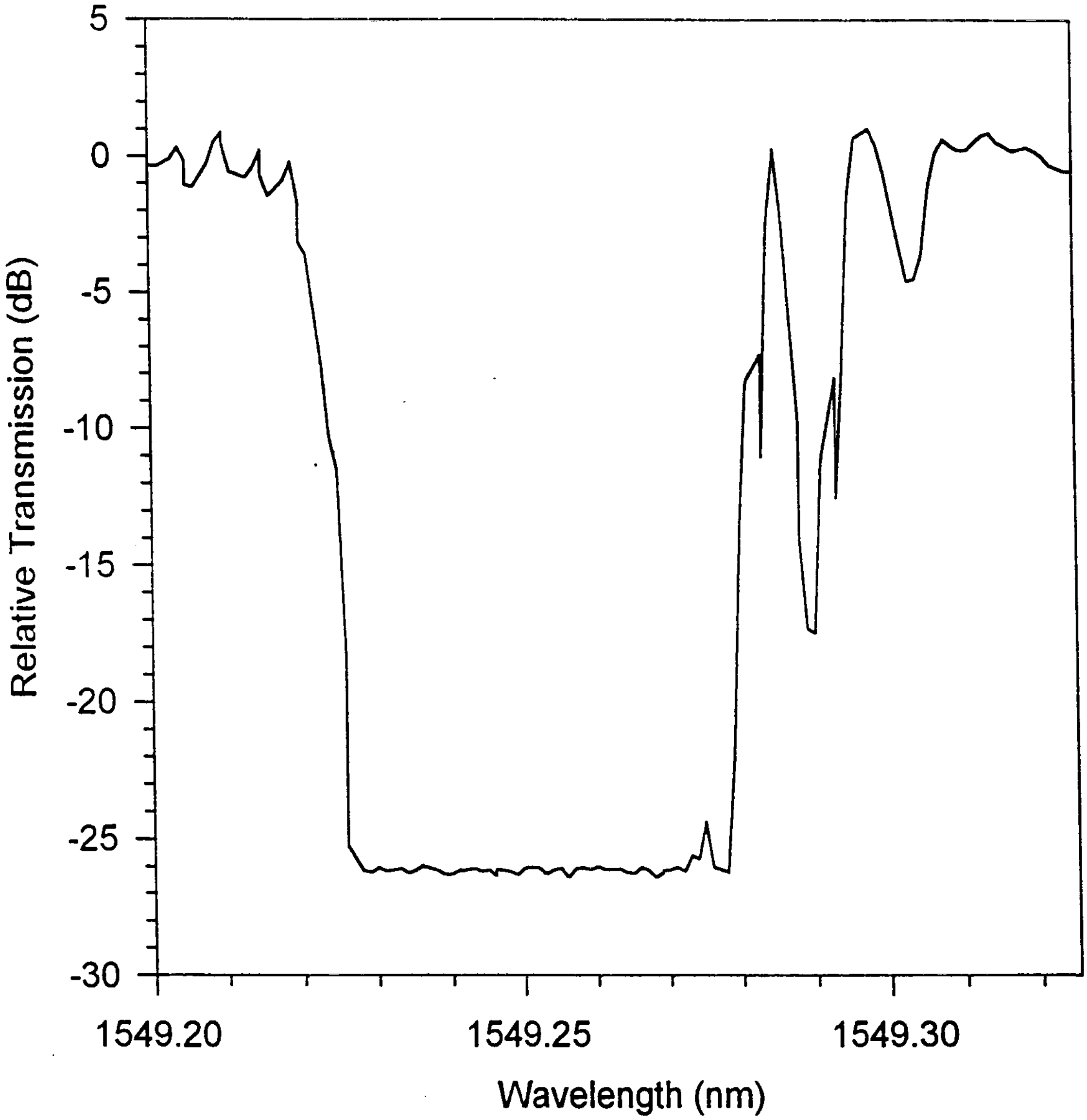
Fig. 3 Lasing characteristics for the DFB fibre laser under direct pumping and intracavity pumping schemes.

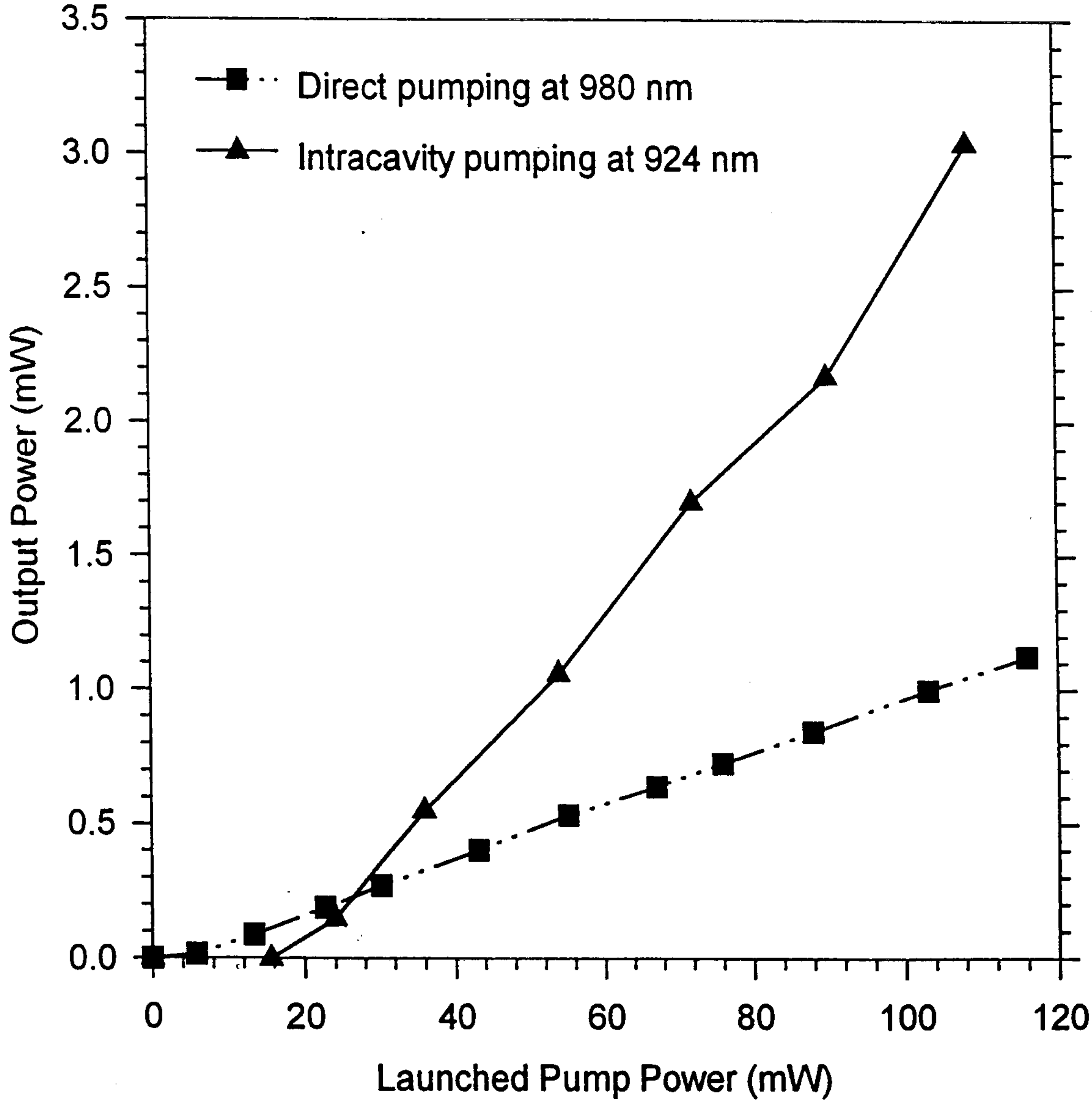

980 nm pump
DFB Laser
WDM
1550 nm output

(a)


DFB Laser
WDM
975 nm grating
1550 nm output
Yb fiber
975 nm grating
924 nm pump

(b)


5
0
-5
-10
-15
-20
-25
-30
Relative Transmission (dB)
1549.20
1549.25
1549.30
Wavelength (nm)



Direct pumping at 980 nm
Intracavity pumping at 924 nm
Output Power (mW)
Launched Pump Power (mW)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
20
40
60
80
100
120