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Intracavity Pumped Distributed Feedback Erbium Fiber Laser

W. H. Loh, Z. Harutjunian, B. N. Samson and R. I. Laming

Optoelectronics Research Centre

University of Southampton

Southampton SO17 1BJ

United Kingdom

Tel: +44 1703 594523

Fax: +44 1703 593142

Email: whl@orc.soton.ac.uk

Abstract

An intracavity pumping scheme for achieving higher output powers from 1.55 μm DFB fiber lasers is proposed and demonstrated. By placing the DFB laser inside the cavity of a Yb^{3+}-fiber laser, up to 3 times higher power has been obtained when compared to the more conventional direct pumping approach.

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Summary

Single frequency erbium fiber lasers are potentially very attractive, particularly in the telecommunications area, e.g. in dense wavelength-division multiplexed systems where there is a need for large numbers of narrow linewidth sources with accurately determined wavelengths. In this regard, fiber grating-based lasers, such as distributed Bragg reflector[1] (DBR) or distributed feedback[2,3] (DFB) fiber lasers, are especially atttractive, as fiber gratings can be made to quite demanding specifications. However, these lasers typically have very short cavities, in order to maintain single mode operation for the case of DBR lasers, while difficulties in making very long high quality gratings chiefly constrains the length of DFB lasers. Such short fiber lengths typically lead to inadequate pump power absorption and low laser output powers of $\sim 100\ \mu$W[1,4]. One solution put forward to address this problem is the use of phosphosilicate Er/Yb co-doped fibers, which has been successful in demonstrating efficient DBR laser operation[5]. However, the low photosensitivity of these fibers makes it difficult to write high quality gratings directly in them, which is essential for DFB fiber laser operation. In this work, we propose and demonstrate another solution to improving the output power/efficiency of short cavity DBR/DFB Er^{3+}-fiber lasers, which is by intracavity pumping in an Yb^{3+} fiber laser cavity.

Fig. 1 shows the conventional direct pumping configuration which we have previously employed[3], and the new scheme. For intracavity pumping, the 10 cm long DFB Er^{3+}-fiber laser is spliced to a Yb^{3+}-doped fiber, and both doped fibers are enclosed by high reflecting 975 nm gratings on each end. By pumping the Yb^{3+}-fiber at 924 nm, lasing at 975 nm is achieved, which in turn pumps the DFB laser.

The 10 cm long grating comprising the DFB laser has a bandwidth of 0.055 nm and a peak reflectivity of 99.8%. The fabrication of the grating is similar to that previously reported[3]; however, in addition, the fiber was deliberately twisted while the grating was being written, as we have found that twisting of DFB fiber lasers enables single polarisation operation[6]. The erbium concentration is ~300 ppm, and has a measured small-signal absorption of 10 dB/m at 980 nm, while the 0.45 m length of Yb^{3+}-fiber used had a dopant concentration of ~550 ppm. As the Yb^{3+}-fiber was not very photosensitive, both the 975 nm gratings were written in the Er^{3+}-fiber, one of which was then spliced to the end of the Yb^{3+}-fiber.

Fig. 2 shows the lasing characteristic of the DFB fiber laser under direct 980 nm pumping and in the intracavity configuration. With direct pumping, the threshold is 5 mW, reaching 1 mW output at 1549 nm for a pump power of 100 mW. The corresponding laser spectrum (resolution 0.05 nm) is shown in Fig. 3. Using a scanning interferometer, the laser was observed to operate in a single mode, and single polarisation state. With the intracavity configuration, the threshold is higher at 15 mW, but the output power increases rapidly to 3 mW for 100 mW pump power, a factor of 3 improvement over direct pumping. With better optimisation, further improvements can be expected.

In conclusion, we have proposed and demonstrated an intracavity pumping scheme which is effective in increasing the output power/efficiency of DFB Er^{3+}-fiber lasers, with a factor of 3 improvement achieved thus far.

References

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[3]Loh, W. H. and Laming, R. I., *Electron. Lett.,* **31**, 1995, pp. 1440-1442.

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[5]Kringlebotn, J. T., Morkel, P. R., Reekie, L., Archambault, J. L. and Payne, D. N., *IEEE Photon. Technol. Lett.,* **5**, 1993, pp. 1162-1164.

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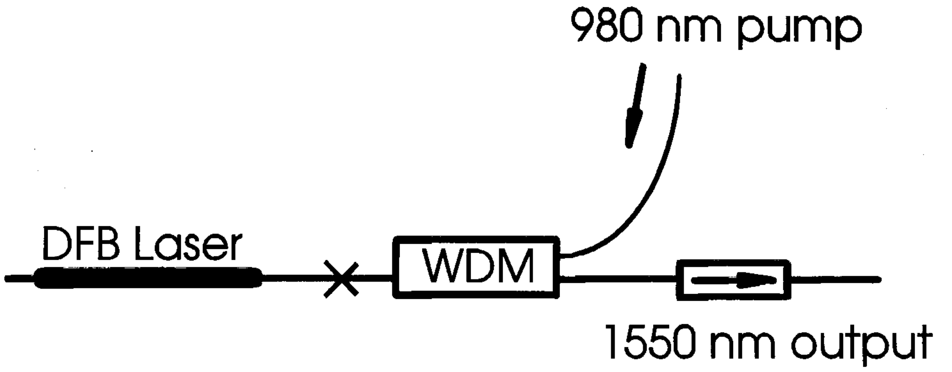
Figure Captions

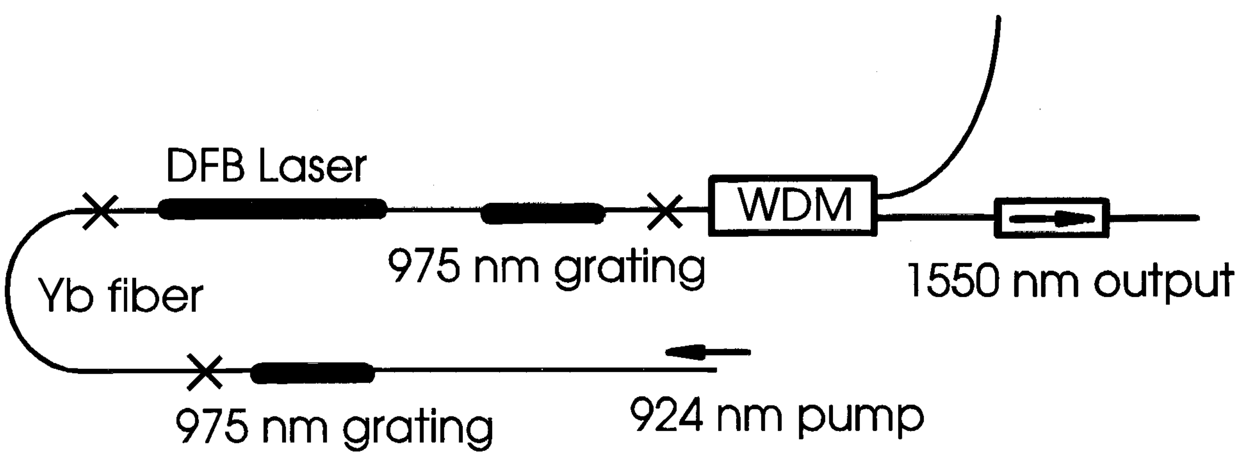
Fig. 1 Experimental configuration for (a) conventional 980 nm direct pumping scheme, (b) intracavity pumping scheme.

Fig. 2 Lasing characteristics of DFB Er^{3+}-fiber laser with direct pumping and intracavity pumping approaches.

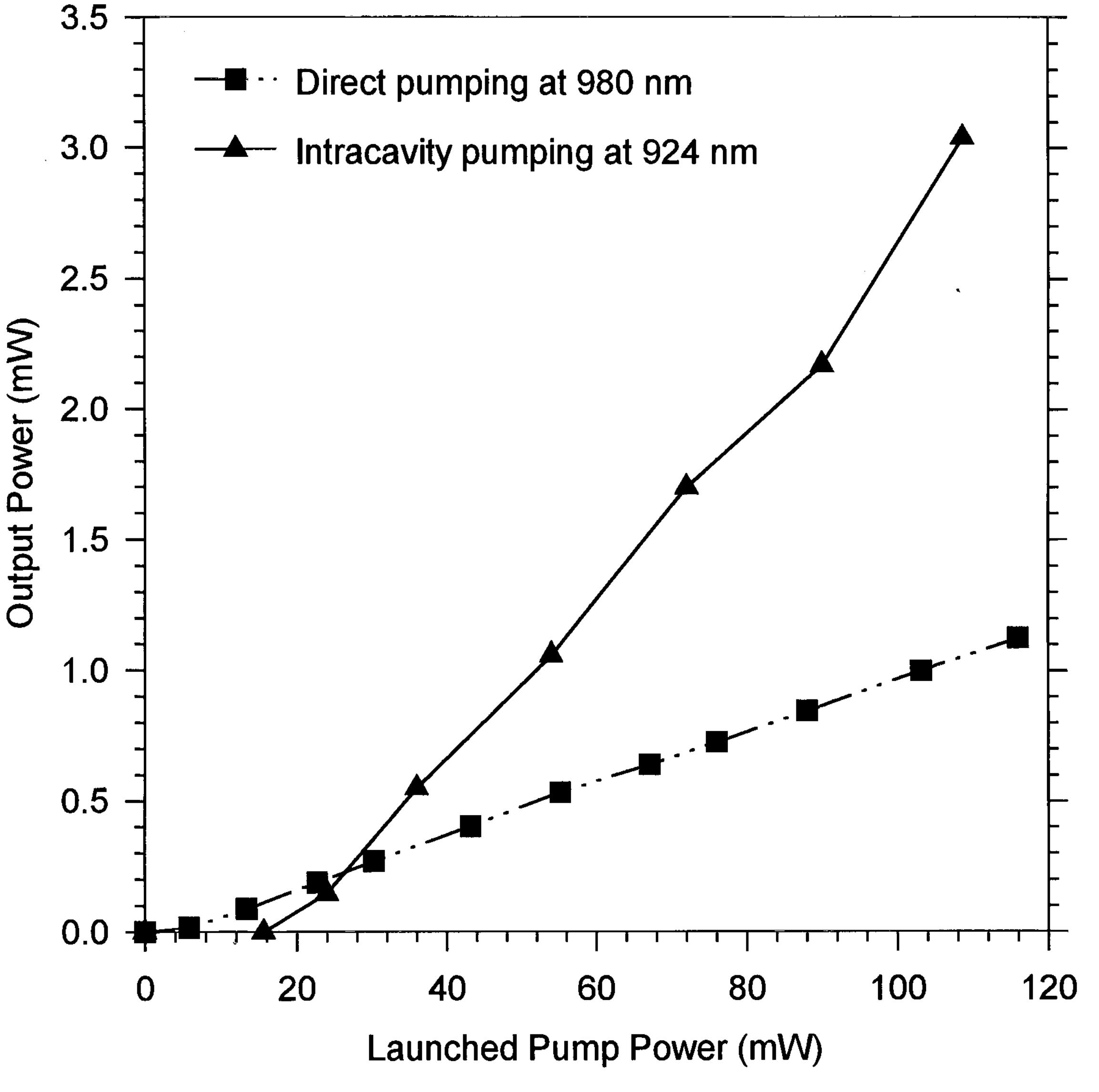
Fig. 3 Optical spectrum of DFB laser.


980 nm pump
DFB Laser
WDM
1550 nm output

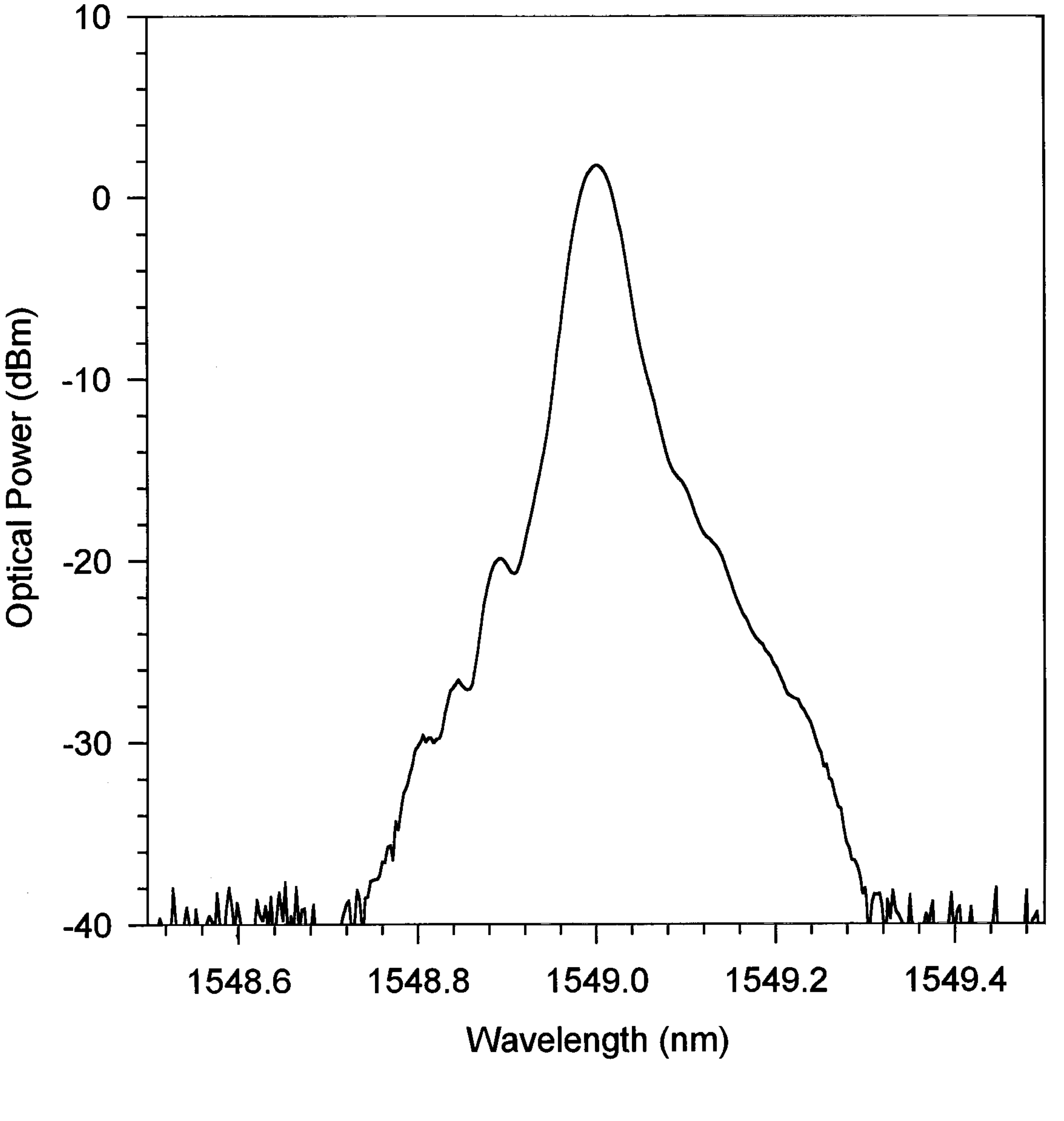
(a)


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

(b)



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



10
0
-10
-20
-30
-40
Optical Power (dBm)
1548.6
1548.8
1549.0
1549.2
1549.4
Wavelength (nm)