SIMPLE BROADRANGE TUNING OF FIBRE-DFB LASERS

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All-fibre distributed-feedback (DFB) lasers providing continuous tuning over 27nm are demonstrated for the first time. Extended wavelength coverage of the lasers is obtained using a simple bend-tuning technique which delivers undistorted outputs over the full tuning-range.

Introduction

Fibre grating distributed-feedback (DFB) lasers exhibit many attractive features for application as laser sources in optical communication /1/. For example, their advantages over semiconductor DFB lasers include ease of fabrication, inherent fibre compatibility for enhanced transparency, high output power, ~10x lower thermal sensitivity and superior optical signal-to-noise ratio. Previously, fibre DFB lasers fabricated in 5cm-long Er/Yb co-doped fibres have been demonstrated with single polarisation and output power in excess of 13dBm, optical signal-to-noise ratios (SNR) of >50dB (0.1nm resolution), and line-widths of ~10kHz /2/. Additionally, they have been demonstrated to be highly suitable for application as transmitter sources in wavelength division multiplexed transmission systems /3/.
As WDM optical communication systems evolve from simple point-to-point links to dynamic optical networks, wavelength tunability of the devices in these systems will become necessary. In order to accommodate these requirements, a number of techniques to tune the operational wavelength of CW fibre lasers have been proposed. One technique for wavelength-tuning a fibre DFB laser was by mechanically stretching the device, as shown in /4/ for a 3nm tuning. The maximum tuning-range using this method is limited by the breaking tensile strain of silica fibre, which is typically ~1%, corresponding to 12nm of wavelength shift. Secondly, Ball *et al.* /5/ demonstrated continuous tuning over a 32nm wavelength range by compression tuning a fibre distributed Bragg reflector (DBR) laser in a master-oscillator/power-amplifier (MOPA) configuration.
However, this system was complicated by the requirement to maintain the straightness of the fibre to prevent buckling using complex ferrule design. Besides, compression was achieved by using a stepper-motor, which is bulky and relatively slow. Moreover, the MOPA configuration could potentially sacrifice the optical SNR. Pan *et al.* /6/ demonstrated a third technique by sandwiching a hybrid DFB/DBR laser between two high-thermal expansion Teflon plates. This system is somewhat complex, and requires a temperature range of 80°C to achieve the 11nm tuning-range.
In this paper, we demonstrate simple wavelength tuning of all-fibre DFB lasers over 27nm. The wavelength tuning method applied is based on a bend-tuning technique that we have demonstrated recently for tuning a passive fibre Bragg grating filters over 40nm /7/. Our results represent the broadest wavelength tuning-range achieved, to the best of our knowledge, for any DFB laser configuration including semiconductor DFB lasers.

Device Design

The devices demonstrated here are 4cm and 5cm in length, and are written into a highly doped Er/Yb/P/Al/Si fibre with an annular photosensitive B/Ge/Si region to the core /8/ using a fabrication system operating at 244nm. Previously these lasers have been demonstrated to operate at power levels of up to 14dBm when pumped with powers in excess of 20dBm at 976nm. To obtain unidirectional output, the fibre lasers are written with a discrete π phase-shift in a 6% off-centre position /2/ resulting in an output power ratio of ~50:1. Furthermore, these devices operate with single-polarisation outputs. After fabrication, the fibre-lasers are cleaved and spliced onto standard fibre at both ends. Otherwise, the high absorption in the excess Er/Yb fibre would prevent sufficient pump-power in reaching the DFB active region.

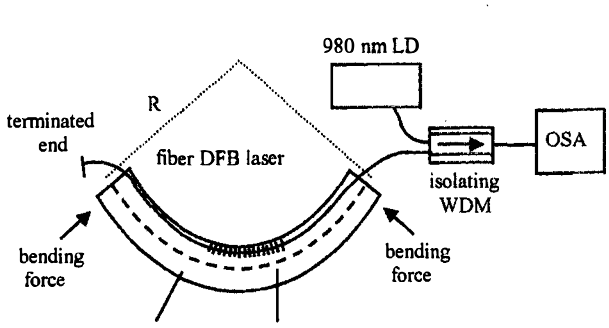

Figure 1: Design schematic of the tunable fibre DFB laser configuration.

Then the fibre DFB lasers are mounted in an off~neutral axial position on a bendable substrate (Fig. I), which allows tuning of the devices by both traction andcompression/7/. The wavelength shift $\Delta\lambda$ using this technique can then be estimated by:

$$\Delta\lambda = 0.78\, \varepsilon\, \lambda, \text{ with } \varepsilon = d/R \qquad (1)$$

where λ is the center wavelength of the device at idle state, ε is the applied strain/stress, R is the bending arc-radius and d is the off-neutral-axis displacement.

In our design, a relatively large displacement factor, d, of 1.6mm enables wide wavelength tunability with little constraint in the bending radius. A 20nm wavelength shift will require only a bending radius of ~10cm.

Experiment, Results and Discussion

The fibre DFB lasers are backward pumped by a 976nm laser diode through an isolating wavelength coupler at 60mW. The output spectra of the lasers are monitored using an optical spectrum analyser. Fig.2 shows the output spectra of the 4cm device which was tuned over ~27nm from 1524nm to 1551nm. The normal (relaxed) operating wavelength of the laser was 1546.5nm with an output power around 0dBm. To demonstrate the tuning technique, we have tuned the laser by 4.5nm or ~0.4% in extension mode and 22.5nm or ~1.9% in compression mode. The output power of the laser follows the Er/Yb gain-profile as expected. At the lower wavelength region, some excess loss may be due to the slight bend loss. The sharp drop in power at 1524nm is due to the Er/Yb gain roll-off, below which the gain is too low for laser operation. Note that we have not seen any bend-tuning limitation, and it would be possible to tune the laser further down in wavelength if the gain was sufficient. To demonstrate higher power operation, we successfully wavelength tuned the 5cm-long fibre DFB laser over 22nm. This laser offers a higher output power of up to 9dBm due to the longer length as shown in Fig.3. In this case we limited the tuning range to the highest gain region, from 1534nm – 1556nm, to show a near uniform output power operation. In order to maintain a high laser output power throughout the tuning-range, the bending uniformity had to be maintained.

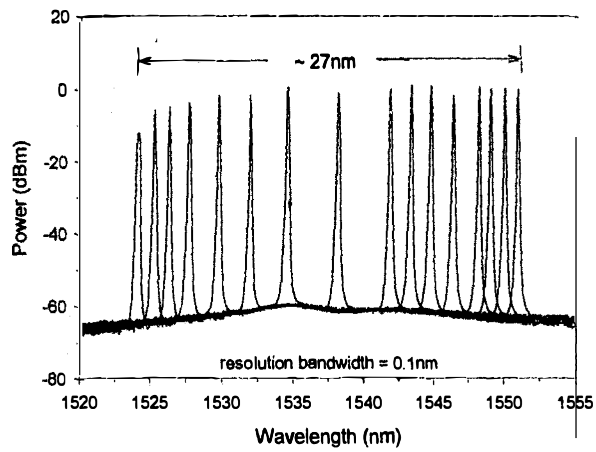

Figure 2: Output spectra of the 4cm-long fibre DFB laser wavelength tuned over 27nm.

Currently, the tuning~range of the devices is mainly limited by the strength of the splice points. Further improvements to the tuning-range should be possible with proper design of a uniform bending mechanism and a technique to prevent stresses across the splice points. Despite this limitation, high quality outputs are maintained across the full range as demonstrated in Fig 2 and Fig 3.

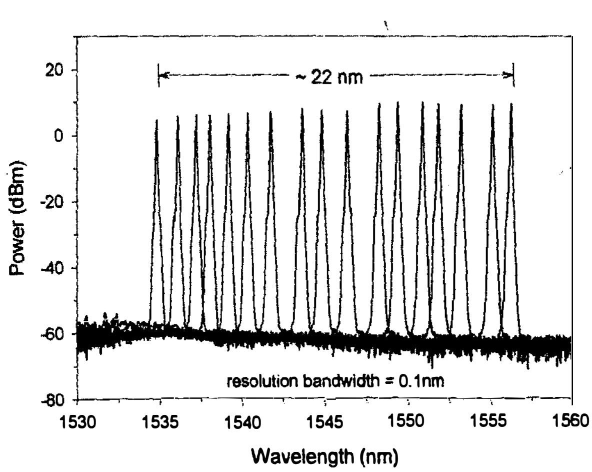

Figure 3: Output spectra of the 5cm-long high power fibre DFB laser tuned over 22nm.

The bending substrate also serves as a good heat-sink base to cool the fibre DFB lasers. Due to the short length and high absorption of the lasers, signifiicant heating occurs /1/ which can distort the stability of the output power. If the laser is not heat-sinked properly, it would give a reduced output power and an unstable polarization operation. Continuous mode-hop fiiree tuning of lasers requires strict control of all the parameters in the cavity. Because the firequency of the lasers are dictated by the Bragg grating, unifiorm tuning of this is necessary if the overall laser perfiormance is to be maintained. However, despite the requirements fior bending unifiormity, the output power can easily be controlled by introducing intentional slight non-unifiorm bend to compensate fior gain variation across the wavelength window, without adjustment of the pump-power to the lasers.

Conclusion

We have demonstrated all-fiibre DFB lasers, which ofifier continuous wavelength tunability up to 27nm using a simple bend tuning technique, which allows both and axial strain and compression. The devices remain operating with single-firequency and ofifier superior optical SNR over the entire tuning-range. We believe that the demonstrated devices are highly placed fior application as tunable sources in fiuture dynamic WDM optical communication networks that require all-optical wavelength tunability.

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