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Highly Efficient L-band Fibre-DFB Lasers

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Abstract:
A more than 12 mW highly efficient fibre-DFB laser operating at 1618.3 nm is fabricated and characterised. Its high-power, low-noise and single-polarisation characteristics make it very suitable WDM-source for L-band transmission.

1. Introduction

All-fibre DFB lasers have inherent fibre compatibility, ultra-low relative intensity noise (RIN), very narrow linewidth, high side-mode extinction-ratio and very high signal-to-noise ratio (SNR) making them ideal source-candidates for dense frequency optical transmission-systems. Compared to semiconductor-DFB lasers, fibre-DFB lasers have much higher yield in fabrication, easier wavelength positioning and much lower temperature sensitivity. Since the first demonstration of all-fibre DFB lasers [1], much work has been done on exploring and exploiting these fascinating devices. Previously powers greater than 13dBm with single-frequency, single-polarisation and single-sided outputs has been demonstrated in the C-band [2]. Additionally, fibre-DFB lasers with keyed axis output have been developed favouring these devices for alignment to, for example, external modulators and other polarisation sensitive components [3]. Furthermore, they can be configured in WDM-transmitter-array configurations to reduce cost and simplify WDM-transmitter management and maintenance [4,5]. All these characteristics make fibre DFB lasers very promising sources for WDM-transmission.

To fully exploit the full low-loss window of the silica-fibres, L-band optical amplifiers have been developed. Therefore, it would be ideal for fibre DFB lasers additionally to cover both the C-band and L-band. Previously, Poulsen et al. have demonstrated L-band fibre-DFB lasers [6,7], however their lasers suffer from poor output-power of <1mW.

In this paper, we demonstrate a high-power (>12mW) single-polarisation fibre-DFB laser operating at the longest wavelength ever reported for a fibre-DFB (1618.3 nm) with high-efficiency, extremely high signal-to-noise ratio (>74dB). Our laser also shows excellent coherence and very low intensity noise at telecommunication frequencies.

2. **Experiment**

The fibre used in this work is Er/ Yb co-doped, with basic properties similar to the fibre discussed elsewhere [8], i.e. high concentration Er/Yb in a phospho-silicate glass host and a photosensitive annular B/Ge ring to the core.

Using a coupling coefficient of $\kappa \sim 125\ m^{-1}$, a 8cm long π-phase-shifted DFB laser is written into the fiber using our continuous grating writing technique and CW UV-light at 244nm. The phase-shift is offset from the centre-position to get uni-directional operation [2]. The fibre-DFB then is annealed at 100 °C for 12 hours.

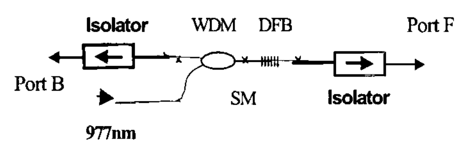

Fig.1. Pumping scheme (the WDM coupler is 980/1550 nm wideband coupler)

The pump-configuration for the laser is shown in Fig.1. The wavelength of the pump semi-conductor laser is 977.3nm and the output from the DFB-laser is monitored from both the forward port F and backward port B. The output spectra are checked using an Advantest optical-spectrum-analyser (OSA) with a resolution of 0.01nm. A typical out-put spectrum of the laser is shown in Fig.2. It has a ultra-high signal to noise ratio of 74dB and a single-mode-suppression-ratio of 55dB, which are significantly higher than that of a semiconductor-DFB laser. The backward isolator and WDM coupler has a loss of 1.2 dB for the signal while the forward isolator has only an insertion loss of 0.7dB. The fibre-DFB laser has a threshold of 30mW, which is higher than the C-band fibre-DFB laser made from the same fibre, but is believed to be due to the much lower gain available in this region. The output-power from the forward and backward ports are characterised as well. The forward slope efficiency is 10.6% and the total slope efficiency is 12.2% respectively. In our case, the π-phase-shift is introduced by moving the translation stage during the writing process hence forming a discrete phase-shift which is different from the phase-shift formed by directly UV post-processing [7]. The intrinsic loss caused by UV-exposure is very small.

For applications in both telecommunication and sensing, low-noise performance is of major interest. The relative intensity noise (RIN) is characterised using Agilent lightwave component analyser, which is depicted in Fig.4. (The relaxation oscillation peak is found to be @ 375kHz). At a total optical output power 11.07 mW(forward power 9.89 mW), the RIN is below -157 dB/Hz for frequencies above 5MHz. Using a delayed self-heterodyne technique, the typical linewidth of this fibre DFB laser is found to be ~10 kHz in the forward direction.

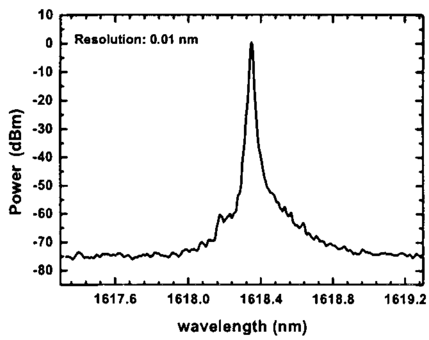

Fig.2. the output spectra of fibre-DFB laser (resolution:0.01nm).

This low noise and narrow linewidth fibre DFB laser make it ideally suited for analog CATV-systems and WDM transmission.

3 Conclusion

We have demonstrated a high-power L-band all-fibre-DFB laser operating at 1618.3nm with high slope-efficiency (total efficiency ~12%). The high SNR, high side-mode-suppression-ratio, low RIN and narrow linewidth fibre-DFB laser is very suitable for CATV and WDM applications utilising an installed non-dispersion-shifted fibre for future WDM expansions of the fibre-capacity.

Acknowledgement: This work is supported by Southampton Photonics Inc.)

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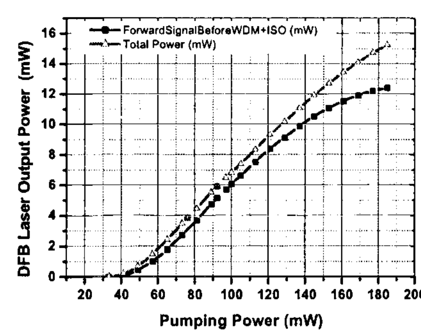

Fig.3. Output-power of the fibre-DFB laser under different pumping power (ISO: isolator)

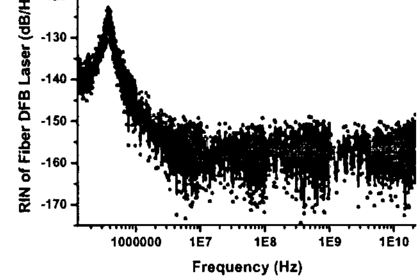

Fig.4. RIN of the fibre-DFB laser (total optical output power 11.07mW, forward power 9.89 mW)