Erbium-Ytterbium L-band Fibre-DFB Laser Pumped at 1534nm

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Abstract: *An L-band (1618nm) fibre-DFB laser pumped at 1534nm is demonstrated for the first time. It has a threshold of <10mW and up to 2mW of optical power in a single-polarisation with a line-width of ~8kHz.*

Introduction

All-fibre DFB lasers have attracted much attention for a plurality of reasons including their inherent fibre compatibility, ultra-low relative intensity noise (RIN), low temperature sensitivity, narrow line-width, high side-mode suppression-ratio and very high signal-to-noise ratio (SNR) making them ideal source-candidates for WDM transmission-systems and sensing applications [1-6]. So far most work on fibre-DFB lasers has been performed on devices for operation in the C-band. Extending optical transmission into the L-band (1570 nm - 1610 nm) and beyond for enhanced network capacity, have increased the interest in sources that can operate with sufficient efficiency in this band.

Previously, Poulsen et al. have discussed the design and demonstrated L-band fibre-DFB lasers [1,2]. However, their work concentrated on pumping the lasers at 980nm and because erbium shows only limited gain in the L-band when pumped at 980nm, their lasers showed only moderate output-powers of <0.5mW. For operation in the C- and L-bands EDFA's and fibre-DFB lasers typically are pumped by either 980 nm or 1480 nm pump diodes. However for operation in the L-band, the larger absorption of erbium ~1535nm suggest that an increased efficiency compared to 1480nm pumping should be expected.

In this paper we report the operation of an L-band fibre DFB laser at 1618.3nm pumped at 1534.2nm and investigate the properties of this. Up to 2.1mW of power is achieved with a very low threshold of just 9mW. The wavelength-drifts of this laser against pump-power demonstrate that the thermal instabilities that exist when pumping these lasers at 980nm, can be reduced by more than an order of magnitude.

Experimental setup

Fig. 1 shows the pumping-configuration of the L-band fibre-DFB laser. A laser signal at 1534.2 nm amplified by a high-power Er/Yb fibre-amplifier is employed as the pump-source. With this a maximum power of 680mW is through a WDM launched into the fibre-laser and the output is monitored through port B. Isolators are employed at the output to prevent back-reflections into the laser that otherwise could cause the output to become unstable.

The laser is an asymmetric (0.44:0.56) π-phase-shifted fibre grating [5] written into a highly doped phospho-silicate Er/Yb-fibre with a photosensitive annular ring to the core [7]. It is 8 cm long with a coupling-coefficient of ~125 m^{-1} and is written using 244nm CW UV-light.

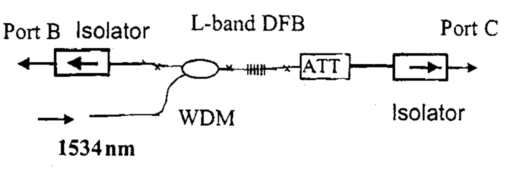

Figure 1 Experimental set-up (ATT: attenuator).

Experimental results and discussion

The measured output-power against absorbed pump-power is shown in Fig.2. With an absorbed power of 180mW (including the splice-losses between the fibre-DFB and fibre pigtails), the fibre DFB laser gives 2.1mW of power before the isolator. The slope-efficiency against the absorbed power is 1.15%. Despite this being lower than that of the 980 nm pumping scheme as we recently have demonstrated [8], the use of 1534.2nm as the pump-source, will result in lasing-transition only between $I_{13/2}$ and $I_{15/2}$ Stark-levels, which implies less non-radiative transition-induced internal thermal heating. Hence the expected wavelength-shift caused by the internal heating should be smaller than that of 980nm pumping. This point is investigated be measuring the wavelength-shift during increasing pump-power with a wave-meter. These results are plotted in Fig.3.

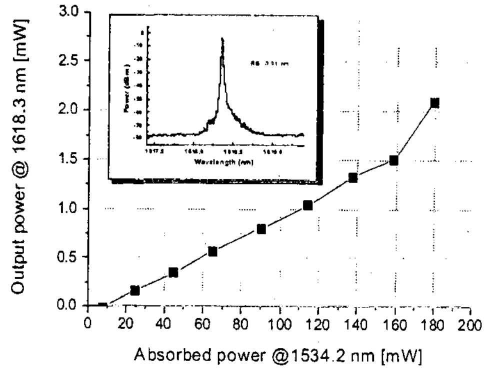

Figure 2 Output-power against absorbed pump. Laser-spectrum (insert).

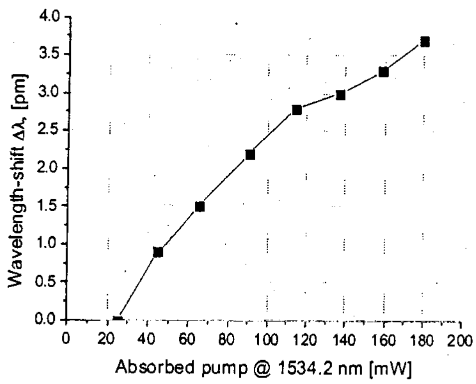

Figure 3 Wavelength-shift @ 1618.3nm against absorbed pump.

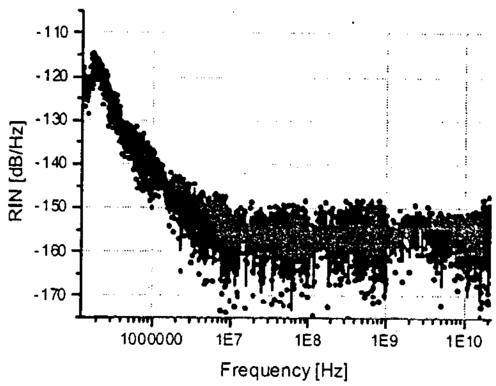

Figure 4 Typical relative-intensity-noise spectrum.

We have found that the wavelength-shift under 977nm pumping is ~0.3pm/mW [8] while it in this case only is ~0.02pm/mW both for similar output-power power levels, corresponding to an ~x15 reduction.

The fibre-DFB laser is also confirmed single polarisation and using the delayed self-heterodyne technique the line-width is found to be ~8kHz for an output-power of 0.57mW. For higher output-powers the line-width was observed to increase only slightly; a broadening that is believed to be due to effects from the high-power amplifier used that exhibited an increased noise-figure for higher output. Despite this our laser shows a side-mode-suppression-ratio of 53dB and signal to ASE noise ratio of 72dB for the highest power as depicted in the insert of Fig. 2.

To check the RF-noise of the laser, the relative intensity noise (RIN) was characterised. This is shown in Fig.4. The peak in the RIN spectrum is the relaxation frequency (~200kHz) and the typical RIN-level is around –154dB/Hz for frequencies above 10MHz, confirming that the laser has ultra-low noise characteristics even when pumped by an amplified 1534.2nm laser source.

The specific pump-wavelength of 1534.2nm was found to give the highest efficiency when tuning the pump-source laser around the maximum absorption-peak of the fibre-DFB-laser. This very conveniently co-insides with a wavelength of maximum gain as well from the Er/Yb amplifier used to boost the pump-wavelength.

The line-width of the laser under these pump-conditions was observed to be narrower than when pumped at 977nm and operated with a similar output-power [8]. This we attribute to the more uniform pump-absorption along the length of the laser, which in turn result in less pump-induced thermal chirping of the grating, and there ensures the maintenance of a high cavity Q.

Currently investigations are underway to optimise the efficiency of the laser and we hope to report the result of these findings at the conference.

Conclusions

In this paper, we have for the first time to our knowledge demonstrated an L-band fibre-DFB laser using pumping at 1534.2nm and investigated the properties of the laser operating at 1618.35 nm when pumped in this configuration. Although it is operating at the low gain region of erbium fibre, the fibre-DFB laser gives 2.1mW. It is found to have an ultra-low wavelength-shift which is believed to be due to less internal thermal heating compared with that of the more traditional 980nm pumping (10-15 times lower). We believe that our results show that the use of pumping with the now well-developed amplified sources around 1535nm can provide an alternative and in some cases low cost choice of pumps for L-band sources for future systems operating in this band.

References

1 P. Varming et al, *OFC 2000*, Vol.3, paper ThA6, 2000.
2 H.N.Poulsen et al, *ECOC'99*, Tech. Digest, paper Mo B2.1, 1999.
3 J.T. Kringlebotn et al., *Optics Lett.*, **19**, (1994), pp. 2101-2103.
4 J. Hübner et al., *Electron. Lett.*, **33**, (1997), pp. 139-140.
5 M. Ibsen et al., *Electron. Lett.*, **36**, (2000), pp. 143-144.
6 L.B. Fu et al., *OFC'02*, paper WJ5, 2002.
7 L. Dong et al., *Optics Lett.*, **22**, pp. 694-696, 1997
8 L.B. Fu et al., in proceedings to *OECC'03*, Shanghai, 2003.