Frequency Drift Characterisation of Directly Modulated SGDBR Tunable Lasers

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SUMMARY

Tunable Lasers (TL) are rapidly becoming key components in Dense Wavelength Division Multiplexed (DWDM) systems, packet switched schemes and access networks. They are being introduced as alternatives to fixed wavelength sources to provide a greater degree of flexibility and to reduce large inventory [1]. The SGDBR laser is an ideal candidate due to its large tuning range (40 nm), high output power (10 dBm), large Side Mode Suppression Ratio (>30 dB) and its ability to be monolithically integrated with other semiconductor devices. Such integration could comprise of a Semiconductor Optical Amplifier (SOA), allowing for extended reach tunable operation, in a very compact and low cost footprint [2]. Thus far, external modulation has been the most popular modulation technique used with TLs. However, the addition of the modulator introduces loss to the transmitted signal due to high insertion and coupling losses. Addressing these short comings would result in increased cost and complexity of the transmitter. Alternatively, direct modulation is one of the simplest and cost efficient ways to modulate the lightwave signal. Hence, it is rational to investigate the performance of a directly modulated SGDBR laser in order to verify its usefulness in a WDM based access network scenario. Previous work in this area has mainly focused on bandwidth characterisation and transmission experiments [3, 4]. In this paper, we characterise the frequency drift associated with a directly modulated SGDBR laser incorporating a wavelength locker. Focus is placed on investigating the magnitude and settling time of this drift. In addition, we also demonstrate how the frequency drift has a detrimental effect on DWDM system performance when the modulated channel is passed through a narrow Optical Band-Pass Filter (OBPF) centred at the target emission frequency.

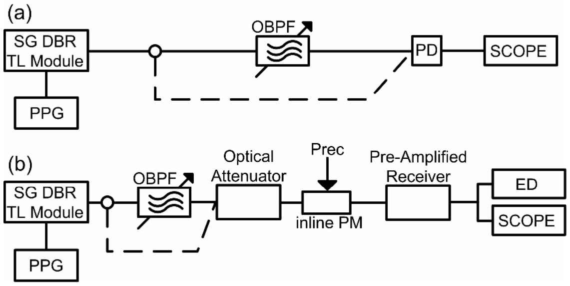

Figure 1: Experimental set-up to measure (a) frequency drift and (b) effect of the drift when filtered

Initially, we measure the magnitude of the frequency drift using the two stage experimental set-up shown in Fig. 1(a). The TL is operated in static mode and the emission frequency is set to channel 38 (193.35 THz). The TL is then directly modulated at 1 Gb/s (bit rate limited by the RF modulation circuitry attached to the gain section of device). Initially, a power reference measurement, shown by the dotted line, is taken where the output of the directly modulated TL is detected by a photodiode in conjunction with an oscilloscope. Subsequently, the modulated signal is passed through an OBPF with a FWHM of 26 GHz, detuned by 0.1 nm to create a sloped frequency discriminator, as depicted in Fig. 2(a). This allows the measurement of the frequency drift by translating the variations in power to frequency variations using the response of the OBPF. The power reference measurement is subtracted from the filtered signal to ensure that any variation in the received power is solely due to the frequency drift of the TL.

Subsequently, a qualitative characterisation of the frequency drift, caused by direct modulation of such a TL employed in a DWDM system, is determined by performing Bit Error Rate (BER) measurements. The experimental set-up with and without (dotted line) the OBPF is illustrated in Fig. 1(b). Here again, the TL is set to emit at channel 38 (193.35 THz) and then modulated with a 1 Gb/s NRZ Pseudo Random Bit Sequence (PRBS) with a pattern length of 2^7-1. The modulating signal is set to be 1 V_{pp}. An optical attenuator incorporated with an inline power meter (P_{rec}) enables the monitoring of the varied received power falling on the pre-amplified receiver. The BER is then measured with the aid of an error detector under three different scenarios namely: no filter (dotted line), with the 26 GHz filter centred at the specified ITU frequency (193.35 THz), and with the 26 GHz filter centred at the average shifted frequency upon direct modulation (193.343 THz). Eye diagrams are also recorded with a 50 GHz sampling oscilloscope for each of the mentioned permutations.

Fig. 2(b) illustrates the frequency drift and the settling time of the directly modulated tunable laser. We defined the frequency drift as the maximum offset caused by the direct modulation during the presence of a

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logical one. The settling time is defined as the time the wavelength locker takes to counteract this offset. The maximum frequency drift caused by direct modulation is 12 GHz as in Fig. 2(b). However, the settling time depends on the pattern length used (number of consecutive ones). In order to measure the longest settling time (worse case scenario), a programmed sequence consisting of twenty ones followed by twenty zeros is used. As can be seen in Fig. 2(b), the settling time is measured to be approximately 18 ns.

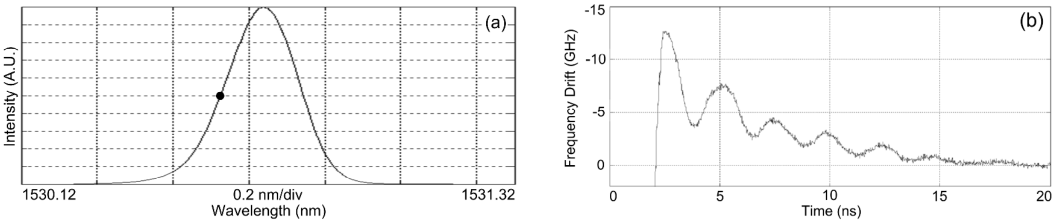

Figure 2: (a) FBG reflection profile (black dot indicates de-tuning of 0.1nm), and (b) Single channel frequency drift due to direct modulation

The effect of the frequency drift on the performance of a typical DWDM system is highlighted by the BER versus received power plot shown in Fig. 3(a). The case where no filter is used acts as the reference plot (●). Alternatively, when the directly modulated signal is filtered with the filter centred at the target frequency of channel 38 on the ITU grid, the frequency deviations are converted into intensity fluctuations. These intensity fluctuations cause degraded performance reflected by the incurred power penalty of 6.7 dB at a reference BER of $10e^{-9}$ (■). A slight improvement in performance (1.64 dB at reference BER of $10e^{-9}$), relative to the latter case, is obtained when the centre frequency of the filter is moved to match the average shifted frequency when under modulation (193.343 THz) (Δ). The recorded eye diagrams, shown in Fig. 3(b-d), further illustrate the BER degradation as described above. Fig. 3(b) shows the received eye where the directly modulated signal is received without a filter. It is clearly seen that the eye is open and supports the excellent performance with received powers in the order of -33 dBm required to achieve a BER of $10e^{-9}$. However, in the case of Fig. 3(c), the filter centred at the ITU frequency causes intensity fluctuations that result in a partially closed eye. It is important to note the comparative difference between these two eyes even though the closed eye is recorded at a higher received power of -31 dBm. Fig. 3(d) illustrates the eye where the filter centre frequency is changed to the average shifted frequency, showing improved performance in comparison to Fig. 3(c).

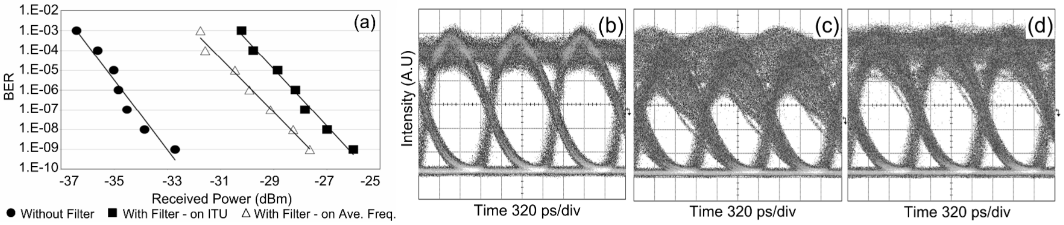

Figure 3: (a) BER as a function of received power, and (b-d) Corresponding eye diagrams (b) without filter (c) with filter centred at ITU wavelength and (d) with filter centred at average shifted frequency

We have characterised the frequency drift of SGDBR tunable lasers under the influence of direct modulation. The magnitude of the drift has been recorded as 12 GHz with a modulation of $1V_{pp}$. In DWDM systems, this drift may result in performance degradation as the signal passes through an optical filter, and this system degradation has been characterised. Results achieved show that a power penalty of 6.7 dB is incurred when using such a filter in comparison to the unfiltered case. A slight improvement in performance (in comparison to the filtered case with filter centred at ITU frequency) is achieved when the centre frequency of the filter is changed to match that of the average output frequency of the tunable laser under direct modulation.

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