Self-Coherent Optical Transmission Using a Narrow Linewidth Tunable Slotted Fabry-Perot Laser

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Abstract: A narrow linewidth slotted Fabry-Perot laser has been employed in a self-coherent optical transmission system. A comparison of the system performance of the tunable slotted laser with a SG-DBR laser has also been shown.

OCIS codes: (060.1660) Coherent communication; (250.5960) Semiconductor lasers

1. Introduction

Widely tunable lasers have become a mainstream component in optical networks because they allow a reduction in inventory management, and offer simple solution to the need for sparing. More recently they have emerged as a key component in reconfigurable optical transport systems by offering dynamic wavelength selectivity. The most common widely tunable laser is the Sampled Grating Distributed Bragg Reflector (SG-DBR) laser which offers quasi-continuous tuning over wide tuning range and side mode suppression ratio (SMSR) of over 40dB [1]. In addition these lasers can switch on nanosecond timescales [2], which makes them suitable for optical packet switching. A disadvantage associated with the SG-DBR laser is the complex fabrication process and low yield.

The primarily employed modulation format in current optical transmission systems is on-off keying (OOK). However advanced optical modulation formats, such as phase-shift-keying (PSK), have seen much interest in recent years due to their lower requirement on optical signal-to-noise ratio (OSNR), higher spectral efficiency and higher tolerance to fiber nonlinear effects [3]. The linewidth of the laser, which is related to the phase noise, is therefore increasing in importance.

We have previously reported on a novel tunable laser structure known as the tunable slotted Fabry Perot (SFP) laser that offers wide (discrete) tunability, high SMSR and sub nanosecond switching [4]. These lasers have a single growth fabrication process and only use standard lithography, which significantly reduces the cost and complexity of fabrication while increasing the yield. A further advantage of the tunable SFP laser over the SG-DBR is its linewidth, which is significantly lower than that of an SG-DBR making it very suitable for PSK transmission.

Self-coherent phase modulation formats such as differential phase shift keying (DPSK) use differential direct detection that does not need an optical local oscillator as is required in fully coherent receivers [5]. DPSK has been used in long-haul point to point transmission systems, as well as for an orthogonally modulated label in wavelength routing packet switching systems [6]. Recently self-coherent transmission has also gained interest in wavelength reuse based WDM-PON [7]. A narrow linewidth tunable laser not only removes the need for digital signal processing (DSP) based phase reconstruction for short distance access networks, but also enables DPSK at lower baud rates [6] and/or higher order modulation formats [8].

In this paper we examine the static system performance of a 1.25Gb/s DPSK system using the SFP laser. The performance improvement over an SG-DBR laser with wider linewidth is presented and error free transmission using the narrow linewidth SFP laser at different ITU channels is shown and compared with error floored transmission using an SG-DBR laser. The results indicate that a low linewidth, low cost tunable laser such as the SFP laser can be used to improve the performance of wavelength tunable self-coherent transmission systems, and may be an ideal transmitter for use in optical access networks that employ advanced modulation formats.

2. Tunable Slotted Fabry-Perot Device

The SFP device consists of a ridge waveguide semiconductor laser, separated into 3 active sections by two single slots etched into the waveguide. By varying the drive current to each section, the gain and index of each section of the laser could be controlled such that single mode lasing was achieved in any of 25 100GHz spaced ITU channels. The linewidth of the SFP and SG-DBR laser was characterized using the delayed self-heterodyne method [9]. Identical dc current sources (Thorlabs ITC-502) were used for both lasers. The measured lineshape of both the SFP laser and the SG-DBR laser are shown in Fig.1. With both lasers, the individual channels could be obtained via

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different drive current combinations and this resulted in varying linewidths, however this linewidth variation was much more pronounced for the SG-DBR laser [10]. The worst measured linewidth of the SFP laser is approximately 738kHz at channel 194.2THz. For the SG-DBR, two sets of operating currents were chosen to give emission of the 194.2THz channel. Both exhibited SMSR greater than 45dB but the linewidths varied (as shown in Fig. 1) from 4.2MHz to 19.8MHz. Thus, the widest linewidth from the tunable SFP laser is over five times narrower than the narrowest linewidth SG-DBR channel.

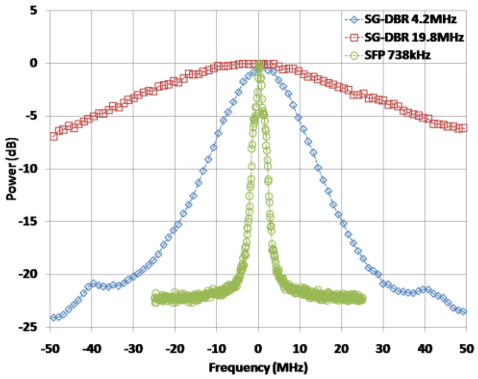

Fig. 1 Measured lineshape of SG-DBR laser with a linewidth of 4.2MHz (◊), 19.8MHz (□) and SFP laser with a linewidth of 738kHz (○).

3. Experimental setup

The experimental setup is shown in Fig. 2. The SG-DBR laser was a commercial device from Agility while the tunable SFP was fabricated within the Tyndall National Institute. Both lasers were butterfly packaged and optically isolated. A Mach Zehnder modulator (MZM), which was biased at the null point, followed the laser transmitter, and this was used to generate the optical DPSK signal. The modulator was driven by a 2^{31}-1 bits pseudorandom bit sequence (PRBS) signal at 1.25Gb/s from a pulse pattern generator (PPG). The power falling onto the receiver was monitored and adjusted using the first variable optical attenuator (VOA). The receiver consisted of a pre-amp erbium doped fiber amplifier (EDFA) and a power amp EDFA, each followed by a 2 nm Optical Band Pass Filter (OBPF) to reduce the out of band amplified spontaneous emission (ASE) noise. A Michelson Delay Interferometer (MDI) was used as a demodulator for the 1.25Gb/s DPSK signal. The delay between the two paths of the interferometer was set to equal the duration of one bit slot, which is 800ps. A second VOA was used to ensure that the power falling on the photoreceiver remained constant, and the photoreceiver was connected to the error detector and oscilloscope that were used to examine the system performance.

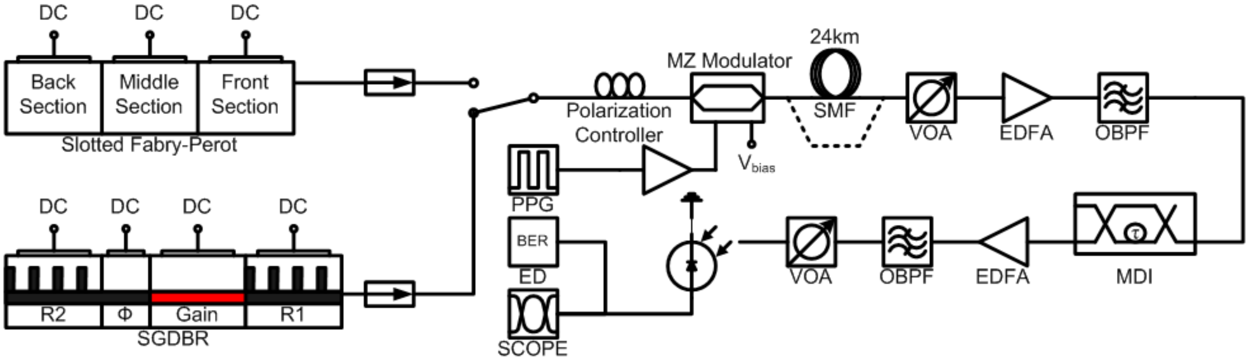

Fig. 2 Diagram of experimental setup

4. Results and discussion

The corresponding demodulated bit error rate (BER), obtained from the error detector, is displayed in Fig. 3. It is important to note that by using a balanced detector, a 3dB improvement in sensitivity could have been obtained. Five channels of the SFP laser were chosen for the experiment with frequencies between 192.0THz and 194.2THz with approximately 0.5THz spacing. Error free performance was achieved with the SFP laser at five different channels (see Fig. 3(a) and (b)) spread across the operating wavelengths of the SFP laser. The 192.0THz channel suffers a performance penalty due to the reduction in EDFA gain at its position towards the edge of the EDFA operating region. The 194.2THz channel of the SFP laser and the 194.2THz channel of the SGDBR laser were chosen for comparison. As shown in Fig. 3(b), a 1dB penalty at a BER of 1×10^{-9} can be found between a 4.2MHz linewidth of the SGDBR laser and a 738kHz linewidth of the SFP laser. An error floor at 1×10^{-5} is observed when the linewidth of the SGDBR laser is 19.8MHz. The received eyes at -41.8dBm of the SFP laser and the SG-DBR laser with 19.8MHz linewidth are shown as the insets in Fig. 3. The phase noise can be found as the random dots spreading across the eye opening in the insets of Fig. 3. Fig. 3(b) also shows the performance of the SFP laser being transmitted through 24km of standard single mode fiber (SSMF). As expected, the penalty between the curves

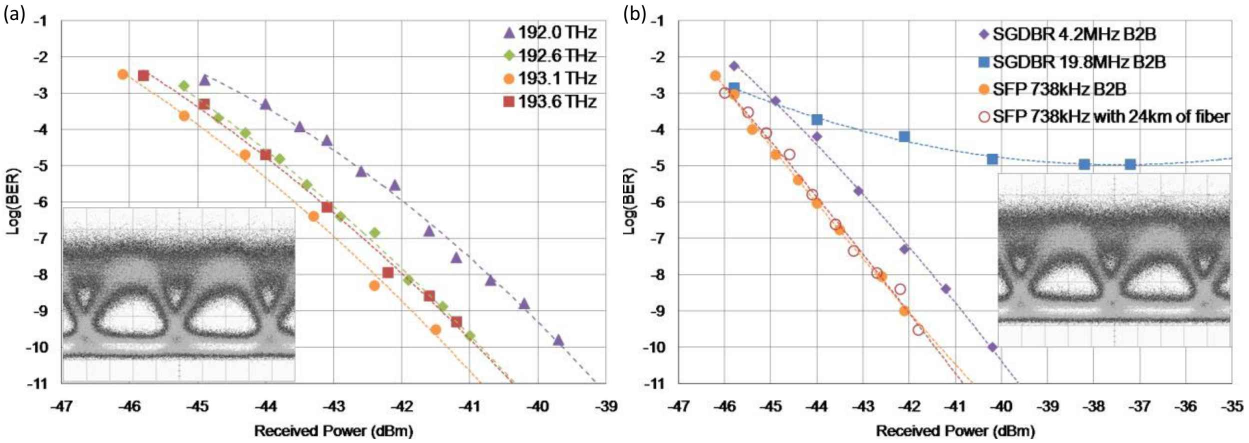

Fig. 3 BER of 1.25G/s DPSK transmission using (a) SFP laser at 4 ITU channels back to back, (b) SG-DBR laser at 194.2THz channel with 4.2MHz and 19.8MHz linewidth. The BER of 1.25G/s DPSK transmission using SFP laser at 194.2THz without (●) and with (○) 24km of fiber is also shown. The insets are the received eyes at power of -41.8dBm for the SFP laser and the SG-DBR (19.8MHz).

without fiber and with 24km of fiber is negligible because at such low data rates the dispersion effect of the fiber is small.

The error floor exhibited by the SG-DBR with binary DPSK indicates that its linewidth would not support higher order modulation formats such as DQPSK and 8-QAM at 1.25Gbaud, which could be used to obtain higher aggregate data rates using low speed electronics. Other varieties of low linewidth tunable lasers such as external cavity lasers (ECLs) would support these higher order modulation formats, but they are expensive, and are too slow for fast switching applications. It is expected that the tunable SFP laser with its low linewidth could support these formats and this, coupled with its low fabrication cost and fast switching speed may make it extremely suitable for future wavelength switched systems such as WDM-PON.

5. Conclusion

A three section tunable laser with narrow linewidth has been employed in a 1.25Gb/s DPSK transmission system. This type of laser has a single growth fabrication process and only uses standard lithography, which reduces the cost while increasing the yield. In addition to its wide tuning range and fast switching speed, the linewidth of the laser has been found to be less than 800kHz for the 25 available channels on the 100GHz ITU grid. This is over 5 times narrower than the optimum linewidth of a commercial SG-DBR tunable laser. Error free transmission has been achieved for five different channels of the laser and similar performance is expected for all channels due to their similar low linewidth. As such, these lasers may prove to be suitable transmitters for wavelength switched systems employing higher order modulation formats.

6. Acknowledgments

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