40GHz all-optical clock recovery using polarization-insensitive distributed Bragg reflector lasers

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Abstract: All-optical clock recovery over 40Gbit/s optical signals using polarization-insensitive distributed Bragg reflector lasers is demonstrated. Low time jitter (<1ps), good extinction ratio (>7dB) and the maintain of locking even for a series of 48 zeros are obtained.

Keywords: self-pulsation, clock recovery, injection locking, semiconductor lasers

1. Introduction

All-optical clock recovery is commonly identified as a key function for all-optical signal processing. Up to now, two types of self-pulsating (SP) lasers have been studied for high bit-rate (>10Gbit/s) clock recovery: distributed feedback (DFB) lasers [1-2], and distributed Bragg reflector (DBR) lasers [3]. The DBR-based solutions offer many advantages such as simplicity of use, possible control of the number of lasing modes, high extinction ratio when associated with a saturable absorber. However, polarization-insensitive clock recovery using DBR lasers without saturable absorber has not yet been demonstrated.

In this paper, we report a polarization-insensitive DBR laser operating as a 40GHz optical clock recovery, along with its free-running SP characteristics. System performance of the device such as phase noise of the recovered clock and its ability to maintain locking for a series of consecutive zeros are also investigated.

2. Laser structure and free running SP characteristics

A schematic view of the DBR laser is shown in figure 1. The laser has 3 sections: an active, a phase and a Bragg section [4]. The active section has a length of 790µm. The guiding layer is a bulk quaternary material with a thickness of 0.4µm and a width of 0.6µm. Such a quasi-square cross-section allows to obtain a polarization-insensitive modal gain. The modal analysis shows a difference of 0.1 in the TE and TM confinement factors with a mean value of 0.58. In the phase section of a length of 130µm, the width of the waveguide expands linearly to match the 1.8µm wide Bragg section. This wider Bragg waveguide has a larger lateral confinement factor for the TE mode. It acts thus as a polarization filter to obtain only TE emission for the DBR laser. The short 200µm-long Bragg section enables to have at least two longitudinal modes inside the 3dB linewidth of the Bragg reflection spectrum. As a result, the DBR laser operates in a multimode regime. It should be noted that there is no saturable absorber inside the laser cavity.

The DBR lasers show a mean threshold current of 40mA with a maximum output power around 20mW. The output wavelength is around 1550nm.

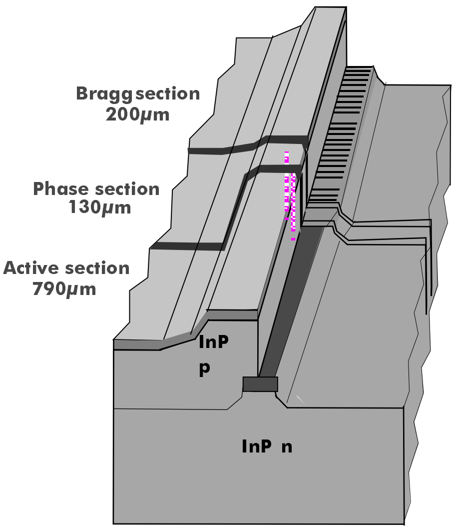
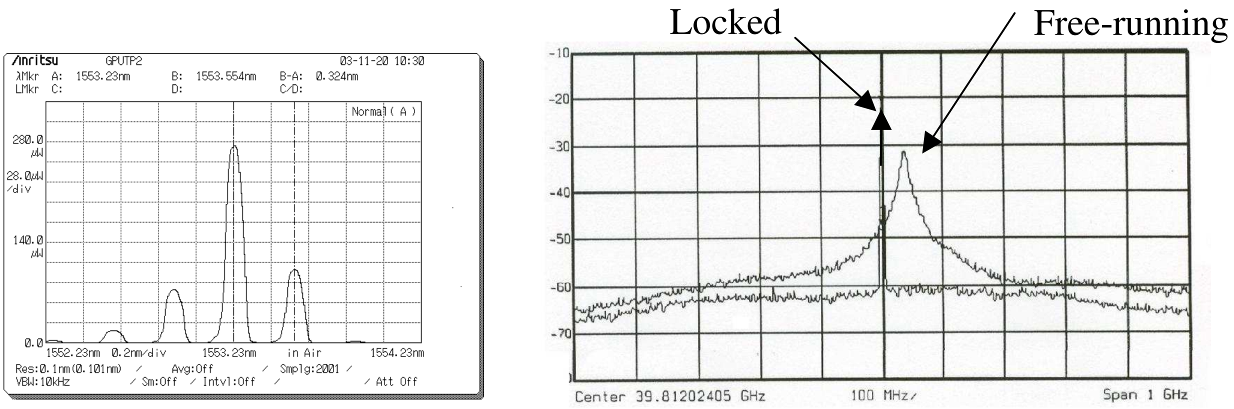


Fig. 1. Structure of the DBR laser.

Figure 2 (a) shows a typical example of the emission optical spectrum in a linear scale. One can observe the presence of 4 modes, with a frequency spacing around 40GHz. Due to the mode beating inside the active section through carrier density modulation and intraband nonlinear effects (spectral hole burning and carrier heating), the modes are partly correlated, leading to self-pulsation [5]. Figure 2 (b) shows the RF spectrum of the output power detected by a large bandwidth photodiode. A SP peak is clearly observed with a full width at half maximum of around 12MHz.



(a) (b)

Fig. 2. (a) optical spectrum, and (b) RF spectrum of the photocurrent.

The dependence of the SP frequency on the injection current to the active and Bragg sections and on the temperature has been studied. Figure 3 shows an example of the SP frequency as a function of the injection current I_B into the Bragg section. One can see a periodic variation of the SP frequency with I_B, which is due to the jumps of the dominant mode. Inside a period, the SP frequency increases with I_B, due to an increase of the Bragg wavelength through thermal effects. Consequently, the dominant mode approaches the Bragg wavelength, leading to a decrease of the effective length of the Bragg section. The tunability of the SP frequency is around 400MHz. The SP frequency can also be tuned by the temperature change. An average value of 80MHz/K was measured for these lasers.

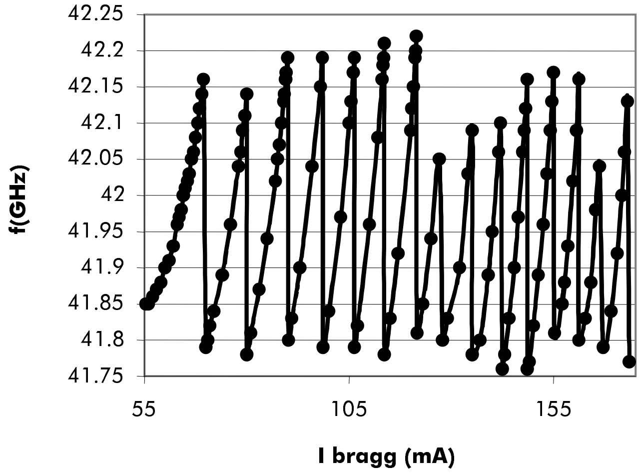


Figure 3 SP frequency as a function of the injection current into the Bragg section

3. Performances of the recovered clock

A 40Gbit/s incoming signal at 1540 nm is coupled via a lensed fiber into the described DBR laser. A maximum polarization sensitivity of 1 dB is estimated from measurements. The recovered clock is then analyzed in the time and RF domains. The RF spectrum of the output power in the locked state is also shown in figure 2(b). A shift of the SP peak to the bit rate of the incoming signal and a drastic decrease of the linewidth of the SP peak are observed from the figure, showing that the SP laser is locked to the incoming signal.

The recovered clock is analyzed by using a sampling oscilloscope. The extinction ratio and timing jitter measured are up to 7dB and around 1ps, respectively, with an injection power of 11dBm. The phase noise of the recovered clock is also studied. Figure 4 shows a typical example of the measured phase noise spectrum for the input clock and the recovered clock. One can observe that these two spectrums are identical for the analysis frequency from 0 to 100 kHz. After 100 kHz, the recovered clock has a higher phase noise than the input clock.

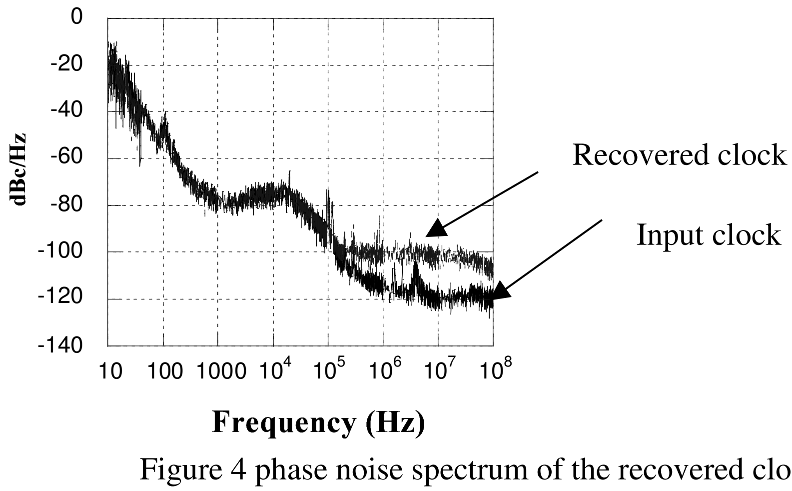
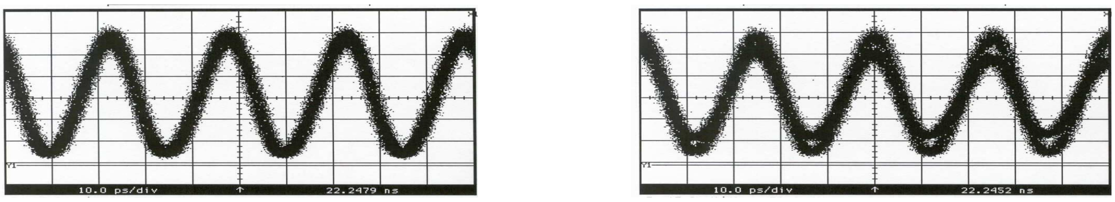


Figure 4 phase noise spectrum of the recovered clock

The ability of maintaining the clock for a series of zeros was investigated in detail. In such a study, the incoming data is programmed such that N marks are followed by N spaces. Figure 5 shows the recovered clock for an incoming sequence with (a) 48 and (b) 64 zeros. In the case of 48 zeros, the phase synchronization is perfectly maintained. For 64 zeros, a slight difference between “1” and “0” is observed, indicating the influence of patterning effects. However, the number of zeros that can be tolerated by the SP laser is much larger that needed for a pseudo-random binary sequence of a length of 2^{31}-1.



(a) (b)

Fig. 5. Recovered clock at 40Gbit/s for an incoming sequence with (a) 48 and (b) 64 zeros.

4. Conclusion

All-optical clock recovery over 40Gbit/s optical signals using polarization-insensitive distributed Bragg reflector lasers is demonstrated. Low time jitter (<1ps), good extinction ratio (>7dB) and the maintain of locking even for a series of 48 zeros are obtained. Experimental results of all-optical recovery in a complete all-optical regenerator will also be reported at the conference.

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