Widely tunable directly modulated sampled-grating DBR lasers

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Abstract: We report on the experimental results obtained for direct intensity modulation of widely tunable sampled-grating distributed Bragg-reflector (SGDBR) lasers. These devices operate in the C-band (1525 – 1562 nm range) and are directly modulated with analog and digital signals. The results obtained show a 6-GHz small-signal bandwidth, and an undistorted Eye- Pattern for a NRZ signal modulation with 2^{31}-1 at 2.5 Gb/s after transmission over a 75-km of S-M ordinary fiber.

OCIS codes: (140.3600) Lasers, tunable

1.Introduction

Widely tunable laser diodes based on the sampled-grating DBR structures are desirable components for Dense Wavelength Division Multiplexed (DWDM) system implementation. They will also play an essential role in future all-optical networks by enabling the realization of optical cross connects (OXCs). The SGDBR lasers used in this work can be continuously tuned over a 40-nm wavelength range, have high side-mode suppression (>36-dB) over the whole tuning range, and the single-mode fiber power output is >4-mW [1].

Typically, SGDBRs intended for DWDM systems require an external modulator to enable the desired light intensity modulation. This approach, however despite its obvious advantages for some applications is costly and cumbersome due to the cost of a modulator and the associated high voltage, high-speed electronic circuitry. It is therefore appropriate to investigate a much simpler and less costly direct intensity modulation of SGDBR which could be used instead for at least short-reach applications.

In this paper we investigate experimentally the direct intensity modulation of SGDBRs for both analog and digital signals over the whole wavelength tuning range. The device structure is shown schematically in Fig.1 including also the biasing and RF- analog (or digital) modulation signal interconnections. These devices were mounted on specially designed microwave carriers using an AlN substrate thus to minimize the effect of parasitic elements on the device response. More details on the device structure are given in [2,3]. The output light from the device was coupled to a lensed single-mode fiber and connected to a broadband high-sensitivity photoreceiver. The photodetected analog signal was then applied to a broadband scalar network analyzer (26-GHz bandwidth) enabling the intensity modulation response to be displayed. In the case of a digital signal modulation a random signal NRZ PRBS-signal generator along with a broadband optical receiver and a bit-error rate detector were used.

2. Experimental Results

The results pertinent to the analog signal modulation are shown in Fig.2. The relaxation oscillation peaks (RIN) are well aligned with the peaks of the intensity modulation response, |M(ω)| over a range of the DC power values (corresponding to $\sqrt{\mathbf{I - I_{th}}}$, where I_{th} = 35-mA) with a slope of 1.5-GHz/mA$^{0.5}$. Both characteristics tend to saturate around 5-GHz which can be attributed to the change of the gain slope **dg/dn** value at higher currents due to a temperature increase of the gain section.

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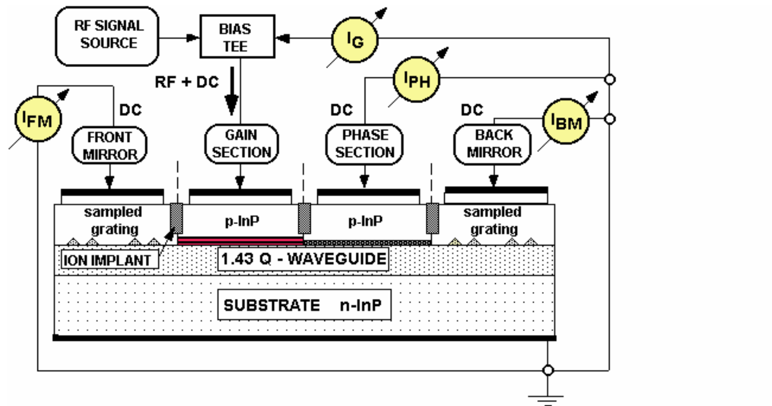

Fig.1 SGDBR layout including interconnections for DC- bias and modulation signal.

The damping factor, γ vs. power is also shown in Fig.2. This is an important parameter of the intrinsic modulation response because it is related to the so-called **K**-factor, and the **K**-factor allows the maximum achievable intensity modulation bandwidth $\mathbf{f_{MAX}}$ to be estimated. The γ - factor and the relaxation oscillation frequency, $\mathbf{f_r}$ (which is determined from the measured RIN response) are related by $\gamma = \mathbf{K f_r^2}$. The maximum achievable 3-dB modulation bandwidth, $\mathbf{f_{MAX}}$ is given by [4] $\mathbf{f_{MAX}} = \sqrt{2}(2\pi \mathbf{K})$. Based on the measured γ and $\mathbf{f_r}$ values as shown in Fig.2 (in their linear range) we estimated that the $\mathbf{f_{MAX}}$ will be 14.8-GHz. In addition, we have also measured the large-signal intensity modulation response to determine the extinction ratio under which the output waveform distortion remains insignificant. We found that the extinction ratio can be as high as 10-dB with the corresponding RF current amplitude -values of 46.6 and 49.2-mA at 1-GHz and 2-GHz modulation signal frequencies, respectively, and the gain electrode bias current $\mathbf{I_G}$ = 100-mA.

Finally, we measured the Eye-Pattern and the BER of our devices under the direct digital signal modulation with and without data transmission over a 75-km ordinary S-M fiber. We used NRZ random signal with 2^{31}-1 PRBS word-length at 2.5-GB/s rate. The Eye-Pattern results obtained at three different wavelengths (1530.70, 1552.38, and 1568.90-nm) for the back-to-back and fiber transmission are shown in Fig.3. It can be seen that the eye opening is large enough for the STM16/OC48 mask standards.

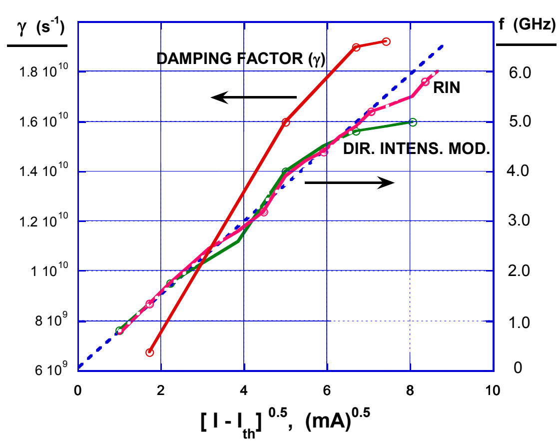

Fig.2 Modulation Response-, RIN – peaks and Damping Factor, γ vs. $\sqrt{I - I_{TH}}$, I_{TH} = 35- mA.

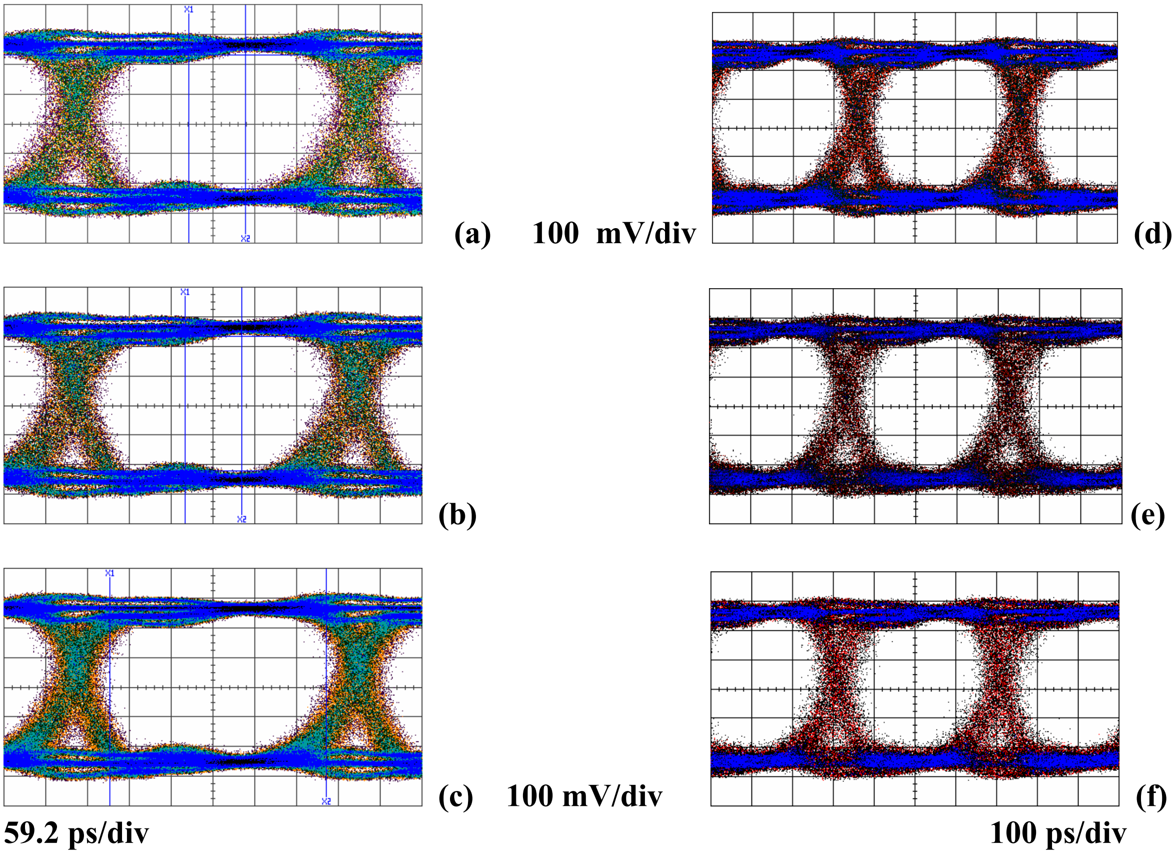

Fig.3 Eye Patterns for 2.5 GB/s with 2^{31}-1 PRBS at three different wavelengths. (a), (d)-1530.70-nm, (b); (e)-1568.90-nm, (c), (f)-1552.38-nm. First column corresponds to the back-to- back, second column to the transmission over a 75-km of ordinary S-M fiber. Extinction ratio is 10 – 12 dB.

The BER characteristics (not shown here) measured under the same conditions <10^{-10} BER. The dispersion penalty ranges between 4 – 6-dB.

3. Conclusions

We investigated widely tunable SGDBR lasers for their operation under the direct intensity modulation using both analog and digital signals. We found that currently available devices can be direct modulated with analog signals up to 6-GHz and can provide single-mode operation up to a 10-dB extinction ratio under the large-signal modulation. These devices can also be digitally modulated, for example at the rate of 2.5 Gb/s and 2^{31}-1 word pattern allowing for their transmission over a 75-km of an ordinary S-M.

4. References

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