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Relative Intensity Noise of Vertical Cavity Surface Emitting Lasers (VCSELs) with Polarization-Selective Feedback

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1. Introduction

850 nm oxide-confined Vertical Cavity Surface Emitting Lasers (VCSELs) have become a standard technology for applications in local area networks (LANs) and storage area networks (SANs). For optical communication applications, consideration must be given to the effects of optical feedback [1]. Although VCSELs have very high facet reflectivity (99%), they remain as sensitive as edge-emitting laser diodes to the effects of optical feedback because of their very short cavity lengths and large emitting areas. Previously, polarization dynamics with optical feedback were also investigated experimentally [2]. Robert *et al.* showed that polarized optical feedback can be used to switch the polarization of VCSELs between two linearly polarized eigenstates [3]. Wilkinson *et al.* and Y. Hong *et al.* experimentally demonstrated that the polarization switch of VCSELs can be controlled by polarization-selected feedback [4-5]. However, to the best of our knowledge, no reports have focused on the noise properties of VCSELs with polarization-selected feedback. In this paper, we demonstrated the elimination of polarization switching by polarization-selective feedback and compared the RIN spectra with polarization-preserving and polarization-selective optical feedback.

2. Experiments

The experimental setup is shown in Fig. 1. An oxide-confined 850nm VCSEL with a threshold current of 1.7 mA was used in our experiments [6]. A beam splitter guided ~ 5% of the laser light into an image-formation lens then the image was recorded by a CCD camera. A multimode fiber was coated with Al thin film on one facet with reflectivity of 10%. The fiber was held by a 5-axises precision fiber positioner and the coated facet was taken as the reflecting mirror. The reflected beam was collimated and re-focused back to the emission aperture of the VCSEL. The tilt of fiber- facet was carefully aligned and formed an external cavity between the top DBR of VCSEL and the fiber-facet. The external cavity length was about 28 cm. Mirror M1 guide the laser to a fast photodetector (PD, Newfocus 1601) and its output is coupled to a 0.5 GHz oscilloscope (Agilent Infinium) to exam the stability of laser. The output of fiber was connected to a 12 GHz photodetector (NewFocus 1580-A) and its output was coupled to a RF spectrum analyzer (HP 8563E).

Figure 2(a) and 2(b) show the light-current relation of the VCSEL under investigation with and without polarized optical feedback. The total output power increases with bias current and the X polarization state and Y polarization state are complementary. Without feedback, the Y polarized state started lasing at 3.6 mA and reached to 44% of the total power while the threshold current of Y state increased to 5.5 mA and output power was suppressed below 11% of total power with X polarized feedback. The suppression in Y polarization can be understood because the X polarized feedback reduced the effective loss in selected polarization, and made the laser favor the selected polarization state. The suppression of unfavorable polarization was strongly depends on the feedback ratio. For the feedback ratio below -20 dB, the polarization state was irregular rather than suppressive in the unfavorable state. For higher feedback ratio, the laser output showed pulsing behavior indicating by the oscilloscope and the L-I characteristics became kinky. However, precise determination on the critical feedback ratio was tough because the value very sensitive to the cavity alignment.

For the optical feedback experiment, it was found that the RIN increases vastly when subjected to the polarization-preserving feedback, similar observations were reported by Ho *et al.* [1] and L. N. Langley *et al.* [7]. In addition, periodic peaks appeared on the envelope of the RIN spectra. In order to investigate origin of the periodic peaks, we changed the cavity length and feedback ratio and found the period corresponding to multiplies of the round-trip frequency of the external cavity. Figure 3 presented the RIN spectra of the investigated VCSEL with and without polarization-selective feedback. A pronounce increasing of RIN was observed in low frequency region and was usually regarded as the mode partition noise. However, the mode selective coupling was carefully avoided in our experiment, and was kept in low level. We attributed the low frequency noise to the polarization switching noise [8]. Although the polarization-selective feedback suppresses the output power of the unfavorable polarization state, it increases the noise instead.

3. Conclusion

In conclusion, RIN spectra are measured on VCSELs subject to polarization-preserving and polarization-selective optical feedback. The RIN increased 20 dB when subject to -20 dB polarization-preserving feedback and showed a multi-peak structure in RIN spectra which resulted from the external cavity between the distributed Bragger reflector and external reflector. Under the polarization-selective feedback, the unfavorable polarization was suppressed while increased additional partition noise in low frequency region (< 3 GHz).

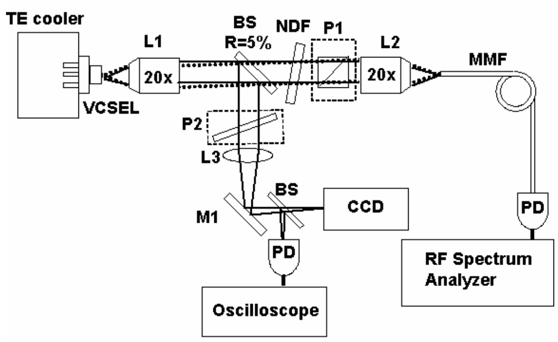

Fig. 1 Experimental setup

Fig. 2(b)

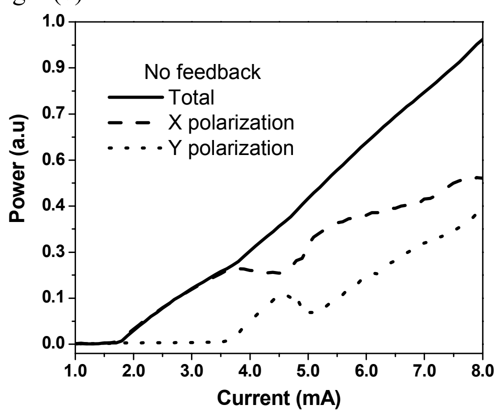

Fig. 2(b)

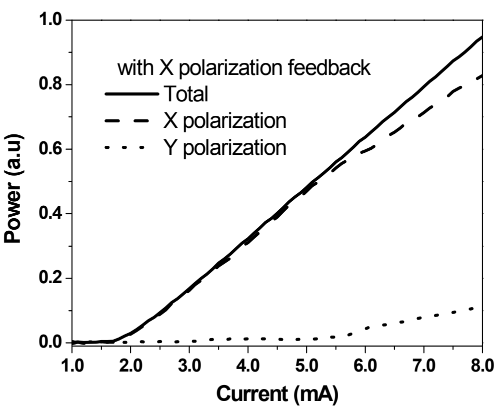

Fig. 2 Polarization resolved L-I characteristics of the investigated VCSEL without polarization selective feedback (a) and with polarization selective feedback (b).

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Fig. 3(a)

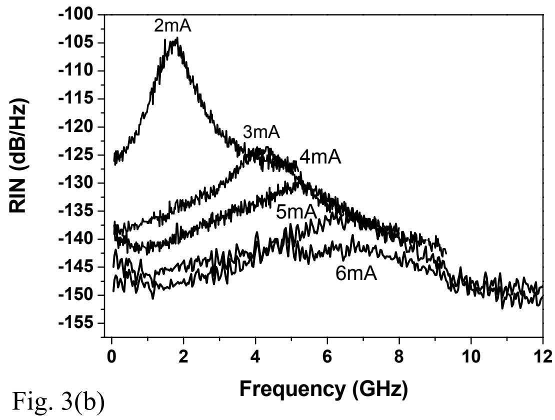

Fig. 3(b)

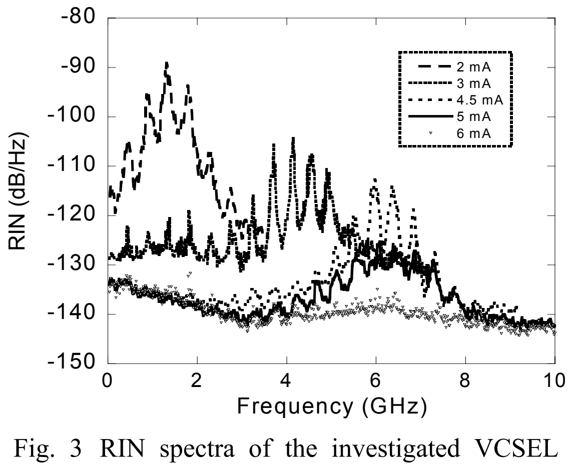

Fig. 3 RIN spectra of the investigated VCSEL without (a) and with (b) polarization selective feedback.