Wavelength Switching Based on Quantum-Dot Vertical-Cavity Surface-Emitting Laser


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Abstract—This study investigates, for the first time, static and dynamic wavelength switching characteristics of the 1.3 μm quantum-dot vertical-cavity surface-emitting laser (QD VCSEL). The free-running QD VCSEL with λ1 and λ2 state innately is injected by a laser source with λ1 state. When the injection power exceeds the threshold power, the dominant state of the QD VCSEL changes from λ2 to λ1 state. Results of this study demonstrate that the wavelength switching based on a 1.3 μm QD VCSEL has a simpler and more cost-effective configuration than those of previous systems.

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1. INTRODUCTION

Wavelength switching and tuning schemes are necessary optical devices for optical communication systems and optical switching applications [1–18]. Wavelength switching schemes using quantum well semiconductor lasers have received considerable attention, owing to their compactness, simple of operation, low cost, and low power consumption [14–18]. However, increasing the wavelength selectivity requires use of tunable bandpass filters or the bandpass filters, possibly increasing system costs.

Recent studies have demonstrated that semiconductor lasers containing quantum dots (QDs) structure in their active region exhibit excellent technological characteristics, including a low chirp, high differential gain, high quantum efficiency and high temperature stability [19–22]. Besides, vertical-cavity surface-emitting lasers (VCSELs) have attracted substantial attention in recent years because they provide various advantages in optical communication systems, such as low power consumption, high-speed modulation, high beam quality, low manufacturing cost, and low threshold current [23–29]. Recently, substantial progress by our group has been made in the development of 1.3 μm QD VCSEL [30–34]. The frequency response, linewidth enhancement factor, and intermodulation distortion have been described. However, the wavelength switching of 1.3 μm QD VCSELs has not yet been studied.

This study describes wavelength switching based on a 1.3 μm QD VCSEL with external light injection. The

Fig. 1. (a) Light—current characteristics and (b) optical polarization characteristics of QD VCSEL.

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QD VCSEL has two wavelength states $\lambda_1$ and $\lambda_2$ innately. Injection of the external light source $\lambda_1$ to that of the free-running VCSEL allows us to observe wavelength switching. When surpassing the threshold value, injection power $\lambda_1$ possesses the dominant $\lambda_1$ state. Also, side-mode suppression ratio (SMSR) surpasses 42 dB when the injection power is 0 dBm. This study also investigates the waveforms and the eye diagrams with 2.5 Gb/s signals. Furthermore, the wavelength switching system based on a 1.3 $\mu$m QD VCSEL without tunable bandpass filters or the bandpass filters is simpler and more economic than previous systems.

**Fig. 2.** Experimental setup for evaluating the optical wavelength characteristics of QD VCSEL with external light injection (VOA: variable optical attenuator; C: optical circulator; PBS: polarization beam splitter; PC: polarization controller).

**Fig. 3.** Measuring the power of QD VCSEL for output $\lambda_1$ and $\lambda_2$. Figures 3a–3b depict the optical spectrum of output $\lambda_2$ and $\lambda_1$ when the power of optical injection is –26 and 0 dBm, respectively.