

RESEARCH PAPER

Performance Characteristics of Conventional Vertical Cavity Surface Emitting Lasers VCSELs at 1300 nm

Faten Adel Ismael Chaqmaqchee

Department of Physics, Faculty of Science and Health, Koya University, University Park, Danielle Mitterrand Boulevard, Koya KOY45, Kurdistan Region-F.R. Iraq

ABSTRACT:

Vertical-cavity surface emitting lasers (VCSELs) are interesting devices because of their low-cost manufacturing and testing methods, circularly shaped output beam for high coupling efficiency and suited for use in fiber-optic networks and as optical interconnects. In this paper, experimental results of output light-current-voltage (LIV), optically pumped VCSELs operating at 1320 nm wavelength are presented. The commercial device is biased just below threshold current of 0.84 mA under pump power of 1 mW. An amplified gain at around 20 dB is obtained. In addition, the influence of temperature on the performance of the device is studied.

KEY WORDS: Commercial VCSEL, Room temperature, Amplification, Thresholds current, Tunable laser power.

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INTRODUCTION :

For future optical metro and access networks it is essential to develop cheap, reliable components with good performance at telecom wavelengths. Such networks are very cost-sensitive, since some components serve just one customer instead of being shared by large numbers of users as in, for example, a trans-oceanic cable. There is therefore a pressing need for optical components that can offer the required functionality at low-cost with high bandwidth at long wavelengths.

The VCSEL is becoming an increasingly important optical source technology for short haul fiber (Haghighi *et al.*, 2018) and long haul fiber communication systems and other applications (Jager *et al.*, 2011 & Cooke 2011)

because of its low cost wafer scale manufacturability and ease of packaging and coupling to optical fiber. The VCSEL device consist of a thin active region generally containing single or multi quantum wells QWs sandwiched between two distributed Bragg reflectors DBRs. Bragg reflectors commonly consist of a quarter wave optical thickness of alternating high and low refractive index layers. The large variation in refractive index layers is responsible for high optical reflectivity, as demonstrated in the GaAs/AlAs material system (Kojima *et al.*, 1993). However, the energy bandgap difference between two layers affects the potential barriers, which slow down the carriers flowing into the mirror, and result in a large series resistance (Huffaker *et al.*, 1996). In addition, AlGaAs (Kim *et al.*, 2004) is an ideal epitaxial material for DBRs due to their lattice match on GaAs, low resistivity, and large variation in the refractive index with change in Al composition in high reflectance mirrors.

* Corresponding Author:

Faten Adel Ismael Chaqmaqchee

E-mail: faten.chaqmaqchee@koyauniversity.org

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All commercially available VCSELs are epitaxially grown on GaAs at operating wavelength of 850 nm. Another possibility is the growth of InGaAs QW VCSEL to push the light from 1150 to 1200 nm because the strain limitation (Sato *et al.*, 1999), while GaAsSb/GaAs was utilized as a replacement for InP baser lasers due to their lasing thresholds and output powers (Kondow *et al.*, 1996). Finally, InP based active region material is grown to be optically pumped at ranges of 1300 nm and 1550 nm (Jayaraman *et al.*, 2000). For conventional VCSEL with circular mesas and oxide apertures, the current is injected through the DBR layers, and the VCSEL is perpendicular to the wafer layers, so their emission is formed from the top of mesa structure.

In this work, we have performed measurements on a commercial VCSEL emits at long-wavelength at around 1336 nm. The device was purchased from Raycan Company and the experimental measurements were performed in optoelectronics research laboratory at University of Essex, United Kingdom. Current, voltage and output light (IVL) is measured at various temperatures. Wavelength as a function of temperature is also characterized. Finally, we have observed an amplification gain at lower threshold current at room temperature.

2. MATERIALS AND METHODS

The Raycan VCSEL coded RC220151-FFP-11333113 is a commercially available device at emitting wavelength of 1336 nm. A more detail of design devices description can be found elsewhere (Piprek, J. *et al.*, 2001, Chaqmaqchee 2016 & Spiewak *et al.*, 2018). VCSELs were designed for high-speed, high-performance communication applications, and have great interest for coarse wavelength-division multiplexing (CWDM) band applications in optical fiber communication technology. All epitaxial layers were grown using either molecular beam epitaxy MBE (Jewell *et al.*, 2008) or metal organic chemical vapour deposition MOCVD technique (Lee *et al.*, 2018), showing flexibility in growing precision controlled layers and in wafer fabrication.

The experimental setup for commercial VCSEL characterization is shown in Figure . The system involves the NI PXI-1033 tunable external cavity laser source to inject the light to the 1336

nm VCSEL. An isolator was used to send the laser light in one direction without reflecting back. The fiber polarization was controlled the polarization state of output signal, whereas the optical attenuator was controlled the tunable laser power. A commercial 10:90 coupler divides the optical signal into two parts. The 10% of the directional coupler is connected into the power meter to monitor the input power, while the 90% of second output coupler is connected into the first of port of a three optical circulator. The second port is connected into the VCSEL and biased diode laser controller. The third port is used to measure the reflected optical power of VCSEL using optical spectrum analyzer.

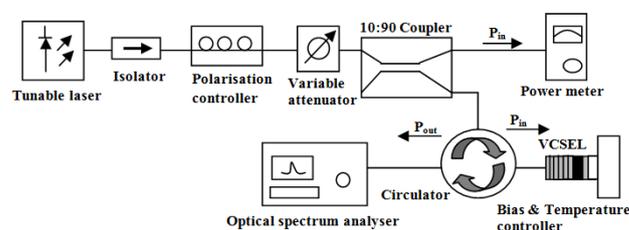


Figure 1: Experimental set up for commercial VCSEL characterization at room temperature

3. RESULTS AND DISCUSSION

The regions of low threshold operation in the light output-voltage versus current (LIV) curve of VCSEL device are selected, as shown in Figure 2. The device is tested under continue wave CW condition at $T=15, 20$ and $30\text{ }^{\circ}\text{C}$ heat sink temperatures. The laser threshold currents were constant and then changed from 0.86 to 0.89 mA at temperatures of $T=15, 20$ and $30\text{ }^{\circ}\text{C}$, respectively. The light output power level is increased linearly by increasing a drive current, in which the lasing threshold is observed to be above a driving current of around 1.4 mA. The maximum output power exceeded 0.25 mW for both temperatures. Moreover, the I-V measurement is taken only for $T=20\text{ }^{\circ}\text{C}$, with no output power saturation is observed.

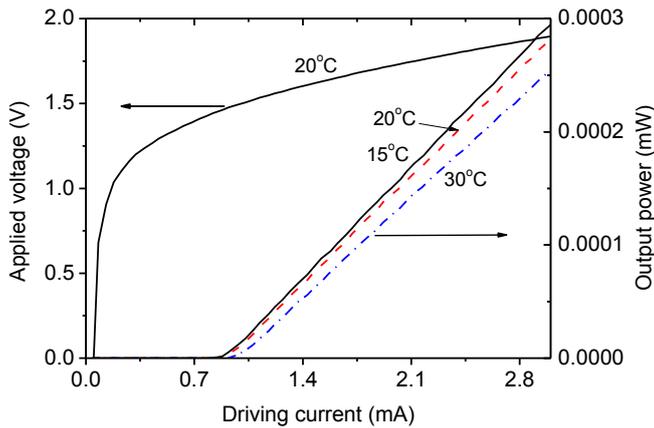


Figure 2: Temperature dependence of I-V-L VCSEL at temperature of T=15, 20 and 30 °C, while I-L is characterized only at T=30 °C.

The VCSEL is biased with different threshold current and at temperature of T= 20 °C. Figure shows VCSEL spectra with two modes that corresponding to the polarizations of the device. The first mode is called the fundamental mode and has a lasing mode, whereas the second mode is called the side mode. The VCSEL emits a single mode at wavelength of around $\lambda=1332.7$. The emission signals are in principle mode, while the emission of the side mode is ignored. The emission peak is increased from 44 dBm to 52 dBm with an increasing of injected current. The emission mode is slightly shifted to the longer wavelength throughout the entire range of current drive from 0.77 to 1.03 mA, probably due to the heating device. The peak gain of VCSEL spectra as a function of threshold currents is also experimentally calculated. The peak gain is increased linearly with increasing threshold current, and maximum amplified gain is measured at threshold current of around $I_{th}=0.85$ mA.

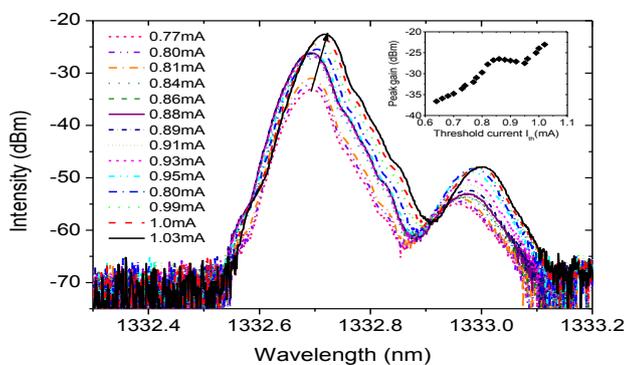


Figure 3: Emission spectra two modes at various threshold currents and at temperature of 20 °C. The inset shows the peak gain versus driven threshold current.

VCSEL operation is strongly temperature sensitive at long wavelength. In this study, the thermal tenability of the amplified signal is measured by varying the heat sink temperature for a fixed tunable laser power and threshold current of 1 mW and 0.84 mA, respectively. Theoretically, the active material peak wavelength with temperature at a rate of 0.1 nm/ °C is predicated. As illustrated in Figure 4, the amplified signal wavelength shifts to the longer wavelength with increasing temperature from T=16 to 28 °C, due to that both the cavity mode and material gain spectrum is changing with temperature (Piprek *et al.*, 1998, Chaqmaqchee & Balkan 2014). The influence of temperature on the device performance with optimized quantum wells intensity peak to cavity wavelength offset were studied elsewhere (Calves *et al.*, 2006 & Li *et al.*, 2017).

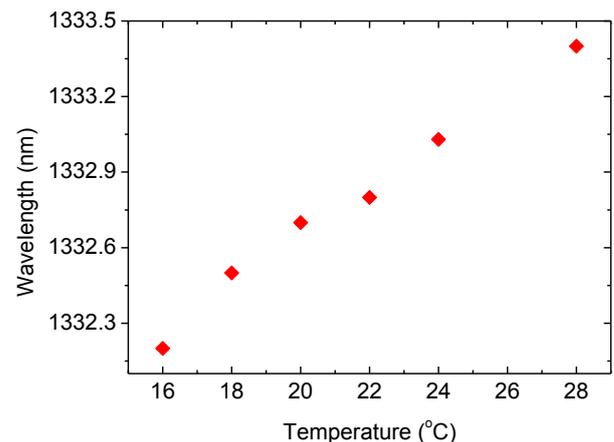


Figure 4: Wavelength tuning with temperature at constant laser power of P=1 mW and threshold current of $I_{th}=0.84$ mA.

The VCSEL is biased just below threshold of 0.84 mA. As shown in Figure , the spectrum has two modes. The first mode is located at around 1332.2 nm and has a lasing mode, whereas the second mode is side mode and it located at ~1332.5 nm. The mode at 1332.2 nm is pumped with tunable laser power of 1 mW. The amplified signal intensity was measured in log scale and has a maximum peak of around 40 dBm. Thus, we obtain a gain at about 20 dBm, which is calculated from the gain= amplified signal-tunable laser.

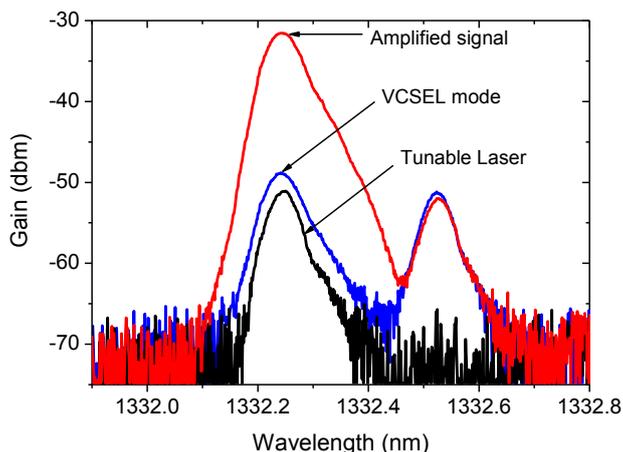


Figure 5: Two modes VCSEL signals, tunable laser signal of constant power of $P=1$ mW and optical amplifier signal operating below threshold current of $I_{th}=0.84$ mA and temperature of $T=20$ °C.

CONCLUSIONS

The VCSEL is becoming an increasingly important optical source technology for long haul fiber communication systems, because of its low cost wafer scale manufacture and ease of packaging and coupling to optical fiber. Commercial RayCan VCSELs were used for optical and electrical characteristics at operating wavelength of $\lambda=1360$ nm. The device was characterized at room temperature of $T=30$ °C and below the threshold current drive and maximum gain at around $\lambda=1332.2$ nm are presented. The technique achieves high reflectivity from the top and bottom DBRs layers. Fundamental and side mode phenomena are demonstrated for an optically injected VCSEL using single mode fiber. The low single mode output powers of $P=1$ mW at below threshold current of $I_{th}=0.84$ mA drive were used, as a consequence high amplification in the fundamental mode at about 20 dBm was demonstrated.

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Conflict of Interest

There is no conflict of interest.

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