Optik 123 (2012) 911–914

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Performance evaluation of VCSEL through single and multi mode fibers

R.S. Kaler

Thapar University, Patiala, Panjab, India

ARTICLE INFO

Article history:
Received 5 October 2010
Accepted 15 February 2011

Keywords:
VCSEL
Temperature
Threshold voltage
Threshold current
Output power
DBR

ABSTRACT

This paper presents influence of the change in temperature of a vertical cavity surface emitting laser (VCSEL) on its output power. It is observed that with increase in temperature of laser its output power decrease. It is also observed that with decrease in threshold voltage of the laser output power increase. Decrease in output power due to increase in temperature can be compensated by increasing driving current. But increase in drive current decrease life of the laser. So a laser with lower threshold voltage can be used to operate at high temperature with long life. Propagation of VCSEL through single mode and multimode fiber is also studied. In single mode fiber only one propagation mode exists due to which signal can be transmitted to longer distances.

1. Introduction

Vertical cavity surface-emitting lasers (VCSELs) are being developed as a light source for optical interconnections. VCSELs enable many types of applications, such as optical computing and optical information processing [1]. VCSELs have such unique advantages as a small size single longitudinal mode, due to the short cavity length, ease in forming a two-dimensional (2-D) array, low power consumption, and a small light beam divergence. Recent years have brought about great improvements in such basic characteristics as the slope efficiency, threshold voltage and light output power [2]. In some applications, VCSELs are to be used without a temperature control circuit, in which case it is important that the VCSEL be temperature-insensitive [3]. Because the cavity mode shifts at a rate of 0.07 nm/°C, and the gain peak shifts at a rate of 0.3 nm/°C, the cavity mode is not aligned with the gain peak as the temperature increases. This reduces the light output power and increase the drive current [4].

An increase in temperature is caused by (a) self heating, (b) thermal crosstalk in simultaneous operation of array devices, and (c) changes in ambient temperature. One way to prevent (a) and (b) is to reduce the electrical series resistance of the device to decrease heat generated in simultaneous oscillation of array devices. VCSELs have a higher electrical series resistance than edge-emitting lasers because current is injected through highly resistive DBR's [5].

With rise in temperature there is shift in gain peak with respect to temperature. This results, decrease in output power of the laser. Fig. 1 shows the effect of rise in temperature on the gain peak and output wavelength of the laser. Operating the laser at high temperatures this shift should be minimum otherwise it would affect the system. For reliable operation of the communication system, it should be less sensitive to temperature effects [7].

Fig. 2 shows variation of the output power with respect to driving current. If current is kept constant and temperature is varied there is significant decrease in the output power. This can be compensated by increasing the driving current. But increasing the driving current decrease the reliability and life of the laser. Also at high-bit rate, the dispersion-induced broadening of short pulses propagating in the fiber causes crosstalk between the adjacent time slots [6]. So here we are used data with 1 Gbps speed. It is observed that with decrease in threshold voltage of laser its output power increase which is opposing the effect of rise in temperature. Laser design with lower threshold voltage will be suitable to operate it at high temperature with long life [8].

Mena and Morikuni [9] presented a simple thermal model of vertical-cavity surface-emitting laser (VCSEL) in which they presented thermally dependent threshold current and output-power roll-over for a range of ambient temperatures. They showed that if the input current is constant and temperature is increased output power of the laser decrease. Nishiyama, Caneau and Hall [10] presented the effect of cavity length, temperature on output power of the laser. They concluded that with increase in cavity length of the laser output power increase. But increase in temperature results decrease in output power of the laser. Decreasing the defects in the active region as well as decreasing the threshold current is important for obtaining a long-lifetime VCSEL [11]. According to [8,9] the output power can be compensated by increasing the driving current of the laser. But increasing the operating current limits the life of laser.

E-mail address: rskaler@yahoo.com

0030-4026/$ – see front matter © 2011 Elsevier GmbH. All rights reserved.
doi:10.1016/j.ijleo.2011.07.004

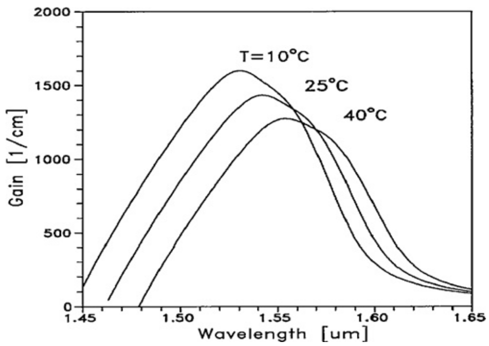

Fig. 1. Optical gain as function of the emission wavelength with the MQW temperature as parameter [7].

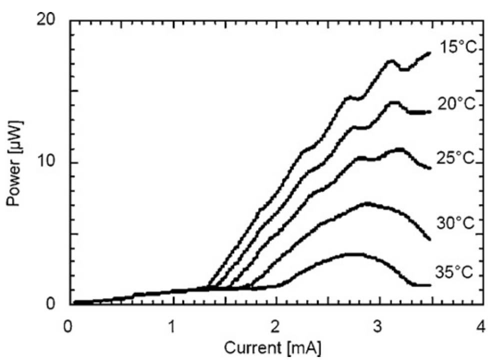

Fig. 2. *I–L* Characteristics with temperature as parameter [7].

In this paper we study the effect of variations in threshold voltage on output of the laser. Observations are made by varying the temperature. Recently, there has been great interest in using single mode fibers [12,13] for high-bit-rate transmission in low loss transmission windows. So the propagation of VCSEL output from single mode and multimode fibers is also studied. It is observed that there is decrease in output power with increase in temperature and to compensate this if threshold voltage is decreased there is significant rise in output power of the laser.

This section discusses the factors which are responsible for heating and how it affects the operation of laser. Section 2 describes the simulation setup using OptSim. In Section 3 results obtained in simulation are presented and finally conclusions are discussed in Section 4.

2. Simulation setup

To investigate the temperature dependent performance of the VCSEL an Optical and Electrical Transmission Systems Design & Simulation Environment based OptSim tool is used. Setup for analysing the effect of temperature is shown in Fig. 3. As shown in figure data source generates data at 2 Gb/s which is converted into NRZ Raised Cosine format by signal driver with low level 0.005 V and high level 0.03 V. This driver drives VCSEL laser operating at

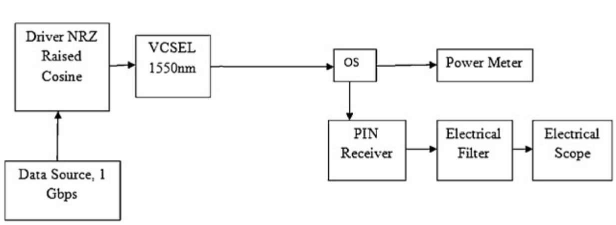

Fig. 3. Setup for analysing the effect of temperature: OS, optical splitter.

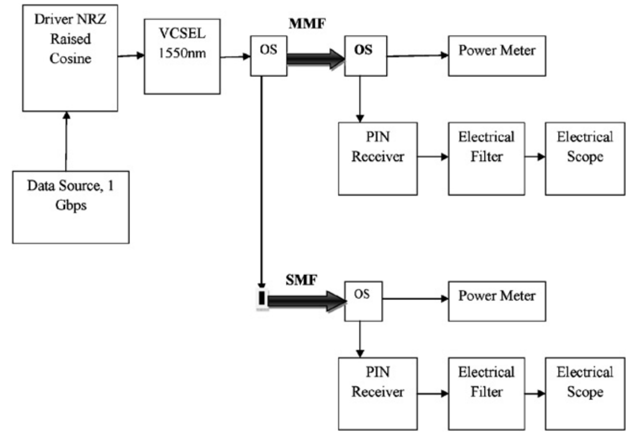

Fig. 4. Setup for propagation through single mode and multimode fiber: OS, optical splitter; MMF, multi mode fiber; SMF, single mode fiber.

1550 nm and signal is modulated directly in the laser cavity. After modulation laser output optical power travel through ideal optical fiber. This signal is splitted with the help of splitter and fed to power meter and optical receiver separately.

Output optical power is measured with the help of power meter. Receiver detector is PIN photodiode with quantum efficiency 0.5599 and responsivity 0.7 A/W. After detection it is passed through electrical filter which is of type raised cosine with bandwidth of 1 GHz this filtered signal is analysed with the help of electrical scope and Q estimator.

To investigate the laser behaviour temperature of laser is varied. Then output in plotted against temperature. To compensate temperature effect on the output of the laser a compensating parameter threshold voltage of the laser is varied. Then output power is plotted as function of threshold voltage.

For analysing the propagation of VCSEL signal through single mode and multimode fiber setup is shown in Fig. 4. Components used here have same parameters used in setup (Fig. 3). It uses single mode fiber with attenuation 14.4 dB/km and multimode fiber with same value of attenuation. Here data generated by data source at 1 Gb/s and is made to travel through these fibers. Length of multimode fiber is varied from 50 m to 250 m and length of single mode fiber is varied from 500 m to 4 km. The signal is analysed with the help of power meter, electrical scope and Q estimator.

3. Result and discussions

In the previous section, we discussed various components used in the simulation setup. Using this setup the measurements of output power by varying the temperature from 20 °C to 70 °C are taken. This is shown in Fig. 5. It is observed that with rise in temperature

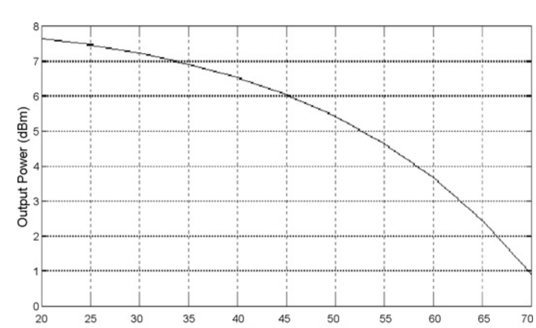

Fig. 5. Temperature vs output power.