TEMPERATURE DEPENDENCY OF SEMICONDUCTOR LASER

Ing. Radek KVÍČALA, Doctoral Degree Programme (1)
Dept. of Radio Electronics, FEEC, BUT
E-mail: xkvica00@stud.feec.vutbr.cz

Supervised by: Dr. Otakar Wilfert

ABSTRACT

This article is focused on an examination of degradation dependency of a semiconductor laser on a temperature of an LD package. Thermal conditions dependence an emitter optical power, spectral component, which is emitted by the laser, electrical to optical power conversion efficiency and many others parameters. The criticality of the parasitic parameters is evaluated in this paper. These parasitic parameters must be considered carefully to eliminate them efficiently.

1 INTRODUCTION

The thin area of an energy pumping, when the rapid transition from a spontaneous emission mode to a stimulated emission mode occur, is called the threshold. A semiconductor laser is related with a term of threshold density of a driving current or threshold current I_{th}, when the laser diode operating mode is changed from incoherent to laser. Increasing temperature introduces decreasing of the features of laser diode. While the temperature increases, the ratio between the electrical power and the optical power decreases. The temperature also depends on the emitted wavelength or the device operating life.

2 CHARACTERISTIC TEMPERATURE

The parameter, which determines the feature degradation of the laser diode, is called characteristic temperature T_0. The characteristic temperature T_0 can be derived from L-I dependency. The L-I dependency must be measured for two different temperatures – indoor temperature of 25 °C and high temperature of 85 °C. It is examined experimentally, that there is an exponential dependency between threshold current and the temperature. Increasing temperature introduces an increase of I_{th}.

Characteristic temperature can be evaluated according to this fact as

$$T_0 = \frac{T_U - T_D}{\ln\left(\frac{I_{thTU}}{I_{thTD}}\right)}, \qquad (1)$$

where T_U determines high temperature, T_D determines base/low temperature, I_{thTU} determines high temperature threshold current and I_{thTD} determines base/low temperature threshold current. The characteristic temperature T_0 denotes the measure of I_{th} dependency on the temperature variations. The more T_0 is higher, the lower the temperature dependency is. Fig. 1 shows the L-I graphs (**RLD – 78 NP – D**) measured for different temperatures [6].

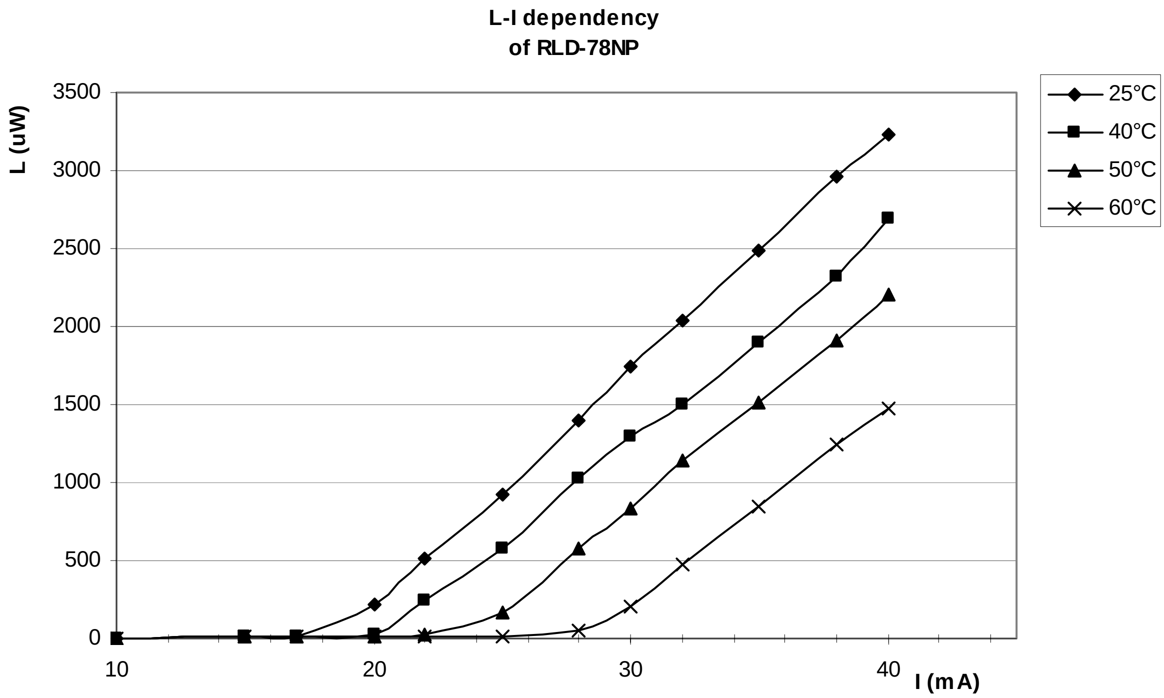

Fig. 1: *Driver current dependence of optical power, where temperature is the parameter*

The characteristic temperature can be computed from the formula (1). The required values of threshold current can be read from Fig. 1. These values are approximately 18 mA at the temperature 25 °C and 41 mA at 85 °C [6]. Thus the characteristic temperature is 72,8 °C for laser diode RLD-78NP. The standard temperature interval is 50-75 °C. These values of the characteristic temperature are used in telecommunication optical links.

3 SLOPE EFFICIENCY - ETA F

It is necessary to use a laser diode with the lowest value of the threshold current. But it is also desirable to affect the emitted optical intensity by an increment of current. In fact, this dependency is given by the rate of intensity rise which is called *Eta f* (slope efficiency, differential sensitivity or differential efficiency of a laser diode). If a laser diode is used in telecommunication, some conditions must be considered. For example, if the current change is 10 mA (the absolute value of current is over threshold), the change of emitted optical intensity is approximately 1mW. The ratio of these changes is called *Eta f* and is defined as

$$Eta\ f = \frac{\mathrm{d}P}{\mathrm{d}I}. \qquad (2)$$

The theoretical L-I dependency is linear in the area over threshold current. But in the real dependency, there is some degree of non-linearity, especially in the area of the saturation.

As it was defined above, parameters of laser diodes get worse with increasing temperature. This fact is given by an activation of radiationless processes in a semiconductor. Then a portion of emitted light is converted to heat energy. Thus a temperature effect on Eta f is following: differential sensitivity of the laser diode is going down with increasing temperature. In the other words, if the current is constant and the temperature is increasing, then the optical power is getting down. Laser diodes, which are used in telecommunication, are characterized by Eta f lying in the interval 100-400 mW/A.

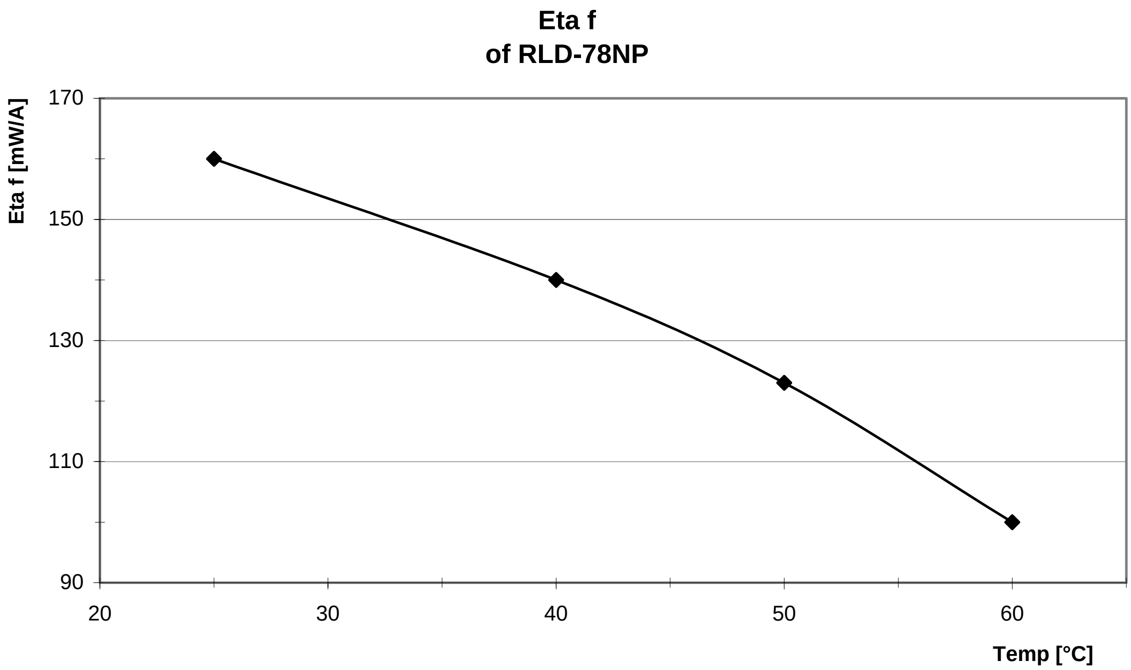

Fig. 2: *Eta f (for output power 1,5 mW)*

4 SPECTRUM DEPENDENCY

The spectrum is a set of wavelengths which are emitted by a laser diode. In comparison with a LED, the spectrum of a laser diode is very narrow (0.1 to 1 nm). A typical spectrum of a laser diode with a Fabry-Perot resonator contains several longitudinal modes. The material and the length of a Fabry-Perot resonator determine the longitudinal mode wavelength.

Laser diode spectrum depends on a temperature. Increasing temperature (the crystal volume and the refraction index increase) introduces spectral shift to the higher part of the spectrum. This phenomenon is called the longitudinal mode drift. The forward diode current affects the laser diode spectrum. Increasing forward diode current increases Joule heat and the laser diode chip temperature goes up, too. The forward diode current variations causes energy shift among the longitudinal modes. This leads to discrete hops of wavelength of the main peak. This phenomenon is called *mode hopping*. Laser diodes using Fabry-Perot introduce this phenomenon [4].

5 NEGATIVE FACTOR ELIMINATION

Integrated monitoring photodiode (usually PIN diode) is used for constant optical power control in semiconductor lasers. This photodiode measures the instantaneous optical power. The instantaneous optical power induces a current in the photodiode. The feedback must be introduced. According to this, the supply current of the laser diode can be controlled and the constant optical power can be set up (the idea is similar to current stabilizer and operating amplifier). Different types of devices can be utilized. Temperature stabilization must be applied to reduce the differential sensitivity and to maintain the stability of the wavelength. A heat exchanger and Peltier elements are usually utilized.

6 SUMMARY

In the paper, there was shown the important dependences of laser features on temperature. The temperature can have negative effect on the important parameters and quality of a semiconductor laser diode. There is a need to know the dependency of parameters on the temperature for successful diode construction. Thus the decent attention must be paid to thermodynamic conditions. It is required that a laser diode can work at a low constant temperature. For this purpose, Peltier element with current source is used. Electronics, which is used with Peltier element, can work duplex. Then Peltier element can work as a cooler or a heating pump. Then the temperature of the laser diode is constant.

ACKNOWLEDGEMENT

This contribution is supported by the project GA ČR č. 102/03/H105.

REFERENCES

[1] Saleh, B. E. A., Teich, M. C.: Základy fotoniky, MATFYZPRESS Praha 1994

[2] Mišek, J., Kučera, L., Kortán, J.: Polovodičové zdroje optického záření, SNTL Praha 1988

[3] Kasap, S. O.: Optoelektronics and Photonic: Principles and Practices, Prentice Hall, New Jersey 2001

[4] Lukáš, M.: Laserové diody 3: Parametry laserových diod a jejich měření, http://www.elektrorevue.cz/clanky/02023/

[5] Prokeš, A., Zeman, V.: Modulation Characteristic of VCSELs In Proocedings of the Telecommunications and signal processing TSP-2002, VUT Brno UTKO, 2002, p. 243 - 245, ISBN 80-214-2172-x

[6] Kvíčala, R.: Optický vysílač pro mikrovlnný signál, diploma thesis, VUT Brno 2004