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Abstract:

This article proposes a modelling method of laser diodes optical output power, especially for mid-high power diodes working in continuous wave (CW) or quasi continuous wave (QCW) modes, and focusing in the optical output power dependency on temperature and its model implementation in Pspice, targeting its computer simulation. It is commented the theory and related mathematical expressions used in the model, the Pspice program model and the purpose of its different parts, and how mathematical expressions are introduced in it. It is proposed a diodes optical output power response characterization method using an automatic data acquisition system to obtain diodes response curve avoiding temperature effects during the measurements. Implementation example of the modelling and characterization method in a laser diode, model results versus real measurements comparison and related conclusions are exposed.

Keywords: Laser diodes optical model, Pspice model, Modelling method, Characterization system

1- Introduction

Modelling need of laser diodes optical output power is related to the fact that the device temperature is increasing due to the laser effect and decreasing the optical output power. This effect is especially important when the laser diode device is used in continuous or quasi continuous wave modes. Most of the laser diodes applications are based in a constant optical output power and in order to achieve it two options are used: either to keep constant the temperature or to use feedback circuits readjusting the injected current [1]. In the first case, even though the device temperature is kept constant by using temperature conditioning systems like Peltier cells or chiller circuits, it is necessary to consider that it may exist a temperature gap between the semiconductor's p-n junction and temperature control elements inside the device or the system like thermistors or thermometers. This gap should be measured, for instance based on the emitted light spectrum using spectrometers, to evaluate the necessary margins to keep the device inside operational limits. In the second case, feedback circuits based on photodiodes measurement, compensating the optical output power decrease with more injected current, will tend to increase the temperature of the laser diode device up to an unknown value that will depend on the overall system temperature dissipation capability. In both cases, constant temperature or feedback circuits, it is worth to simulate device response at different temperatures assuring its usage inside operational limits to avoid possible device damages. Laser diodes are the most robust of the laser devices, but temperature and current limits should be respected.
The laser diodes optical power output dependency on temperature is a known effect. Information of how this temperature variation works and related theory are available [2] and it is used for this methodology proposal. The novelty of this work is to adopt some hypothesis to complete the temperature dependency mathematical expressions and to define a modelling method targeting this temperature dependency to be programmed in a computer simulation tool like Pspice environment. This includes:

- to identify which are the required parameters and how to obtain their values
- to propose the mathematical expressions for the temperature dependency
- to propose a Pspice simulation model schema
- to include the obtained mathematical expressions in the simulation schema and obtain its Pspice programmed model, and
- to define a temperature independent measurement method including testing signal conditions and measurement tools to properly achieve the correct parameters values required for the model.

This last item refers to the so-called cold measurement method and the characterization system setup. This setup includes developing an automatic data acquisition system to measure the relation between the optical output power Popt, the laser diode current Ild and the temperature T, to be used with temperature conditioning systems like chillers circuits or climatic chambers.
To be able to define the temperature dependency model of the optical output power of a laser diode with this proposed modelling method it is necessary to know how is the variation of two parameters of the optical response with the temperature, the threshold current I_{th}, minimum injected current to start optical emission, and the slope efficiency SE or differential efficiency η_D, defined as the relation between the optical output power and the injected current increments. Some assumptions or hypothesis are taken related to the variation of the slope efficiency with the temperature. No information about this variation has been found in the state of the art of the theory, so this is also a novelty of this work. This hypothesis is based on some laser diode devices specification data, and it is confirmed with results obtained in a climatic chamber. Those results also confirm the variation of the threshold current with the temperature as exposed in the theory.
The selected electronic circuits simulation tool in this work is Pspice and the programmed models are developed and simulated using it. Even thought the mathematical model and expressions are of course general and could be used to program any other simulation tool.
The modelling method proposed in this article has been applied to different output power ranges laser diodes devices of different wavelengths, from 5 mW diodes up 40 W laser bar diodes. Model has been validated by comparison of simulation results and measured values in all of them. In this article, as a use case example, the overall modelling method and characterization system are mainly applied to a concrete diode, an 8 W single emitter laser diode, even some references to other laser diodes are sometimes done to help the explanation of certain concepts.
The structure of the article is as follows:

- Section 1, the Introduction where motivation and overall view of the article's contents is explained.
- Section 2 is a state of the art explanation regarding laser diodes modelling methods