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# Modal Behavior of an External Cavity Diode Laser

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This paper reports the results of numerical investigations of the modal behavior of an external cavity diode laser device composed of a semiconductor laser and a distant Bragg grating, which provides an optical feedback. Due to the influence of the feedback, the laser device can operate at of various dynamic modes. The numerical calculations are based on the solution of the homogeneous coupled-wave equations using a transfer function approach. We show that the number and stability of laser modes is closely dependent on the material and device parameters such as transmission and reflection coefficients of the laser facets and sectional lengths.

**Keywords:** Cavity Diode Laser, Simulation of Modes.

## 1. INTRODUCTION

During recent years semiconductor lasers under the influence of an external feedback have attracted attention due to its fundamental and applicative interests. A semiconductor diode laser subject to a proper external feedback resulting in a stabilized wavelength is required for various applications in spectroscopy, metrology, space communication etc.[1] The stabilization of the wavelength can be achieved by a Bragg grating as external mirror. Recently, a new micro-integration approach was used to create a compact diode laser with a narrow linewidth and an external cavity for quantum-optical precise experiments in space.[2]

A simple model for the simulation of a semiconductor laser subject to weak and moderate optical feedback was proposed by Lang-Kobayashi (LK).[3] It constitutes a system of differential equations with a delay term. The LK model allows a reasonable qualitative agreement with experiments and provides a good understanding of the nonlinear dynamics in this device.[4] The LK approach has also been successfully used to obtain a good understanding of the stabilization or destabilization of the states of the continuous radiation on different configurations of the external cavity.[5] However, the LK model is mainly suitable for the study of a system where a laser is subject to weak feedback from a distant mirror and where the distance of the mirror is much larger than the length of the laser.

A more appropriate way to describe the dynamics of semiconductor lasers with an external cavity is the traveling wave model. It represents a system of differential equations, which includes a description of the spatial distribution of fields.[6,7] In this paper the eigensolutions (modes) and eigenvalues (frequencies) of the travelling wave model are calculated. Our paper is organized as follows. In the section II the basic equations is introduced. Section III is devoted to the computer simulation and analysis of the obtained results. Section IV contains the conclusions.

## 2. BASIC EQUATIONS

We study a three-section external cavity diode laser. Its scheme is shown in Figure 1. It consists of an active section with length $L_1$, an air gap with length $L_2$ and a passive section with length $L_3$. More details about the laser chip used for the active section can be found in Ref. [8].

The laser is described by the homogeneous coupled wave equations.[6,10,11]

$$\begin{bmatrix} +\dfrac{\partial}{\partial z}+i\Delta\beta(z) & i\kappa^{+}(z) \\ i\kappa^{-}(z) & -\dfrac{\partial}{\partial z}+i\Delta\beta(z) \end{bmatrix} \begin{bmatrix} a(z) \\ b(z) \end{bmatrix} = 0 \tag{1}$$

where

$$\Delta\beta(z,\lambda)=\beta(z,\lambda)-\beta_{\mathrm{Bragg}} \tag{2}$$

is the relative complex propagation factor with

$$\beta_{\mathrm{Bragg}}=\frac{N\pi}{\Lambda} \tag{3}$$

being the Bragg wave vector.

These equations are solved subject to homogeneous boundary conditions at $z=0$

$$a(0)-r_0 b(0)=0 \tag{4}$$

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