Investigations of external cavity diode lasers: simulations, analysis and experiments

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***Abstract* - We report the results of numerical and experimental investigations of the dynamics in an external cavity diode laser device composed of a semiconductor laser and a distant Bragg grating, which provides an optical feedback. The traveling wave model was used to simulate and analyze the nonlinear dynamics of the considered laser device. Finally, it is shown, that the simulation results are in good agreement with experiments.**

I. INTRODUCTION

During recent years the control and stabilization of laser emission of semiconductor laser (SL) by an external cavity has received considerable attention. In particular, wavelength stabilized SL are required for different applications such as frequency conversion, quantum-optical accurate experiments in space, space communications, spectroscopy etc. It is well known, that the integration of a Bragg grating into a laser chip leads to the stabilization of the lasing wavelength. Recently, a novel micro-integration approach was used to build a compact, narrow linewidth External Cavity Diode Laser (ECDL) with a volume holographic Bragg grating [1]. The laser module is ideally suited for quantum-optical precise experiments in space.

Semiconductor lasers subject to the delayed optical feedback from a distant mirror have been investigated extensively during the past two decades. Different dynamical regimes, including continuous-wave (CW) states, periodic and quasi-periodic pulsations, low frequency fluctuations, and a coherent collapse were examined (see [2] and references therein). A simplest method for modeling a SL with a *weak* optical feedback is given by the Lang-Kobayashi (LK) model [3]. The LK modeling approach was also successfully used to get a deeper understanding of the stabilization or destabilization of the CW state by different configurations of the external cavity. A more appropriate way to describe the dynamics of semiconductor lasers with a *short* external cavity is given by the Traveling Wave (TW) model, which is a partial differential equation model that includes the spatial (longitudinal) distribution of the fields [4,5]. The TW model is used in the present paper, which is devoted for an investigation of the dynamics of the ECDL device composed of an amplifying semiconductor section and a distant Bragg grating that provides an optical feedback. The paper is organized as follows. The device structure and mathematical model are described in Section II. Section III presents the related numerical and experimental results. Finally, some conclusions are given in Section IV.

II. SETUP AND EQUATIONS

We focus on the ECDL device, schematically represented in Fig.1. It consists of an active section S_a containing the laser chip, an external holographic volume Bragg grating S_b, and a glass lens S_l located close to the inner facet of the laser chip. Two air gaps $S_{g'}$ and $S_{g''}$ separate the active section from the lens and the lens from the Bragg grating, respectively.

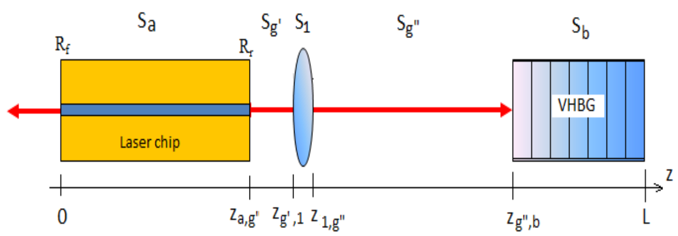

Fig. 1: Schematic representation of the ECDL device.

We use the traveling wave equations for the slowly varying complex amplitudes $E^+(z,t)$ and $E^-(z,t)$ of the counter-propagating optical fields within each section of the laser

$$\frac{n_g}{c_0}\partial_t E^{\pm} = \left[\mp\partial_z - i\beta(\mathrm{N},\mathrm{I})\right]E^{\pm} - i\kappa E^{\mp} + F_{sp}^{\pm}, \qquad (1)$$

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