Analysis of the dynamics of a blue-violet $In_xGa_{1-x}N$ laser with a saturable absorber

V. Z. Tronciu,[1,*] Minoru Yamada,[1] and R. A. Abram[2]
[1]*Faculty of Engineering, Kanazawa University, 2-40-20, Kodatsuno, Kanazawa, 920-8667, Japan*
[2]*Department of Physics, University of Durham, Durham DH1 3LE, United Kingdom*
(Received 29 September 2003; revised manuscript received 29 April 2004; published 17 August 2004)

We report the results of numerical investigations of the dynamical behavior of a blue-violet InGaN laser with a specially incorporated saturable absorber. We have identified the nature of the bifurcation that occurs in the device dynamics and also the conditions that are necessary for self-pulsating and excitable operations. We also demonstrate the influence of the relevant device parameters on the laser dynamics and show how the properties of the saturable absorber and its position in the device have a considerable influence on the laser behavior. Finally theoretical investigations of the excitable behavior and a confirmation of the excitability properties of an InGaN laser are presented and discussed.

DOI: 10.1103/PhysRevE.70.026604 PACS number(s): 42.55.Px, 42.65.Sf

I. INTRODUCTION

In the last decade violet InGaN laser diodes (LD's) have been the subject of considerable attention, with the studies mainly motivated by the prospect of the application of the devices to high-density optical disk storage and optical data processing [1]. In particular, blue-violet laser diodes are required for CD or DVD systems to increase the disk storage capacity up to 25 Gbytes. As a result of recent research, 400 nm (blue-violet) LD performance has been improved and the lifetime has been extended to over 15 000 hours [2]. Blue-violet CW LD's are already commercially available and several reports have recently appeared concerning the CW operation of blue lasers at room temperature [3–7]. In this paper we consider the phenomena of excitability and self pulsation (SP) in blue-violet InGaN lasers.

The use of self-pulsation is attractive for the reduction of feedback noise [8,9] in CD and DVD systems but since the early investigation of Nakamura *et al.* [10], self-pulsating violet and blue-violet LD's have not been studied in any detail. Although less well known than self-pulsation, excitability is a new and rapidly expanding topic in optics, having initially received much more attention in biology [11] and chemistry [12]. However, in recent years there has been growing interest in excitability in the physics and engineering communities, and recognition that the phenomenon might have device applications in optics. Recently, there have been theoretical predictions of excitability in devices, such as optical cavities and different types of lasers [13–17], and in some cases these predictions have been supported by experimental observation. For example, there is particularly convincing experimental evidence of excitability in a laser with a short external cavity [18]. In addition, an experimental investigation of the excitable properties of a solid-state laser with an intracavity saturable absorber is reported by Larotonda *et al.* [19].

In this paper, we report studies of the dynamics of a multiquantum well InGaN laser with a saturable absorber (SA). In particular, we investigate the self-pulsation and excitable operation of the laser, with particular emphasis on the latter. We start in Sec. II with a description of the laser structure and the theoretical model and the associated equations used to calculate the device behavior. The results of numerical calculations of the device dynamics are presented and discussed in Sec. III and the conclusions are given in Sec. IV.

II. LASER STRUCTURE, MODEL, AND EQUATIONS

Figure 1 shows the structure of the InGaN laser with saturable absorber that has been considered; it consists of a multiquantum well (MQW) InGaN active layer and a saturable absorber in the form of a single *p*-type InGaN quantum well. Relatively thin saturable absorber layers varying from 1 to 3 nm have been used with a view to maintaining a low threshold current. The AlGaN layer prevents significant carrier overflow from the active region. In the fabrication process, the saturable absorber layer was grown as a layer parallel to the active region, which is different from the situation treated in previous papers where the SA's were grown perpendicular to the active region [20–23]. Further details on the fabrication method are given by Ohno *et al.* [24]. The lasing wavelength is at 395 nm and three different cavity

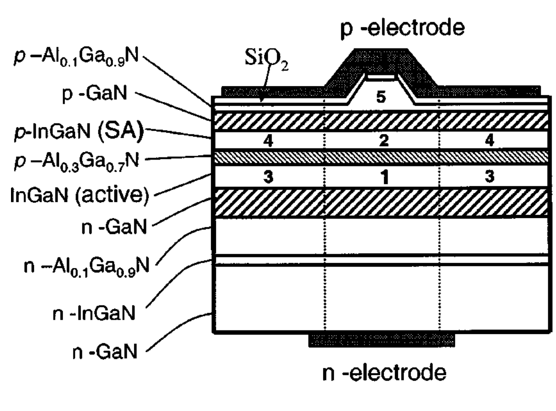

FIG. 1. Schematic illustration of the blue-violet InGaN laser with a saturable absorber incorporated.

*Email address: tronciu@ec.t.kanazawa-u.ac.jp

