BLUE LASERS A KEY ELEMENT FOR NEW GENERATION OF CD AND DVD SYSTEMS

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Abstract: The theoretical and experimental investigations of the dynamics of blue InGaN quantum well lasers with different designs are reported in this paper. The bifurcations, which are on the origin of the phenomenon of self-pulsation are identified and the effect of the lasers parameters on laser dynamics is discussed. It is shown how different laser structures can be used to control laser behaviour. Finally, an agreement between the results of numerical calculations and experimental measurements is demonstrated.

Key words: GaN blue lasers, quantum well, CD and DVD

1 INTRODUCTION

Blue-violet semiconductor lasers are very attractive for high-density optical storage applications [1]. In particular, laser diodes operating at 400nm are required for CD or DVD systems to increase the disk storage capacity up to 30 Gbytes. A number of other applications, such as full colour electroluminescent displays, laser printers, detectors, sources for undersea communications, and many others in biology and medicine have increased the interest in such lasers. In recent years, specific interest has been focused on the self-pulsating operation of blue-emitting devices. Self-pulsation (SP) can significantly increase laser performance for certain applications. In our previous work we have reported self-pulsation for a blue InGaN laser with a saturable absorber (SA) [2,3] and for tandem blue lasers [4] based on the Yamada model [5]. In this paper we present an investigation of the self-pulsation in the blue-violet lasers with different designs, which extends and complements our previous study of blue laser dynamics.

2 BLUE INGAN LASER WITH SATURABLE ABSORBER

Fig. 1 shows the structure of the InGaN laser (lasing wavelength 395 nm) with SA that has been considered; it consists of a three-quantum well InGaN active layer and a single p-type

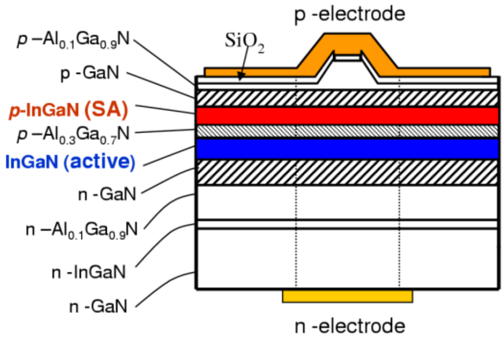
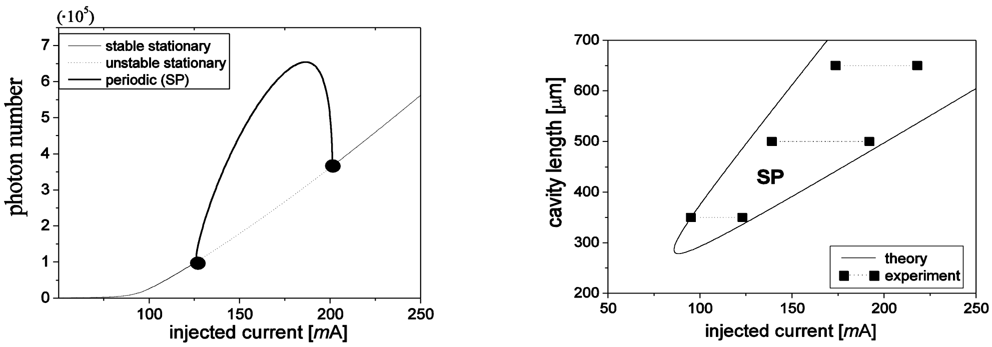


Fig.1 Schematic view of laser with SA

quantum well SA with thicknesses varying from 1 nm to 3 nm (see for fabrication details [6]). The field distribution in the transverse cross-section is analyzed by the effective refractive index method. To investigate the laser properties, we use the Yamada model [5] adapted to the specific case of the blue lasers. A typical example of a bifurcation diagram for periodic solutions is shown in Fig. 2[a]. A stability analysis shows that the limit cycle is created at a current of 125mA by a Hopf bifurcation (solid circle). This bifurcation diagram is completely different from that obtained in GaAs lasers that have been studied previously with a SA [7,8], where the self-pulsations appear just after the threshold due to a homoclinic bifurcation. Both Hopf bifurcation points in Figure 2[a] are subcritical. We found that a large carrier lifetime in the active region requires a short carrier lifetime in the SA to get self-pulsating operation, which confirm our previous predictions [2]-[4]. The region of self-pulsation in the cavity length – injected current plane is shown in Figure 2[b]. For a laser with a small cavity length, the range of self-pulsation is narrow. As the cavity length is increased the SP range becomes wider. However, this spread is accompanied by a shift of the operating point to higher injected



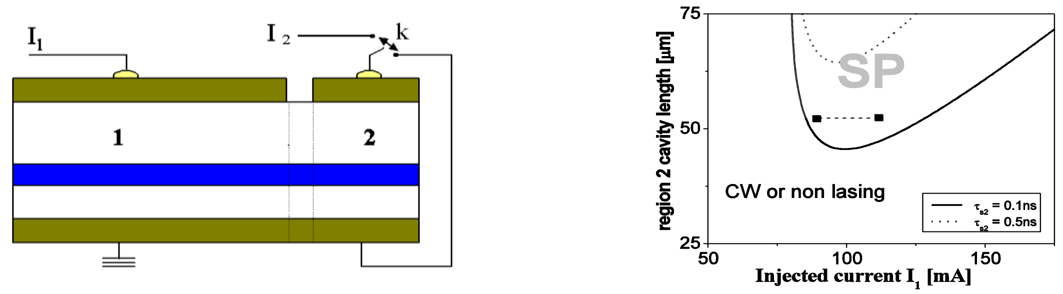
a) b)

Fig 2.a) The bifurcation diagram. b) The region of self-pulsation

currents. This figure also shows quite good agreement between the experimental data (dotted lines terminated by squares) and the regions of SP predicted by numerical calculation.

3 TANDEM BLUE LASERS

Now we examine tandem InGaN lasers with a design, which is shown schematically in Fig. 3. The devices consist of two regions, 1 and 2. Note that saturable absorber is grown next to the active region in the longitudinal direction, which is a completely different structure from that investigated in the Section 2.



a) b)

Fig. 3: a) Schematic illustration of the tandem blue-violet InGaN laser. b) SP region

The laser dynamics have been investigated using the single mode rate equations [5]. We consider three cases determined by the injected current I_2 and the position of the switch K for the devices in Fig. 3[a]. The first case is the configuration, where injected currents are supplied to the regions 1 and 2. In this case both regions are active. The calculations predict in this case that there is hysteresis in the stationary dependence of photon number on the injected current of region 1. Also in this case the experimental data show that switching occurs but pulsation does not. As the injected current in region 2 is increased, the threshold current of region 1 is lowered and the hysteresis disappears. However, only CW operation can be achieved in the case of two currents supply. Now consider the second case where the switch K of Fig.3[a] is closed, so that there is carrier transport through it and a consequent reduction of the carrier life time in region 2, which results in the appearance of SP. The region of SP in the plane region 2 cavity length vs. injected current of region 1 for two values of carrier life time of region 2 is plotted in Figure 3[b]. For a 0.1ns carrier lifetime in region 2, the region of SP is wide and is in a good agreement with the experimental data marked by the dashed line terminated by solid squares. Increasing the carrier lifetime of region 2 makes the SP region smaller and shifts it to higher cavity lengths (dotted line in Fig. 3[b]). We believe that our work provides a good basis for future study and, in particular provides some pointers for more detailed investigations of SP and possibility of excitability, and the associated phenomenon of coherence resonance, in InGaN lasers and of their possible practical applications.

4. SUMMARY AND CONCLUSIONS

In this paper we have investigated the cw and self-pulsating operations of blue-violet InGaN lasers with different designs. The ways in which the properties of the SA determine the laser output characteristics have been considered. It was found that a short carrier lifetime in the SA is conducive to SP one the other hand we suggest that lasers with a large SA carrier lifetime are more suited to excitability. For tandem lasers, an injected current into one region produces a low threshold current in the other but results only in CW operation. However, self-pulsating operation of tandem InGaN lasers is possible with an external circuit. Finally, we have presented the results which show a good agreement between numerical calculations and experimental data.

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