Appl Phys B (2010) 99: 215–222
DOI 10.1007/s00340-009-3868-2

Applied Physics B
Lasers and Optics

Impact of size upon lasing in ZnO microtetrapods

V.V. Zalamai · V.V. Ursaki · I.M. Tiginyanu · A. Burlacu · E.V. Rusu · C. Klingshirn · J. Fallert · J. Sartor · H. Kalt

Received: 17 August 2009 / Revised version: 1 November 2009 / Published online: 18 December 2009

Abstract High optical quality, well end leg faceted ZnO microtetrapods with leg length between 1 and 12 µm have been grown by carbothermal chemical vapor deposition. Lasing with mode quality factors of 2500–3000 is demonstrated. The origin of laser resonator cavity is discussed as a function of the tetrapod size. It is shown that in big tetrapods with legs of 12 µm in length the laser emission lines are well explained by longitudinal Fabry–Pérot modes generated in cavities formed by individual tetrapod legs. The dispersion of the ZnO refractive index is experimentally determined from the position of lasing modes in the temperature interval from 10 to 300 K. It is shown that the lasing mode structure is seriously affected by the decrease of the tetrapod size. For a small tetrapod with a leg length of 1 µm, the lasing modes cannot be explained anymore by the formation of longitudinal Fabry–Pérot modes in separate tetrapod legs, and the generation of guided modes by multiple total internal reflections in single tetrapod legs or in pairs of legs should be taken into account. The correlations between the lasing threshold and the tetrapod size are discussed.

V.V. Zalamai · V.V. Ursaki (✉)
Institute of Applied Physics, Academy of Sciences of Moldova, 2028 Chisinau, Moldova
e-mail: ursaki@yahoo.com
Fax: +373-22-509920

I.M. Tiginyanu · A. Burlacu · E.V. Rusu
Institute of Electronic Engineering and Industrial Technologies, Academy of Sciences of Moldova, 2028 Chisinau, Moldova

C. Klingshirn · J. Fallert · J. Sartor · H. Kalt
Institut für Angewandte Physik, Universität Karlsruhe (TH), Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany

1 Introduction

ZnO provides conditions for the formation of a rich diversity of micro/nanostructures [1–3], many of which may be suitable for lasing. Stimulated emission in ZnO nanostructures has been extensively studied due to their great potential for short-wavelength optoelectronic and photonic applications [4–8]. Among various ZnO structures, tetrapods are of particular interest, since they form a 3D cavity with a tetrahedral symmetry [9–17]. While the emission mechanism is common for various ZnO nanostructures, it being determined by the fundamental properties and the quality of the material [2, 3, 18, 19], the resonators are specific for different structures. Several models of resonators have been proposed for ZnO tetrapod lasers including lasing due to longitudinal Fabry–Pérot modes in cavities formed by individual legs [10–13], or twinned tetrapod legs [16], or guided mode lasing due to multiple total internal reflections in twinned tetrapod legs [17]. The contradiction between different models may be explained by the complexity of the problem, which depends on the conditions of excitation (a single or multiple legs are excited), on the substrate coupling, and the emission collection geometry. One can suggest also that the dimensions and the quality of the tetrapod, i.e. the quality of the junction of tetrapod legs to the tetrapod core may seriously affect the lasing mode structure. Additionally, cavity resonances are dependent on the dispersion of the refractive index. On the other hand, the structure of lasing modes can be used for the investigation of the dispersion of refractive index, which is difficult in the region of exciton resonance by means of traditional methods such as variable-angle spectroscope ellipsometry (VASE) [20–23], and the analysis of interference fringes in optical spectra [23, 24]. The refractive index is reliably determined in the long-wavelength region, where the data are well modeled by the