Refractive index dispersion deduced from lasing modes in ZnO microtetrapods

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High optical quality, well end leg faceted ZnO microtetrapods sustaining lasing modes with quality factors of 2500–3000 have been grown by carbothermal chemical vapor deposition. It is shown that lasing is due to longitudinal Fabry–Pérot modes in individual tetrapod legs and the analysis of the wavelength position of these modes is an effective instrument for the investigation of temperature dependence of the refractive index dispersion in the region of exciton resonances. The dispersion of the ZnO refractive index is experimentally determined in the temperature interval from 10 to 300 K and is compared with available literature data. © *2009 American Institute of Physics*.
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Among various ZnO structures, tetrapods are of particular interest for short wavelength optoelectronic and photonic applications including stimulated emission since they form a three-dimensional cavity with a tetrahedral symmetry.[1–8] While the emission mechanism is common for various ZnO nanostructures it being determined by the fundamental properties and the quality of the material,[9–12] 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,[1–4] or twinned tetrapod legs,[7] or guided mode lasing due to multiple total internal reflections in twinned tetrapod legs.[8] The mode structure is strongly dependent on the dispersion of the refractive index. The wavelength dependence of the ZnO refractive index has been previously investigated by means of variable-angle spectroscope ellipsometry (VASE),[13–16] prism-coupled waveguide measurements,[17] or by analyzing the interference fringes of optical spectra.[16,18] The refractive index is reliably determined in the long-wavelength region were the data are well modeled by the Sellmeier or Cauchy dispersion equation. At the same time, the data presented by different authors differ very much in the near band edge region were the lasing modes are observed. At these short wavelengths the measurements are markedly affected by strong absorption, exciton resonances and the interference of additional waves[19,20] resulting in an interference fringe structure significantly different from the classical Fabry–Pérot one.

The knowledge of the refractive index dispersion is important for interpretation and calculation of lasing modes, design of ZnO based optoelectronic devices, calculation of photonic band structure, and design of ZnO based photonic crystals and photonic crystal lasers.[21] On the other hand, if one knows the nature and the parameters of a laser resonator, the structure of lasing modes can be used for the investigation of the dispersion of the refractive index since the spacing between modes is very sensitive on the refractive index dispersion. The goals of this paper are to identify the resonator cavity in a ZnO microtetrapod laser and to make use of lasing modes in this cavity for the investigation of temperature dependence of the dispersion of ZnO refractive index.

ZnO tetrapods with sizes ranging from microns to tens of microns have been grown by a carbothermal evaporation process in a horizontal furnace with an argon/oxygen flow. A mixture of ZnO (99.999%) and graphite (99.999%) powders at molar ratio of 1:1 was placed in an inner quartz tube with a substrate located downstream. A temperature profile was set in the furnace with the maximum of 1050 °C at the place of the source material and 1020 °C at the Si or silica substrate. The duration of the growth process was 1 h.

The photoluminescence, Raman scattering and x-ray diffraction analysis (not presented in this paper) demonstrates a high crystalline quality of the produced tetrapods. In this paper we analyze lasing characteristics of a tetrapod with well hexagonally faceted legs, each having the length of 12 μm as illustrated in Fig. 1.

The lasing characteristics of the tetrapod were measured in a temperature interval from 10 K to room temperature in a He-flow cryostat, under the pumping by the third harmonic

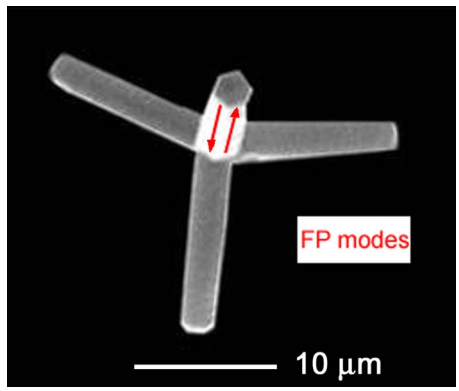

FIG. 1. (Color online) Scanning electron microscope image of a ZnO microtetrapod.

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