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ZnO lasing in complex systems with tetrapods

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Abstract A ZnO structure in the form of a core–shell wire was grown with a modified vapour transport and condensation method. The wire consists of a dense core which may play the role of a waveguide and a shell formed mainly from tetrapod-type crystallites. The high optical quality of the produced ZnO material is confirmed by continuous wave photoluminescence (PL) analysis demonstrating that low-temperature PL is related to the recombination of bound excitons, while room-temperature PL is due to free excitons. Good quality of the crystal structure is demonstrated also by the Raman spectrum. The shell of the wire exhibits room-temperature laser action due to lasing modes in tetrapods under the excitation by nanosecond laser pulses. The nature of the lasing modes is discussed. A simplified model for one of the possible modes is suggested.

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1 Introduction

Oxide semiconductors are typically characterized by outstanding stability and remarkable optoelectronic properties. Among them ZnO is an important semiconducting and piezoelectric material which has high potential for numerous applications such as phosphors, transparent conducting films, field emission devices, varistors, piezoelectric transducers, resonators, and sensors [1, 2]. With a wide band gap of 3.3 eV and large exciton binding energy of 60 meV (excitons being stable at room temperature), ZnO holds also an excellent promise for blue and ultraviolet optical devices [1], including ultraviolet microlasers. Due to the possibility of multiple and switchable growth directions of the wurtzite structure and the high ionicity of its polar surfaces, ZnO provides conditions for the formation of a rich micro/nanostructure diversity (see [3–5] and references therein) many of which may be suitable for lasing. Remarkable lasing properties have been demonstrated with microcrystalline thin films [6–8], arrays of ZnO nanorods [9–17], nanowires [18], nanoneedles [19], and nanobelts [20]. The corresponding emission mechanism is related with the near-band-edge radiative recombination of free excitons (FE, ∼3.26 eV), exciton–exciton scattering (EES, ∼3.18 eV), and electron–hole plasma (EHP, ∼3.14 eV) recombination [20]. The nanolasers based on ZnO structures are promising for diverse applications including optical computing, information storage, and microanalysis [9].

The vapour phase transport and condensation method mediated by vapour–liquid–solid or vapour–solid growth is one of the most cost-effective methods for producing high optical quality ZnO structures [9, 13, 14, 16, 18].

In the present paper a modification of vapour phase transport was applied to produce ZnO nanostructures with a com-