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Lasing with guided modes in ZnO nanorods and nanowires

**V.V. Zalamai · V.V. Ursaki · C. Klingshirn · H. Kalt ·
G.A. Emelchenko · A.N. Redkin**

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Abstract A vertically arranged nearly parallel array of ZnO nanorods and randomly oriented nanowires has been grown by low pressure chemical vapor deposition (CVD) on silica substrates and on stainless steel gauze woven from a wire with a diameter of 40 μm, respectively. The quality of the produced material is high enough to act as a gain medium for stimulated emission in the ultraviolet spectral region. Multiple sharp lasing peaks were realized from single hexagonal nanorods and arrays of hexagonal ZnO nanorods. The lasing peaks display successive onset and saturation with increasing excitation power density and fit well the expected resonance spectrum of guided modes in hexagonal nanorods. The behavior of lasing spectra from shot to shot of pumping in randomly oriented nanowires along with the independence of the lasing threshold on the excitation spot area suggest that the emission spectrum results from the superposition of lasing modes in individual nanowires, rather than from random lasing due to photon coherent scattering.

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

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

G.A. Emelchenko
Laboratory of Crystallization from High-Temperature Solutions,
Institute of Solid State Physics, 142432 Chernogolovka,
Moscow district, Russia

A.N. Redkin
Laboratory of Integrated Optic, Institute of Microelectronics
Technology and High Purity Materials, 142432 Chernogolovka,
Moscow district, Russia

1 Introduction

With a wide bandgap of 3.36 eV at room temperature and large exciton binding energy of 60 meV (excitons being stable up to room temperature), ZnO holds promise for use in 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 diversity micro/nanostructure [1–5], many of which in combination with remarkable optical properties may be suitable for lasing. Lasing has been demonstrated with epitaxial and microcrystalline thin films [6–8], arrays of ZnO nanorods [9–17], nanowires [18], nanoneedles [19], and nanobelts [20]. The lasing characteristics are to a wide extent determined by the type and the properties of the resonator. Usually the feedback mechanism in nanorods and nanowires is related to the formation of Fabry–Perot cavities for longitudinal modes [9, 10, 12], or to the guided modes [14, 21]. Additionally, random lasing is possible in arrays of ZnO nanorods and nanowires [18, 20]. To discriminate between the feedback mechanisms in ZnO nanostructures is not an easy issue, especially in microstructures consisting of nanorods with various orientations.

Note that nanolasers based on ZnO structures are promising for diverse applications including fluorescent sensor technologies, information storage, and microanalysis [9].