Lasing properties of ZnO nanostructures

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Zinc oxide is a wide gap semiconductor material (bandgap is 3.5 eV at room temperature) on his base are produced white and blue LED and lasers. Also zinc oxide is perspective and promising material for application in optoelectronics, nanoelectronics, photonics, transparent electronics and gas sensors. On the base of zinc oxide was developed solar cells, although it efficiency is lower then industrial one using cost effective and uncomplicated technology of chemical bath deposition (CBD) makes this material very perspective. On the base of zinc oxide different nanostructures as nanorods, nanocombs, nanowires, nanoarrows etc. was received. These nanostructures are very effective resonators for laser application due to its optical properties. Also in ZnO structures sow random lasing effect in such case zinc oxide layer work as a resonator and active medium. The wide-band gap semiconductor ZnO and related compounds with their excellent thermal conductivities, large breakdown fields, and resistance to chemical attack are the materials of choice for these applications.

The photoluminescence (PL) measurements demonstrate that the produced ZnO structures have a high crystal quality which is comparable with high quality bulk ZnO single crystals. The low temperature PL spectra are dominated by neutral donor bound excitons emission. The grown structures demonstrate similar PL spectra with a small variation of the PL band intensities. The spectrum is dominated by lines of the neutral donor bound excitons with phonon replica, along with a band related to the recombination of free excitons and a band due to the donor acceptor pair recombination with phonon replica.

The transition from spontaneous to stimulated emission is observed in the array of hexagonal nanorods with the almost uniform diameter of 200 nm and length of 1.5 μm above a certain threshold under excitation by 5 nm laser pulses. Multiple sharp peaks representing different lasing modes emerge in the emission spectrum above the lasing threshold. The lasing modes are better resolved when the emission from a single nanorod is analyzed. A monotonous shift of the modes to higher photon energies occurs with increasing the excitation power density which results from the increase of carrier density. The lasing modes display successive onset and saturation with increasing the excitation power density. Additional lasing modes appear successively on the low energy side of the spectra with increased optical pumping while previously dominating modes vanish.

Since the lasing of an additional mode consumes a certain fraction of the available electron-hole pairs created by the excitation pulse, the threshold-like rise of one mode is accompanied by a quenching of its predecessor. Apart from that, at higher excitation densities the gain is redshifted due to band gap renormalization and therefore modes with longer wavelength are preferentially amplified. A broad stimulated emission band is characteristic for randomly oriented ZnO nanostructures with a variety of geometrical parameters. This band represents a superposition of lasing modes coming from ZnO nanorods with different diameters and length.

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