OPTICAL AND LASER PROPERTIES OF THE ZNSE/ZNMGSSE MULTIPLE QUANTUM WELL HETEROSTRUCTURES

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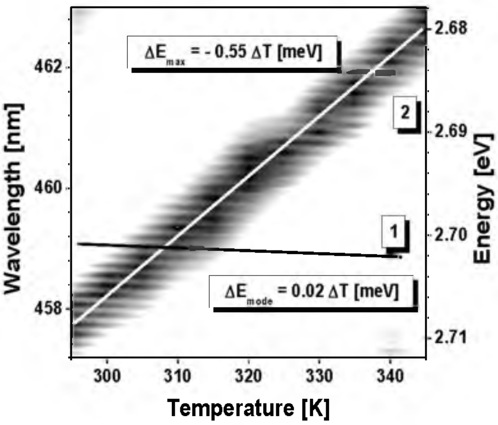
A pronounced laser threshold and directivity of laser emission having TE polarization were observed for the investigated ZnSe/ZnMgSSe MQW-SCHs at excitation intensity enhancement. The full width at half-maximum (FWHM) of the PL band at the laser threshold was 15 nm and the FWHM of the total laser spectrum was 0.5-1 nm. The laser threshold value I_{thr} was 10-30 kW/cm^2 at RT depending on the cavity length. The laser action was observed up to temperatures of 620 K.

A near RT fragment of the temperature dependence of the ZnSe/ZnMgSSe MQW-SCH laser spectra at $I_{exc} = 1.1 \cdot I_{thr}$ is presented in Fig. 1. The total laser spectrum maximum shifts to the long-wave region with the temperature enhancement (line 2) whereas the spectral position of the individual longitudinal laser mode (line 1) shifts slightly to the short-wave side. Coefficients of the temperature shift were 0.02 meV/K for the individual longitudinal laser mode and -0.55 meV/K for the position of the total laser spectrum maximum.

The laser spectra behaviour depending on I_{exc} is presented in Fig. 2. An insignificant short-wave shift of the total laser spectrum maximum occurs up to intensity of exciting emission of 150 kW/cm^2 (region I) which can be attributed to the band filling. A considerable long-wave shift of the total laser spectrum maximum is observed at $I_{exc} = 150\text{-}600$ kW/cm^2 (region II). The shift can be attributed to the active region heating and band gap renormalisation. A comparison of excitation shift with the same of temperature gives the maximum value of the active layer overheating of about 7 K at $I_{exc} = 600$ kW/cm^2.

Short-wave shift of the position of the individual modes is of the order 0.58 meV at $I_{exc} = 70 - 600$ kW/cm^2 (Fig. 2) whereas overheating of $\Delta T = 7$ K can lead to the shift of $\Delta E_{max} = 0.02 \cdot \Delta T = 0.4$ meV. Obviously the short-wave shift of the individual laser modes is not caused only by active region heating but also by the change of the waveguide region refractive index. In turn it is due to an revising of the optical confinement factor and the active region refractive index caused by an increase of the electron-hole plasma oscillations frequency with pumping increment.



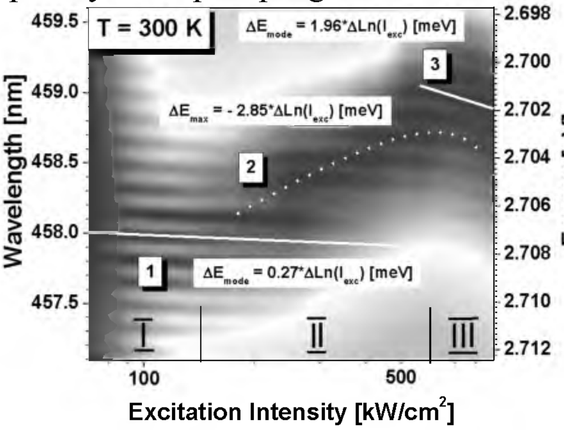


Fig. 1. Normalised laser spectra depending on temperature for ZnSe/ZnMgSSe MQW-SCH laser: 1 – individual laser mode peak position; 2 – total laser spectrum position.

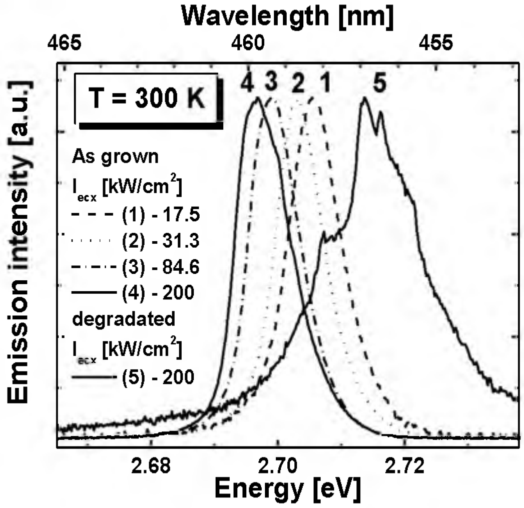
Fig. 2. Normalised laser spectra of the ZnSe/ZnMgSSe MQW-SCH laser as a function of excitation intensity. 1, 3 – individual laser mode position, 2 – position of the total laser spectrum maximum.

Strong short-wave shift of both the total laser spectrum and the laser modes position is observed for excitation levels of above 600 kW/cm^2 (Fig. 2, region III). It indicates a significant reduction of the refractive index of the active region similar to that observed at high-temperature degradation [1, 2] with diffusion of the barrier, waveguiding and cladding layer components into the active region. This shift is accompanied by an irreversible laser emission intensity reduction indicating the intensive degradation processes under excitation intensity far above the threshold.

Since overheating of 7 K at RT can not be an origin of the degradation process, a series of experiments was carried out on determination of the PL and laser spectra and intensity dependence on the amount of the exciting pulses in order to establish reasons of degradation. Fig. 3 shows the laser spectra of a sample at different excitation levels (curves 1-4) and the same measured after irradiation with number of pulses $N = 10^6$ at $I_{exc} = 900$ kW/cm^2. The total laser spectrum after degradation is short-wave shifted on about 20 meV comparing to that before degradation. Seemingly the large shift is due to formation in the active layers the quaternary or ternary compound as a result of the S and/or Mg atoms diffusion from the ZnMgSSe layers stimulated by laser light.

In order to clarify the pumping and inherent laser light role in the degradation of the ZnSe/ZnMgSSe heterostructures, measurements of the laser output and PL intensities (in the lasing absence) as a function of N

were carried out at two I_{exc} (200 kW/cm^2 and 600 kW/cm^2, Fig. 4).



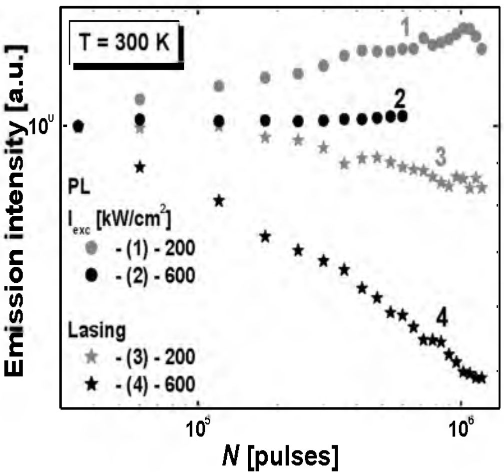


Fig. 3. Laser spectra of as grown (1-4) and degraded (5) ZnSe/ZnMgSSe MQW-SCH laser.

Fig. 4. PL (1, 2) and laser (3, 4) intensities of ZnSe/ZnMgSSe MQW-SCH as a function of number of N_2 laser pulses.

PL intensity without lasing in contrast to the laser output power of the ZnSe/ZnMgSSe MQW-SCH laser structures does not show any decrease with *N* rise at the same *N* and I_{exc}. On the contrary, the PL intensity rises step by step with *N* evidencing of laser annealing of the initial defects as it was observed for the bulk crystals [3] and epitaxial layers [4] of ZnSe. This fact lets us to assume that namely interaction of inherent ZnSe/ZnMgSSe laser emission with the heterostructure layers is the reason of the degradation process. The ZnSe based laser energy per pulse was 10 nJ and the inherent light intensity in the active layers was estimated to be of about 5 MW/cm^2, taking into account the optical confinement factor value of $\Gamma = 0.13$ calculated for this structure.

It was shown that the active region of the ZnSe/ZnMgSSe MQW-SCH lasers overheating value does not exceed 10 K. A significant decrease of the laser power during operation takes place for $I_{exc} = (5\text{-}10)\, I_{thr}$. It was shown that the degradation takes place due to action of intrinsic laser emission and it is defined seemingly by stimulated diffusion of the elements of ZnMgSSe claddings and barriers into the ZnSe active region.

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3. *Yablonskii G. P.* // Sov. Phys. - Semicond. 1984. V. 18. P. 570.
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