Exciton Luminescence in $In_{0.3}Ga_{0.7}As/GaAs$ Quantum Well Heterostructures

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Abstract **– Radiation maxima were observed in photoluminescence spectra of GaAs/ $In_{0.3}$ $Ga_{0.7}$As/ GaAs in case of 632.8nm and 532nm He-Ne laser excitation conditioned by the recombination from ground (e1-hh1, e1-lh1) and excited (e2-hh2, e2-lh2) states of polarionic excitons in quantum wells. The doublet character of e1-hh1, e1-lh1 transitions can be explained by the interaction of excitons in quantum wells. Radiation maxima are revealed in the region of 1.5eV energy conditioned by recombination transitions E^b-hh1, E^b-lh1of the GaAs buffer layer.**

Index Terms **– quantum wells, heterostructure, exciton, luminescence.**

I. INTRODUCTION

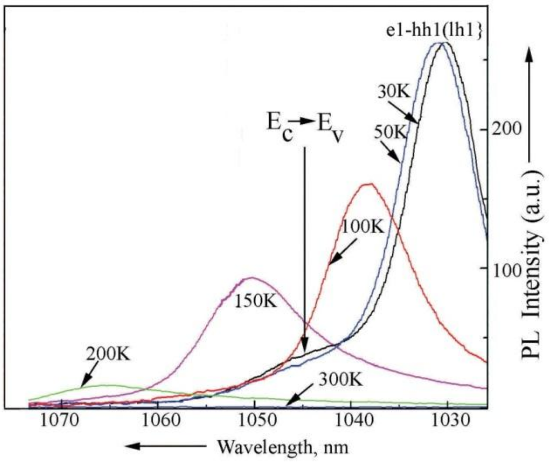
In quantum wells intersubband and intrasubband optical transitions are possible, as well as processes of quantum wells "photoionization", accompanied by a transition from size-quantized discrete states in overbarrier states of the continuous spectrum.

II. EXPERIMENTAL METHOD

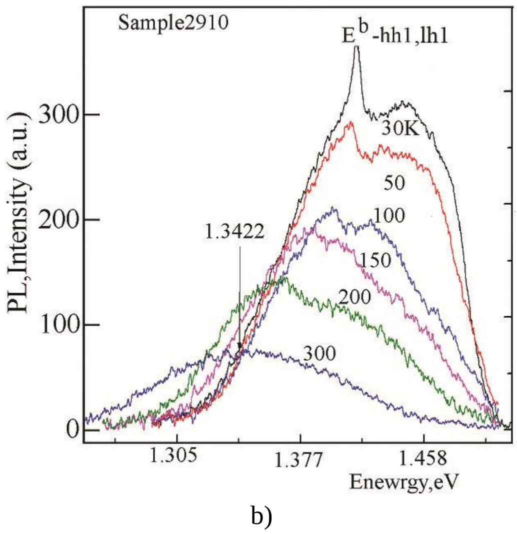
The luminescence spectra were measured at 10 and 300K temperature with excitation lines of 632.8nm He-Ne and 532nm laser at high-aperture (1:2) МДР-2 and double diffraction spectrometer СДЛ-1.

III. EXPERIMENTAL DATA AND DISCUSSIONS

The transitions between different subbands of size quantization of the V-zone into C-zone, caused by light with $\hbar\omega > E_q$, can generate a whole family of electronic transitions and hence the bands of interband absorption and luminescence [1 – 3]. Figure 1 shows the luminescence spectra of $In_{0,3}Ga_{0,7}As$/GaAs structure excited with a He-Ne laser line 632.8nm. At room temperature and low level of excitation the luminescence is practically absent. The luminescence is detected at 200K temperature and with further temperature decreasing the luminescence intensity increases. The emission maximum 1.163eV (200K) while the temperature is shifted to the energy of 1.2032eV (30K), has a FWHM equal to 10meV and is conditioned by the transitions *e1-hh1* (*e1-lh1*) from the quantum well layers A and B of $In_{0.3}Ga_{0.7}As$/GaAs structure. In the high-energy region of $In_{0.3}Ga_{0.7}As$/GaAs structures with quantum wells it is observed an emission band at 1.342eV (300K), which is shifted to higher energies with temperature decreasing (fig. 2). At 30K temperature it was revealed a narrow peak at 1.4131eV due to radiative recombination of electrons with heavy holes E^b-*hh1* and the maximum E^{x1} at 1.5433 eV, which, we believe, is due to radiative recombination from a discrete level of E^{x1} excitons located in the continuum region at the level of heavy and light holes.In order to increase the intensity the light was focused on the surface area. Radiation maxima at 1.2071 eV and 1.2201 eV, which are due to exciton recombination in quantum



a)



b)

Fig.1 a) - The luminescence spectra of $In_{0.3}Ga_{0.7}As$/GaAs structure with quantum wells at different temperatures (30-200K) and 632.8 nm He-Ne laser excitation line; b) - Temperature dependence of the energy maxima of radiation for $In_{0.3}Ga_{0.7}As$/GaAs structure with quantum wells excited with 632.8nm He-Ne laser line.

wells from the *e1-hh1* and *e1-lh1* states are detected at high intensities and 10K temperature in the long wave region. In this case, the splitting of the heavy (hh1) and light (lh1) holes in the quantum well is equal to 13.0 meV and the value of FWHM is 5 meV.

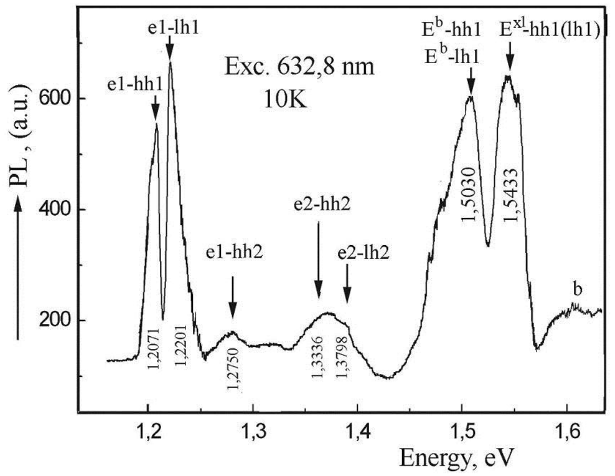


Fig.2 The luminescence spectra of $In_{0.3}Ga_{0.7}As/GaAs$ structure with quantum wells at 10K excited with a 632.8 nm He-Ne laser line (curve b is shown not to scale).

Radiation maxima at the energies 1.2750, 1.3336 and 1.3798 eV, which are due to transitions *e1-hh1*, *e2-hh2* and *e3-lh2*, respectively, are also found at 10K temperature. Intense emission lines at 1.5030eV energies and a weak shoulder at 1.4899eV energy and an intense maximum at 1.5433eV are found at these temperatures in a higher-energy region. The first two peaks are conditioned by bulk excitons in GaAs buffer layer, i.e. *Eb-hh1* and *Eb-lh1* transitions. In the related articles [1-3] the luminescence energy of the exciton transitions from the GaAs buffer layer at 8K temperature is detected at the energy 1.500-1.505 eV, which agrees with our determined value of 1.5030eV. The zones' splitting value of the heavy and light holes defined by the location of high-energy transitions is 13.1eV, which, practically, agrees with the splitting value (13.0 meV) determined from the maxima conditioned by the *e1-hh1* and *e1-lh1* transitions. The most short-wave radiation maximum at 1.5433eV we believe is due to recombination transitions from discrete energy states of the quantum well located in the E^{k1} continuum to the heavy holes zone *hh1*.

Temperature dependences of the detected transitions *e1-hh1* (*e1-lh1*) and E^{k1}-*hh1*, E^{k1}-*lh1* are presented in figure 3. Transition energies are shifted to higher energy almost linearly with temperature decreasing in the range 100-200K. The transitions energy *e1-hh1* (*e1-lh1*) and E^{b1}-*hh1* (*lh1*) vary linearly in the temperature range 100-10K, and the transitions energy E^{x1}-*hh1* (*lh1*) remains linear. The different temperature coefficient of the transitions' shift is linked with the difference of the coefficients of linear displacement of the heavy and light hole's zones, effective mass of heavy and light hole levels and exciton polariton levels in quantum wells [1 - 3].

Peaks at 1.2003 and 1.2138 eV are detected in the luminescence spectra at 10K and 532nm laser line excitation in unpolarized light, which are due to the transitions *e1-hh1* and *e1-lh*1 (fig. 4). It is evident that the luminescence maxima at 1.2003 and 1.2138 eV have the doublet character with a splitting of a several meV order In the luminescence spectra excited by unpolarized light and recorded in case of E_P and E_S polarization there are detected, as low-energy (1.2003eV) as high-energy (1.2138eV) peaks.

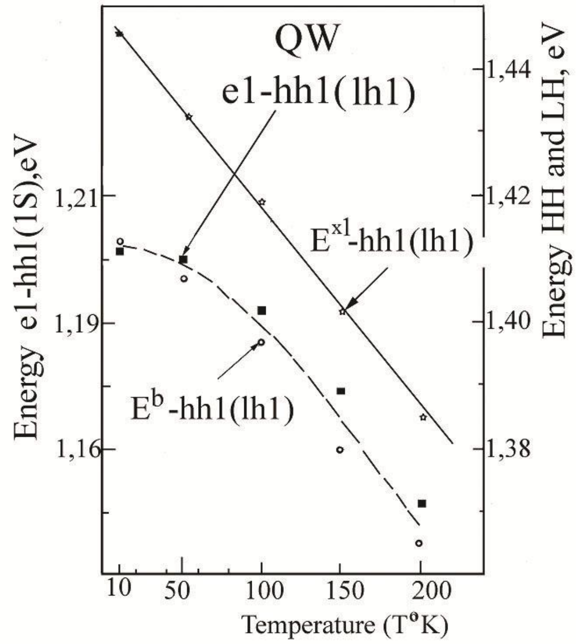


Fig.3 Temperature dependence of the levels of exciton polaritons in a quantum well

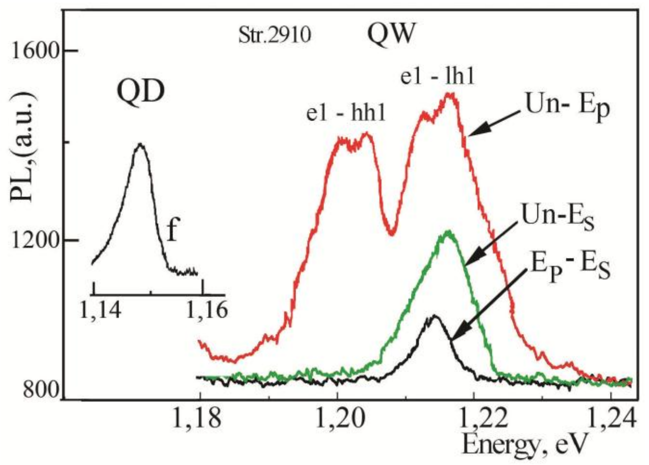


Fig.4 Luminescence spectra of $In_{0.3}Ga_{0.7}As/GaAs$ structure with quantum wells at 10K and excitation with 532 nm laser line, U_n-E_p curve corresponds to the excitation of unpolarized light and radiation in the P-polarization; curve U_n-E_S is unpolarized radiation excitation in the S-polarization; E_p-E_S corresponds to the excitation of P-polarized radiation in the S-polarization; f - the curve measured in unpolarized light and with the intensity increased up to 10 times.

When excited with E_P polarized light and a recorded luminescence at E_S and E_P there can be found also high-energy radiation maximum, but the emission intensity decreases because of reducing the intensity of the exciting light. In the study of photoluminescence spectra of localized excitons in GaAs/AlGaAs (001) quantum wells in the optical near-field regime it was observed the exchange splitting of the doublet *el-hh1* (*Is*) into two components polarized along the [100] and [110], i.e. the phase of these waves varies by ± 90 °. The emission maxima *e1-hh1* and *e1-lh1* (fig. 4) have a doublet character in the luminescence spectra considered by us at 10K temperature. The luminescence maximum (1.2133 eV) is observed at lower energies in the E_S polarization than in the E_P polarization (1,2166 eV).

IV. CONCLUSIONS

Photoluminescence spectra of $GaAs/In_{0.3}Ga_{0.7}As/GaAs$ nanostructures are formed by the recombination of exciton polaritons in quantum wells from the main (*e1-hh1*, *e1-lh1*) and excited (*e2-hh2*, *e2-lh2*) states.

Recombination transitions E^b*-hh1*, E^b*-lh1* of the GaAs buffer layer and the transitions from the quantum level located in the continuum of barrier layer E^{k1}-hh1 contribute to the luminescence from the short-wave part of the spectrum. The doublet nature of the transitions e1-hh1, e1-lh1 is explained by the exchange interaction of excitons in quantum wells.

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