Linear polarization of the luminescence of dipolar exciton Bose condensate

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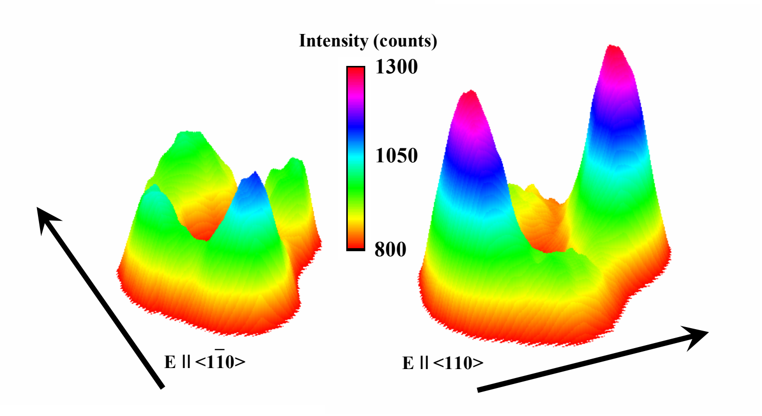
Recently, we have reported that spatially indirect, dipolar excitons in both double and single GaAs/AlGaAs quantum well (QW), when confined in a ring-shaped lateral potential trap, demonstrate a set of properties which can be explained in terms of exciton Bose-Einstein condensation (BEC) [1-2]. The properties include, in particular: a) rather narrow (≤300 μeV) line rising in photoluminescence spectrum in threshold manner with pumping and disappearing rapidly with temperature (at 4-10 K, depending on pumping rate), b) axially symmetric luminescent spot patterns within a ring trap, c) concentration of light emission close to the sample normal which enhances with pumping, d) symmetric far-field interference patterns (optical Fourier-transform) - typical for spatially-coherent light source, e) distinct interference of light emitted from two luminescent spots separated spatially as far as 4 μm. In addition, the luminescence of dipolar excitons in ring lateral trap exhibits linear polarization aligned along <110> direction in {001} crystallographic plane coinciding with the QW plane.



Now we have analyzed experimentally polarization properties of the luminescence light emitted by the dipolar exciton Bose condensate. A lateral trap was formed, as previously, by inhomogeneous electric field along the perimeter of a circular 5μm-window in Schottky-gate atop heterostructure. It is worth mention that the experiments were performed under compensation of extra charges in photoexcited exciton system within the trap. We have found that the sharp luminescence line of dipolar exciton Bose condensate is strongly linearly polarized. The polarization degree is maximal (around 70%) when the condensation threshold is slightly exceeded and it diminishes gradually with pumping due to the heating. The equidistant luminescent spot pattern observed in the ring trap is strongly linearly polarized as well (see Figure): two pairs of spots located at the ends of two orthogonal window diameters are polarized orthogonally, along directions [110] and [1$\bar{1}$0] coinciding with the diameter directions. Under the same experimental conditions the luminescence of direct excitons is completely depolarized. The observed spontaneous linear polarization does not depend on the state of polarization of exciting light.

We assume that the observed phenomenon originates from anisotropic electron-hole (e-h) exchange interaction caused by strong anisotropy of confining potential in the {001} crystallographic plane. The interaction results in exchange energy splitting of dipolar exciton states with $|m| = 1$. So, the produced split states represent linear combinations of the $m_z = \pm 1$ excitons. Finally, the mixing should result in a linear polarization of dipolar exciton emission. The anisotropy of confining potential in GaAs/AlGaAs heterostructures is usually oriented along either [110] or [1$\bar{1}$0] direction in the (001) crystallographic plane. Therefore, the spin split components should have orthogonal linear polarizations parallel to either [110] or [1$\bar{1}$0] direction. For GaAs/AlGaAs 250Å QW the splitting is less that 50 μeV, i.e. $\ll k_B T$ in considered experiments. In our case it is not observed in the emission spectra below BEC threshold due to inhomogeneous broadening. However, above the threshold the system of interacting dipolar excitons selects the lower energy state, i.e. when BEC occurs the lowest of the two states split due to the e-h-exchange anisotropy becomes macroscopically occupied. Such a selection is a strong evidence of occurred phase transition. As a result of macroscopic occupation of the lower spin-split state, the experimentally observed luminescence of Bose-condensed excitons exhibits strong linear polarization along <110> direction. We believe that the discovered phenomenon is a direct evidence of *spontaneous symmetry breaking under BEC condensation* of dipolar excitons in a lateral trap.

References

[1] A. V. Gorbunov and V. B. Timofeev, JETP Letters **83**, 146 (2006); *ibid*. **84**, 329 (2006).
[2] V. B. Timofeev and A. V. Gorbunov, J. Appl. Phys. **101**, 081708 (2007); phys. stat. sol. (c) **5**, 2379 (2008).