Influence of electric field on recombination dynamics of quantum confined carriers

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We will present time-resolved photoluminescence (TRPL) measurements of GaN/AlGaN low dimensional structures showing very characteristic changes of dynamics related to strong electric field. TRPL measurements of GaN/AlGaN low dimensional structures can provide important information about carrier dynamics, electric field and localization effects in the structures. Strong piezo-electric and spontaneous polarizations built-in in nitride structures lead to the changes in spatial separation of carriers what leads to changes in recombination energies and radiative lifetimes of the carriers.

The investigated structures consisted of three GaN QWs of the width: 2 nm, 4 nm, and 6 nm embedded in \( \text{Al}_{0.15}\text{Ga}_{0.85}\text{N} \) barriers. They were grown by MBE technique on bulk slightly misoriented GaN substrates. Time-resolved photoluminescence (PL) was measured from 10 to 300 K. A monochromator and a streak camera were used to obtain the spectral and temporal distribution of the PL.

As expected, the sample showed PL from excitons in the GaN barrier \( \text{X(GaN)} \) and had three PL bands from quantum wells QW1 at 3.51 eV, QW2 at 3.37 and QW3 at 3.21 eV. Excitonic Moreover, additional band (Qn) consisting of few lines was present at energies 3.40-343 eV. Band Qn was unusual. It consisted of few peaks. Most probably different peaks came from the 4-nm QW, from places with different thickness or different electric field. The PL energy could changed due to steps in the QW thickness or due to step-like changes in Stark effect. The step-like changes of electric field could be due to partial relaxation of strain. The peaks were relatively narrow, what suggested that the QW was of very good quality between the steps. Lifetime of luminescence changed strongly from step to step (see figure). It seems that the lifetime depended exponentially upon energy of the PL peak. Moreover, the main peak of QW2 was in line with the observed changes between Qn peaks, what suggested that the QW2 was fully strained.

The effect of exponential dependence of lifetime vs. energy can be explained by quantum-confined Stark effect. The energy shift should be proportional to product of field and thickness. The lifetime should be proportional to overlap of electron and hole wave functions, which is proportional to exponent of the product of field and thickness. Detailed calculation will be presented on the school.