Overcoming limits of internal electric fields in nitride emitters

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It is well known fact that InGaN/GaN based light emitters suffer from the high built-in electric field in their quantum wells (QWs), up to even 4 MV/cm. The presence of this field induces a number of phenomena known as Quantum Confined Stark Effect (QCSE). This effect results from spatial separation of the electron and hole wave functions, leading to reduction of their overlap and causing strong red-shift of the emission energy. QCSE leads also to the increase of radiative and non-radiative recombination time. When we drive InGaN light emitters with higher current, we observe the screening of QCSE. The arising shift of the emission energy (E_{EL})is commonly used as a monitor of the screening efficiency. Saturation of the E_{EL} at high currents is often interpreted as the entire elimination of the built-in electric field.

In case of electroluminescence (EL) from emitters operating at high carrier density regime – laser diodes and superluminescent diodes – the presence of QCSE may lead to two opposing mechanisms. The separation of electron and hole wave functions leads to lowered matrix element (lowered light generation intensity), but also longer carrier lifetimes and easier building up of the carrier reservoir. Our study [1] reveals that the full screening of QCSE is usually not reached at lasing conditions. This indicates that nitride structures can reach high gain even at the presence of the negative effect of QCSE. To get more insight on the process of QCSE screening we applied an experimental method based on comparison of pressure coefficient of EL obtained for different driving current [2]. It allows us to determine the amount of internal electric field remaining or eliminated entirely from the quantum wells. We observe that the electric field screening saturates at higher operation currents and that in the studied example only around 70% of electric field is screened at the lasing threshold.

Our further experiments show that the use of thinner quantum wells (characterised by smaller shift of electron and hole wavefunctions) allows to significantly reduce emission wavelength shift. But, the design of the active region needs to be carefully adjusted to compensate the reduced carrier injection.

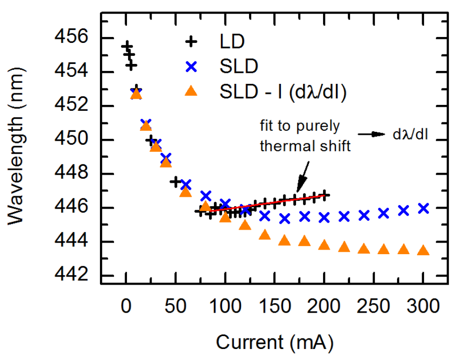

Fig. 1. Comparison of EL shift of a laser diode and superluminescent diode.

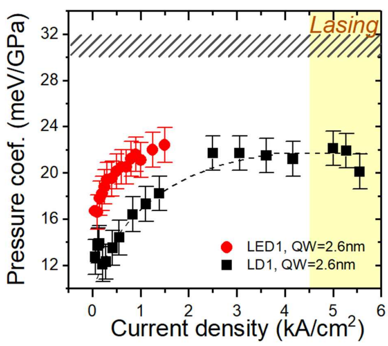

Fig. 2. Screening of electric field observed through changes of pressure coefficient.

[1] A. Kafar et al., *Appl. Phys. Express* **12** 044001 (2019).
[2] K. Pieniak et al., *Optics Express* **29**, 40804 (2021).