Internal Quantum Efficiency of InGaN Quantum Well LEDs determined by Differential Carrier Lifetime Measurements

Felix Nippert[1,*], Ines Pietzonka[2], Bastian Galler[2], Alexander Wilm[2], Sergey Karpov[3], Thomas Kure[1], Christian Nenstiel[1], Gordon Callsen[1], Martin Straßburg[2], Axel Hoffmann[1]

[1] *Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany*

[2] *OSRAM Opto Semiconductors GmbH, Leibnizstraße 4, 93055 Regensburg, Germany*

[3] *STR Group – Soft-Impact Ltd., P.O.Box 83, 27 Engels av. St. Petersburg, 194156 Russia*

*Email: felix@physik.tu-berlin.de

Much progress towards understanding the droop phenomenon in InGaN quantum well LEDs has been made in recent years. In particular it could be shown that an unknown proportion of the droop is caused by carriers undergoing Auger processes in the active region [1,2].

In order to quantify the significance of the Auger effect on the droop it is necessary to obtain the internal quantum efficiency (from which the parameters A, B and C of the standard model can be readily extracted) as a function of drive current. There are methods to extract these parameters from external quantum efficiency measurements [3], however assumptions about the light extraction have to be made. An alternative approach is to directly measure the internal quantum efficiency by measuring the differential carrier lifetime (the lifetime of an additional carrier injected into the operating device), as is commonly done in laser diodes. If this is done by modulating the device bias [4], the measurements may include artifacts from the modulation of the space charge zones, especially at low currents. This can be avoided if the carriers are injected directly into the active region with a resonant optical pulse.

In this work state-of-the-art InGaN (single and multi) quantum well LEDs are investigated over the whole range of operating currents which allows to extract the internal quantum efficiency as a function of drive current without any further assumptions. From this the contribution of the Auger effect to efficiency droop can be deduced.

This is achieved by operating the devices at various operating currents (DC) in combination with weak excitation by a frequency-doubled Ti:Sa laser, resonantly pumping the quantum wells. The decay of the additional carriers excited by the laser pulses is recorded as a small signal transient decay with a multi channel plate detector.

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