

# Novel Evaluation Procedure of Internal and Extraction Efficiency of High-Power Blue LEDs

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**Abstract**—Internal quantum efficiency (IQE) of a high-brightness InGaN/GaN blue LED was evaluated from the external quantum efficiency (EQE) measured as a function of current at the room temperature. Processing the data with a novel evaluation procedure based on the ABC-model, we have determined IQE of the LED structure and light extraction efficiency (LEE) of the Osram UX:3 chip. Separate evaluation of these parameters is helpful for further optimization of the heterostructure and chip designs.

**Keywords** — Light-emitting diodes, III-nitrides, internal quantum efficiency, light extraction efficiency.

## I. INTRODUCTION

Nowadays, understanding of all the possible reasons for the efficiency droop at operation currents is quite critical to find ways for further improvement of III-nitride LED performance [1]. EQE provides integral information on the recombination and photon emission processes in LEDs. Meanwhile EQE is the product of the IQE and LEE at negligible carrier leakage from the active region. Separate determination of IQE and LEE would be much more helpful, providing correlation between these parameters and specific chip and epi-structure design. Therefore, development of the techniques separate evaluation of IQE and LEE is in the focus of researches for a long time. In this paper, we show that the approach presented in [2,3] can be easily extended to the whole range of the current/optical power variation, providing an express tool for separate evaluation of the peak IQE and LEE.

## II. SAMPLES AND EXPERIMENT

We have studied high-brightness InGaN-based blue LEDs fabricated at Osram OS. The LED structures were grown by Metalorganic Chemical Vapor Deposition on (0001)-sapphire substrates. The structures were processed as UX:3 chips and mounted into the Golden Dragon packages without molding with silicon and forming lenses. The experimental and

processed data results are presented at the Fig. 1 (a, b)

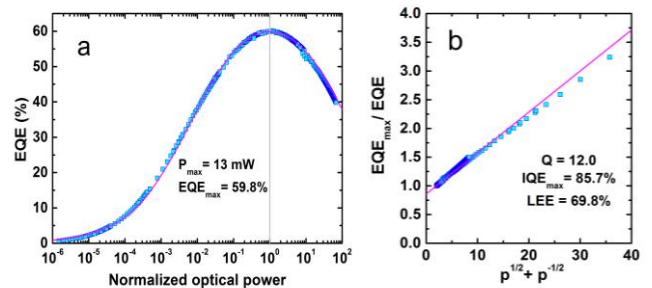


Fig. 1. (a) EQE as a function of the normalized optical power  $p$ . (b)  $EQE_{max}/EQE$  ratio as a function of the  $p^{1/2}+p^{-1/2}$  combination and symbols indicate experimental points, solid curves are the fittings by ABC-model. Q-factor was obtained as 12.0 by fitting and corresponding values of LEE and maximum IQE. The temperature was 300K.

## III. CONCLUSION

New express method of IQE and LEE calculation was presented. With this method we obtained LEE as 69.8% and IQE as 85.7% for Osram HP blue LED.

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