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On the importance of radiative and Auger losses in GaN-based quantum wells[1]

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Non-radiative carrier losses due to Auger recombinations have been suggested as a possible reason for the efficiency droop in GaN-based laser diodes [1]. This hypothesis is based on the observation that measured efficiencies can be reproduced using the classical power law for the density dependence of the loss current, $J = AN + BN^2 + CN^3$, with an Auger constant $C \approx 10^{-31} - 10^{-30}\, cm^6/s$. Auger losses can only be deduced indirectly from the overall loss if all other loss processes are know. Thus, it is not clear whether they are indeed responsible for the droop or whether it is an alternative loss process with a similar density dependence, like, maybe, density activated defect recombination. To investigate this we use fully microscopic many-body models to calculate absorption/gain as well as carrier losses due to radiative and Auger recombinations. These models have been shown to give excellent quantitative agreement with the experiment for materials ranging from the mid-IR to less than one micron [2]. These models have shown that the classically assumed density and temperature dependencies for the loss processes are generally far from reality, especially at densities relevant for laser operation [2]. In particular, in this regime the density dependence of Auger losses usually becomes less than cubic. This makes the use of the simple power laws rather questionable. Using the microscopic analysis we find for a typical InGaN/GaN system that carrier losses are dominated by radiative recombinations for all relevant densities [3]. At densities at which the onset of droop has been observed the Auger losses contribute only about 0.1%. Fits to the microscopically calculated losses yield for radiative losses $B = 3.5 \times 10^{-12} cm^2/s$ in agreement with traditional estimates. However, for Auger losses one finds $C = 3.5 \times 10^{-34} cm^6/s$ which is far too small to reproduce the experiment. Thus, we do not think that the direct Auger processes investigated here are responsible for the droop. Preliminary investigations lead us to believe that in general also phonon-assisted Auger processes or Auger processes including higher bulk electron bands are not strong enough to explain the droop.

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