# Many body effects in heavily doped GaN

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by

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CERTIFICATE OF ORIGINAL AUTHORSHIP

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative Doctoral degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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# Abstract

In this work the fundamental optical signatures of highly Germanium doped GaN are investigated. This work gives fundamental new insights in interactions of carriers in a three dimensional degenerated electron gas.

The first part of this thesis is dedicated to the investigation of compensation mechanisms in GaN samples with Germanium concentrations up to $10^{21}$ cm$^{-3}$. The combination of Hall effect measurements, secondary ion mass spectrometry (SIMS), Raman spectroscopy and temperature-dependent and time-resolved photoluminescence spectroscopy shows the influence of compensation mechanisms on the structural, electrical and optical properties of the crystal.

In the second part of this doctoral thesis, Germanium doped GaN samples are examined, which do not show any compensation effects. This fact is illustrated through comparison with Silicon doped GaN samples, which were grown with the same growth conditions as the Germanium doped samples. By the means of photoluminescence spectroscopy a new quasi particle was discovered, the collexon. The collexon is an exciton-like many-particle complex, which is stabilized by a three dimensional electron gas. The stabilization enhances with increasing electron gas density and is featured by small spectral half-width (≈10 meV), temperature stability up to 100 K and longevity (≈250 ps). In contrast to other many-particle complexes, e.g. trions and biexcitons, the collexon is observed in a three-dimensional structure and not in a low-dimensional structure, such as quantum wells and quantum dots. Contradicting the common behavior of heavily doped semiconductors, the entire emission intensifies and its decay time slows towards increasing free electron concentration, while the collexonic emission narrows spectrally, as long as no compensation occurs.

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