LABORATOIRE CHARLES COULOMB MONTPELLIER

Master 2 Project
Optical spectroscopy of indirect excitons

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Indirect excitons (IX) are bosonic quasi-particles in semiconductors with unique properties: they have long lifetime and spin-relaxation time, can travel over large distances before recombination, can be cooled down to low temperatures and form a quantum gas, and can be controlled by voltage in-situ. Due to these properties, they form a model system both for the studies of **fundamental properties of light and matter** and for the development of **conceptually new excitonic devices.** [1, 2].

Excitons in polar quantum wells (QWs) based on wide-band-gap semiconductors, like Gallium Nitride (GaN), can be considered as naturally indirect excitons, because of the strong built-in electric field in the growth direction, induced by spontaneous and piezoelectric polarization in these **wurtzite materials**. Such IX are robust up to room temperature. This opens the possibility for practical excitonic devices. They can also be created at high densities. This property is particularly interesting for the realization of **collective quantum states in solid state**.[3, 4].

The proposed research project consists in exploration of IX properties in GaN-based polar quantum wells by optical microscopy. We work on this subject in close collaboration with CHREA (Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications), where the samples are elaborated (ongoing funding from French National Research Agency (ANR)). The student will start from the **UV optical microscopy experiments** on the set of samples with electrode patterns realized by optical lithography. Such electrodes have been shown to enable the formation of the traps for the excitons, but quantum coherence properties of trapped IXs in GaN QWs remain to be demonstrated. Different trap sizes and geometries, as well as different IX dipole lengths will be tested by optical microscopy and interferometry, to provide the evidence of the excitonic collective states at low temperatures (T=4K).

We are looking for a motivated student **interested in optical experiments**. The applicants are expected to have a background in semiconductor physics, quantum mechanics and optics.

References

[1] M. Combescot, R. Combescot, and F. Dubin, Bose–Einstein Condensation and Indirect Excitons: A Review, Rep. Prog. Phys. 80, 066501 (2017).

[2] A. A. High, E. E. Novitskaya, L. V. Butov, M. Hanson, and A. C. Gossard, Control of Exciton Fluxes in an Excitonic Integrated Circuit., Science 321, 229 (2008).

[3] F. Chiaruttini, T. Guillet, C. Brimont, B. Jouault, P. Lefebvre, J. Vives, S. Chenot, Y. Cordier, B. Damilano, and M. Vladimirova, Trapping Dipolar Exciton Fluids in GaN/(AlGa)N Nanostructures, Nano Lett. 19, 4911 (2019).

[4] F. Chiaruttini, T. Guillet, C. Brimont, D. Scalbert, S. Cronenberger, B. Jouault, P. Lefebvre, B. Damilano, and M. Vladimirova, Complexity of the Dipolar Exciton Mott Transition in GaN/(AlGa)N Nanostructures, Physical Review B 103, 045308 (2021).