ID de Contribution: **367**

Type: **Poster**

Enhancing polariton-polariton interactions in microcavities

The nonperturbative interaction between cavity photons and quantum well excitons results in the creation of hybrid light-matter excitations known as exciton-polaritons. They merge the substantial nonlinearity of the excitonic component with the photonic component, whose potential landscape can be conveniently designed in micro-fabricated micropillar lattices [1]. These aforementioned features have allowed for the investigation of intriguing nonlinear phenomena, including Bose-Einstein condensation, superfluidity, and parametric instabilities. Nevertheless, most experiments with exciton-polaritons have been conducted in a regime that can be described in terms of a mean-field theory based on a Gross-Pitaevskii equation. To study strongly-correlated phases of light, a regime of strongly interacting polaritons is required, which needs large nonlinearities at the single-photon level such that the many-particle system is no longer described by a single macroscopic wavefunction [2]. Such a regime could be reached thanks to structures where photon absorption results in the formation of excitons with aligned permanent dipoles. It is anticipated that the fundamental excitations, known as dipolar polaritons, will exhibit enhanced interactions [3]. For this purpose, we aim to use a coupled quantum well structure embedded into a microcavity where the electron tunneling between wells creates a permanent dipole by spatial separation of the hole and the electron. This structure can be realized by designing coupled quantum wells in such a way that the energy levels of the conduction band are resonant, while the energy levels of the valence band are non-resonant. Another way is to apply an electric field to the coupled quantum well structure and take advantage of the Stark effect to manipulate the energy levels of the valence and conduction bands. In parallel, we develop an excitation scheme based on a two-photon spectroscopy to systematically measure the polariton interactions into our micropillars which will allow to characterize the modification of the interaction strength in such new structures.

References

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Affiliation de l'auteur principal

C2N

Auteur principal: COLOMER, Théo (C2N)

Co-auteurs: M. HAROURI, Abdelmounaim (C2N); M. LEMAÎTRE, Aristide (C2N); M. KRISO, Christian (C2N); Mme SAGNES, Isabelle (C2N); M. BLOCH, Jacqueline (C2N); Mlle SCHULZ, Johanna (C2N); M. LE GRATIET, Luc (C2N); Mme MORASSI, Martina (C2N); M. RAVETS, Sylvain (C2N)

Orateur: COLOMER, Théo (C2N)

Classification de Session: Session Poster 2: MC1, MC4, MC8, MC10, MC12, MC14, MC20, MC21, MC23, MC24, MC25, REDP

Classification de thématique: MC8 Dernières avancées dans le domaine des technologies quantiques