Quantum cascade structures and electrical injection into polaritons

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Quantum cascade (QC) lasers are unique devices based on intersubband (ISB) transitions of electrons that have tunnelled into higher-lying subbands in active quantum wells. The study of polaritons, i.e. electronic excitations strongly coupled to photonic modes in a semiconductor microcavity may be especially interesting for light emitting devices (LED) based on ISB transitions, where the light-matter interaction can be dominated by the time of a Rabi oscillation rather than the radiative lifetime. ISB polaritons are also fundamentally different from exciton polaritons in that the injection plays a fundamental role.

We have realized MBE-grown polariton LEDs based on GaAs/AlGaAs quantum cascade structures embedded in a planar microcavity. At zero bias, reflectivity measurements show a polariton anticrossing between the intersubband transition and the cavity mode. Under electrical injection, electrons are resonantly injected in a reduced part of the polariton branches. By changing the bias applied to the device, the energy of the emitted photons can be tuned, thanks to the formation of hybrid states arising from strong light-matter coupling. This suggests a less conventional approach to achieve frequency tuning in a QC structure: by dressing the material excitations with photons, we alter fundamentally the dispersion of the electronic states accessible for light emission, thus the properties of our device. This experiment also opens the way to a class of optoelectronic devices where electronic polarizations coherently interact with photons trapped in a microcavity.

Furthermore, if polariton based quantum cascade structures can be extended to the THz regime, they have the potentiality to become a new important tool for the study of cavity quantum electrodynamics in solid state systems in the so-called ultra-strong coupling regime, where the Rabi oscillation become comparable to the ISB energy.