Ultra-strong coupling of Landau levels in semiconductor heterostructures to THz metamaterials

Light-matter interactions using vacuum fields [1] have been studied on many different systems and depending on the coupling strength, one can define different coupling regimes. The ultra-strong coupling regime [2] is attained, where the vacuum Rabi frequency Ω reaches a sizeable fraction of the transition energy of the system ω. In our group we developed an experimental platform where subwavelength THz split ring resonators (SRR) ultra-strongly couple to the Landau level transition of a two dimensional electron gas [3, 4]. Using the same approach, recently a coupling beyond unity was demonstrated [5].
After an introduction to the peculiar properties of an ultra-strongly coupled system, such as the theoretically predicted existence virtual photons in the ground state [2], I will focus on two topics. The first one concerns the proposal to release the virtual ground state photons into real photons upon non-adiabatic switching of the coupled system is one exciting pathway to explore. We employ high Tc superconducting metamaterials to achieve a switchable cavity [6] and we manipulate the coupled system by THz pump THz probe spectroscopy. Secondly, I will talk about the controversial possibility of a Dicke quantum superradiant phase transition in solids, for which various no-go theorems [7] have been formulated. I present and discuss recent experimental data obtain with sGe quantum wells with strongly non-parabolic heavy hole band forming a 2D hole gas coupled to THz metamaterials [8], which deviate from the standard Hopfield model which describes extremely well all experiments with AlGaAs/GaAs QWs.

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