Ultrastrong coupling cavity QED of the magnetic cyclotron transition in a 2D electron gas: massive versus Dirac fermions

DAVID HAGENMÜLLER, SIMONE DE LIBERATO, CRISTIANO CIUTI, Laboratoire Matériaux et Phénomènes Quantiques, Université Paris Diderot-Paris 7 and CNRS, 75205 Paris Cedex 13, France — We show that the cyclotron transition of a two-dimensional electron gas can be ultrastrongly coupled to a cavity photon mode. The ratio between the vacuum Rabi frequency $\Omega_0$ and the cyclotron frequency $\omega_0$ can be much larger than 1 for large filling factor $\nu$ of the Landau levels (the normalized coupling $\Omega_0/\omega_0$ scales as $\sqrt{\alpha n_{QW}\nu}$, where $\alpha$ is the fine structure constant and $n_{QW}$ is the number of quantum wells). We present a comprehensive cavity QED theory both for semiconductors with massive electrons[1, 2] and graphene with Dirac fermions[3]. We show the dramatic impact on the quantum ground state and excitation properties, drawing the comparison between the two different types of 2D electron gas.

[2] Experiments demonstrating ultrastrong coupling of the cyclotron transition in a GaAs-system in the THz regime have been reported, see G. Scalari et al., submitted.