Superradiance mediated by graphene surface plasmons

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As it has been recently shown, a graphene sheet can support Surface Plasmon Polaritons (SPPs) in the THz regime [1-3]. Compared to conventional SPPs in metals, the properties of graphene surface plasmons (GSP) can be tuned by means of a gate potential that modifies the conductivity of the electrons in graphene.

In our work [4], we first study the emission properties of an emitter close to a graphene sheet and, in particular, the decay through GSP. Within a certain range of distances to the graphene sheet, the decay rate of one emitter can be fully dominated by the GSP channel. Due to this efficient coupling, the enhancement of the decay rate of the emitter, known as Purcell factor, can be enhanced by several orders of magnitude.

We show that this efficient coupling to GSP can be used to tailor the interaction between two emitters. When two emitters are close to a graphene sheet a superradiant state can be achieved where the collective emission is greater than the sum of the individual emissions. Remarkably, due to graphene's properties, the interaction between the emitters can be tuned by means of a gate potential, allowing to change from subradiance to superradiance by modifying the gate. This means that the coupling between the emitters can be strongly enhanced or supressed. Moreover, we also study the interaction between two emitters mediated by one-dimensional (1D) graphene ribbons supporting waveguide modes [5], which provide a very efficient coupling between the two emitters

For both the two-dimensional (2D) graphene sheets and the 1D graphene ribbons, we investigate the super- and subradiant regimes in the reflection and transmission configurations. Importantly, the length scale of the coupling between emitters, which in vacuum is fixed by the free-space wavelength, is now determined by the wavelength of the GSP, which can be extremely. Additionally, confinement in 2D or 1D results in an interaction with a larger decay length as compared to interaction in free-space.

References

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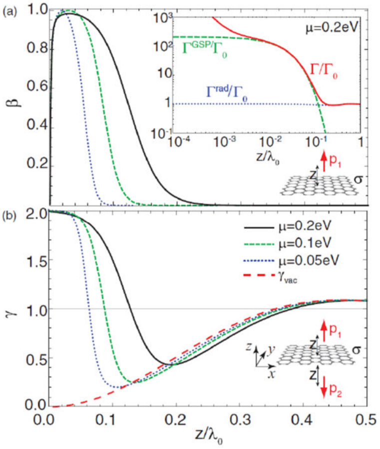

Figure 1: (a) β factor for an emitter at $\nu = 2.4$ THz as a function of the distance to the graphene sheet, z. Inset panel: total decay rate and decay rates through the plasmonic and radiative channels. (b) Tuning superradiance between two emitters mediated by a graphene sheet by means of the chemical potential. The emitters are placed in a transmission configuration.

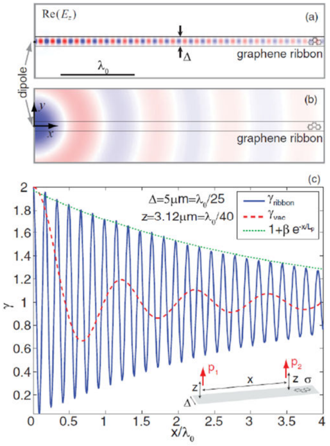

Figure 2: Interaction between two emitters mediated by 1D graphene ribbons. (a)–(b) Electric field profile for a dipole decaying to the ribbon GSP. The dipole is placed at x = 0, y = 0, and $z = \lambda_0/40$ in panel (a) and at $z = \lambda_0/10$ in panel (b) [the same would be obtained for $z > \lambda_0/10$]. (c) Superradiance mediated by the ribbon-GSP mode shown in panel (a). The dotted green line shows the exponential decay of the interaction.