

## Electrically controllable strong light-matter interactions with graphene

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The nanoscale interaction between light emitters and graphene can lead to a plethora of novel applications in fields such as sensing and telecommunications. Here we demonstrate a hybrid device containing graphene and near infrared light emitters that play a very important role in modern telecommunications: Er<sup>3+</sup> ions with stimulated emission at ~1530 nm. By changing the Fermi energy of graphene, we demonstrate, for the first time, the unique capability of in-situ tuning of the optical density of states experienced by emitters in near proximity of graphene. In particular, we access three distinct regimes of emitter-graphene coupling: i) the **non-radiative coupling** regime, ii) the **reduced coupling** regime, and iii) the **plasmon coupling** regime. We witness the transition through these regimes by monitoring the lifetime of the emitters and their emission, which are strongly modified by the graphene.

In the first regime, non-radiative coupling leads to energy transfer from the emitter to the graphene sheet, where electron-hole pairs are generated with the same energy as the excited state dipole of the emitter. By increasing the Fermi level in graphene, we suppress almost completely this energy transfer process, and thus the emitter-graphene coupling strength. Therefore, in this second regime the emission and the excited state lifetime approach the same value as for uncoupled emitters. Finally, in the third regime, the very high electron density can give rise to collective excitations (plasmons).