Interaction of a graphene nanoflake with an adatom under optical illumination

Marta Pelc[1]
M. Kosik[1], M. Müller[2], G. Bryant[3], A. Ayuela[4], C. Rockstuhl[2,5], K. Słowik[1]
[1] Institute of Physics, Faculty of Physics Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland
2 Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
3 Joint Quantum Institute, University of Maryland and National Institute of Standards and Technology, College Park and Nanoscale Device Characterization Division, National Institute of Standards and Technology, Gaithersburg, Maryland, USA
4 Donostia International Physics Center (DIPC) and Centro de Física de Materiales, CFM-MPC CSIC-UPV/EHU, San Sebastián / Donostia, Spain
5 Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
mpelc@umk.pl

Graphene nanoantennas sustain strong electro-magnetic field localization upon resonant illumination. To exploit the local field enhancement, quantum emitters such as atoms or molecules should be positioned close to the flake, where electron tunneling may influence the optical response of the system. In our work, we develop an analytical framework and numerical tools to account for dynamics and optical properties of hybrid systems made of graphene nanoflakes coupled to adatoms in the presence of an external electromagnetic field.
We use this framework to investigate the optical phenomena, including plasmons and spontaneous emission of an atom in proximity to graphene antennas. We focus the analysis on the interplay of two distinct physical mechanisms that may influence the optical response, namely the optical coupling between the atom and the antenna and electron tunneling between them. We distinguish different regimes in adatom – flake distances where these effects determine optical properties. While optical coupling dominates at larger distances, the tunneling may be significant at distances of the order of a nanometer leading to hybridization of the antenna and adatom orbitals. In consequence, transition energies and transition dipole moment elements of the coupled system are modified. These quantities determine the spontaneous emission rate. As a result, we find that the spontaneous emission, optically enhanced at moderate atom-antenna distances, can be modified and quenched at short distances.

Figures