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Efficient Multi-emitter Near Field Response Calculation for Multilayer Graphene Environments

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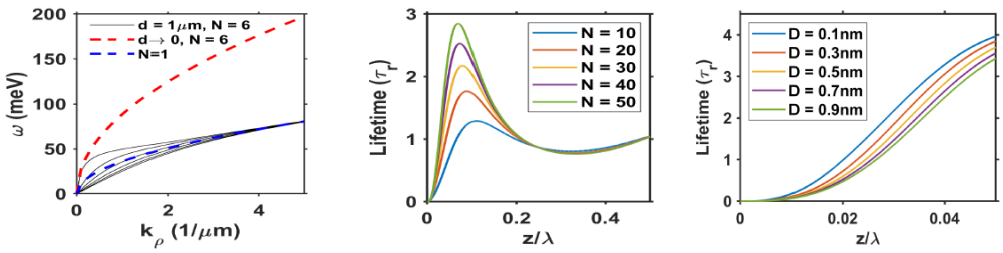
Abstract— Layers of different 2D materials can be combined to form multilayers on the atomic scale with new functionalities, known as Van der Waals materials [1]. These can be obtained from the bulk material by exfoliation. Graphene, one of the first material to be synthesized in family of the 2D materials has exotic optical and electronic properties [2]. Recently there has been a keen interest in creating quantum emitters in and near the 2D materials aimed for various quantum information processing applications [3]. By coupling with the surface plasmon (SP) modes in graphene, which can be tuned, the quantum emitters can exhibit a tunable optical response. Moreover, due to the confinement of SP modes in graphene, multiple emitters can be made to interact with each other, resulting in an enhancement or suppression of collective emission properties in comparison to those observed in a free-space environment. Calculating the Green's function of these structures offers insights into the interactions between single or multiple emitters with their environment, as well as among themselves. But obtaining the Green's function is neither analytically nor numerically straightforward. We simplify this problem by providing analytical expressions for the polarization dependent reflection and transmission coefficients for the multilayered graphene (MG) structure that are used as an input to calculate the Green's function [4]. This simplification is achieved by utilizing the Chebyshev identity in the transfer matrix method under the assumption that the layers are electronically non-interacting [5]. By utilizing this approach, we can ascertain the upper bounds of absorption in MG structures as well as derive the dispersion relation of the guided modes semi-analytically [Fig. 1(a)]. This provides essential information for engineering the coupling of emitters to various surface plasmon modes. To exemplify the efficacy of our method we calculate the relative dipole lifetime, τ_r near the MG structure for varying numbers of layers [Fig. 1(b)] and for varying interlayer separations [Fig. 1(c)]. This way we can identify whether the graphene multilayer can be described as bulk graphite or not for emitters in the near field, thereby complementing our analogous investigation of far-field properties of MG in Ref. [5].



(a) (b) (c)

Figure 1: (a) Guide-mode dispersion for six graphene layers ($N = 6$) separated by $D = 1\,\mu$m (in black solid lines) and for $D \to 0$ (in red dashed line) compared to a single graphene layer (blue dashed line). (b) Relative dipole lifetime (RDL) of a horizontal dipole versus the distance z above multilayered graphene with an interlayer separation (D) of 0.5 nm for different N. (c) The same as (b) but for $N = 100$, for variable D.

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