Tunable nanoantenna based on graphene

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Nanoantennas play a fundamental role in the nanotechnology due to their capabilities to confine and enhance the light through converting the localized fields to propagating electromagnetic fields, and vice versa. The characteristics of nanoantennas can be modified by carefully designing the geometric size and shape as well as choosing different materials of nanoantennas. However, the features cannot be dynamically tuned once the nanoantenna is fabricated. In the literatures, the pristine graphene has been used as a transparent electrode due to the properties of high optical transmittance and electrical conductivity. Meanwhile, due to the forbidden interband transitions by the Pauli blocking, the chemically or electrostatically doped graphene can support strong plasmonic effects particularly at the far-infrared or terahertz regime. These capabilities of dynamically modifying chemical potentials enable to fabricate controllable devices by introducing the graphene sheet.

Here we propose to utilize tunable properties of the doped graphene sheet to achieve a controllable nanoantenna. The conceptual architecture comprises a gold (Au) dipole antenna composed of two Au arms separated by a feed gap, a graphene sheet, and an aluminum oxide (Al_2O_3) as the insulator inserted between the dipole antenna and graphene. The thickness of the insulator is chosen as 12 nm so that electrical (quantum) tunneling effect from the graphene to metal can be ignored. The dispersion relation of the graphene sheet on the insulator with tunable chemical potential is investigated to demonstrate the possibility of the mode couplings between the graphene sheet and the metallic nanoantenna, which is further confirmed by the rigorous numerical simulation. Interestingly, our results show that the in-phase and out-of-phase couplings between metallic plasmonics and graphene plasmonics not only split the single resonance frequency of the convectional metallic dipole antenna but also modify the near-field and far-field responses of the metal-graphene nanoantenna. Furthermore, the bandwidth of full width at half maximum (FWHM) modified by the graphene sheet is enhanced by 17.1%. In addition, the far-field radiation intensity is drastically reduced by 50% due to the optical absorption induced through the graphene plasmonics. The most important property of the metal-graphene hybrid nanoantenna lies at its tunable or switch on/off feature. We show that the low resonant peak of the two split frequencies can be dynamically tunable through increasing the chemical potential. Especially, the hybrid nanoantenna can be restored to the conventional metallic dipole antenna by simply employing an intrinsic graphene or electrostatically tuning the chemical potential of graphene. This work is of a great help to design high-performance electrically-tunable nanoantennas applicable both in nano-optics and nano-electronics fields.