Graphene: a new platform for capturing and manipulating light at the nanoscale

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The ability to manipulate optical fields and the energy flow of light is central to modern information and communication technologies, as well as quantum information processing schemes. However, as photons do not possess charge, controlling them efficiently by electrical means has so far proved elusive. A promising way to achieve electric control of light could be through plasmon polaritons - coupled excitations of photons and charge carriers – in graphene. In this two-dimensional sheet of carbon atoms, it is expected that plasmon polaritons and their associated optical fields can be readily tuned electrically by varying the graphene carrier density.
In the first part of this talk, I will discuss recent experiments revealing propagating optical plasmons in tapered graphene nanostructures, using near-field scattering microscopy with infrared excitation light [1]. The plasmonic field profiles are visible in real-space images with nanometer resolution. We find that the extracted plasmon wavelength is remarkably short - over 40 times smaller than the wavelength of illumination. We exploit this strong optical field confinement to turn a graphene nanostructure into a tunable resonant plasmonic cavity with extremely small mode volume [2]. The cavity resonance is controlled in-situ by gating the graphene, and in particular, complete switching on and off of the plasmon modes is demonstrated, thus paving the way towards graphene-based optical transistors. This successful alliance between nanoelectronics and nano-optics enables the development of unprecedented active subwavelength-scale optics and a plethora of novel nano-optoelectronic devices and functionalities, such as tunable metamaterials, nanoscale optical processing and strongly enhanced light-matter interactions for quantum devices and (bio)sensing applications.

The second part of the talk is devoted to a novel hybrid graphene-quantum dot photodetector [3] which exhibits a gain mechanism that can generate multiple charge carriers from one incident photon. Strong and tunable light absorption in the quantum-dot layer creates electric charges that are transferred to the graphene, where they recirculate many times due to graphene's high charge mobility and long trapped-charge lifetimes in the quantum-dot layer. We demonstrate a gain of 10^8 electrons per photon and a record-high responsivity of 10^7 A/W. Our devices also benefits from gate-tunable sensitivity and speed, spectral selectivity from the short-wavelength infrared to the visible, and compatibility with current circuit technologies.

References

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