Special issue on graphene nanophotonics

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Graphene nanophotonics has recently appeared as a new research area, which combines the topics of nanophotonics (devoted to studying the behavior of electromagnetic fields on the deep subwavelength scale) and the several extraordinary material properties of graphene. Apart from being the thinnest existing material, graphene is very attractive for photonics due to its extreme flexibility, high mobility and the possibility of controlling its carrier concentration (and hence its electromagnetic response) via external gate voltages. From its very birth, graphene nanophotonics has the potential for innovative technological applications, aiming to complement (or in some cases even replace) the existing semiconductor/metallic photonic platforms. It has already shown exceptional capabilities in many directions, such as for instance in photodetection, photovoltaics, lasing, etc. A special place in graphene photonics belongs to graphene plasmonics, which studies both intrinsic plasmons in graphene and the combination of graphene with plasmons supported by metallic structures. Here, apart from the dynamic control via external voltages previously mentioned, the use of graphene brings with it the remarkable property that graphene plasmons have a wavelength _p that can be even one hundred times smaller than that in free space _ (for instance _p_ 100nm at_ _10_m). This provides both extreme confinement and extreme enhancement of the electromagnetic field at the graphene sheet which, together with its high sensitivity to the doping level, opens many interesting perspectives for new optical devices. The collection of papers presented in this special issue highlights different aspects of nanophotonics in graphene and related systems. The timely appearance of this publication was apparent during the monographic workshop ‘Graphene Nanophotonics’, sponsored by the European Science Foundation and held during 3–8 March 2013, in Benasque (Spain). This special issue, although it cannot be considered as the proceedings of that workshop, was conceived there. Several topics at the cutting edge of research into graphene nanophotonics are covered in this publication. The papers by Polyushkin et al. and Thackray et al. consider structures where graphene is placed in close proximity to metallic plasmonic resonators. There graphene is used either as a substrate for metallic nanoparticles or as a top layer covering metallic stripes. Both studies find that the plasmonic response of metallic nanoparticles is notably modified by the presence of a graphene. The papers of Nefedov et al. and Bludov et al. analyze how a metamaterial based on a stack of graphene layers can provide unusually high absorption and reflection. These findings suggest that dynamical tuning of the reflectance and absorbance is possible at specific frequencies.

The theory of the transverse current response for graphene within the random phase approximation is presented, from a general standpoint, in the paper by Gutiérrez-Rubio et al., which considers non-local effects, as well as the dependence of both temperature and surrounding dielectric media. Forati et al. present a study on conductivity and current distributions in a graphene sheet located over a ridge-perturbed ground plane, showing how the resulting plasmonic waveguide is more sensitive to the bias voltage than to the geometric ridge parameters.

Effective analytical methods to address the electromagnetic resonances related to the excitation of graphene plasmons in different structures are presented in the papers by Balaban et al. (devoted to individual graphene discs and stripes) and Slipchenko et al. (which considers periodic graphene gratings).

Popov et al. predict lasing of terahertz radiation in graphene due to the stimulated generation of plasmons. Their paper demonstrates that the dynamic and frequency ranges, as well as the energy conversion efficiency, of the terahertz graphene amplifier can be strongly enhanced in a structure with a narrow-slit Bragg grating and/or a thin barrier layer. Reserbat-Plantey et al. report on the fabrication and optical characterization of microcavities, made of multilayer graphene cantilevers, clamped by metallic electrodes and suspended over Si/SiO2 substrate. The authors demonstrate the potential of these simple systems for high-sensitivity Raman measurements of generic molecular species grafted on a multilayer graphene surface. In addition to graphene structures, the studies of related low-dimensional systems are also represented in this special issue. Renoux et al. investigate how reduction in the size of subwavelength metallic thin-film bolometers affects their performance. The major finding is that, due to plasmonic effects, the responsivity can strongly increase when the sample width is narrowed, something that may also occur in graphene-based structures. Di Gaspare et al. discover that a channel in a high electron mobility transistor can work as a resonant microcavity for plasma waves.

The results presented in these studies are an excellent overview of the activity being currently conducted in this nascent field and form the basis for very interesting potential applications, such as active optical elements, bio- and chemical sensors, highly sensitive Raman detection, lasing, optical graphene amplifiers, and switching or frequency demultiplexing.