Graphene metasurfaces to design broadband polarizers and non-reciprocal devices

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In this work, we present ultrathin broadband linear-to-circular or elliptical polarization converter designs (quarter-wave plates) operating in transmission at low THz frequencies. They can be constructed by patterning a graphene monolayer to form metasurfaces based on periodic rectangular graphene patches placed over a dielectric substrate. In addition, cross-polarization converters (half-wave plates) operating in reflection are also designed and reported. These are based on an array of L-shaped graphene patches placed over a dielectric spacer layer and backed by a gold substrate. Compared to previous works, the proposed THz polarizers are simpler to be experimentally verified, they have an ultrathin thickness and can work at a wide frequency range. In addition, their properties can be dynamically tuned along the entire THz frequency spectrum without changing their geometry, just by electrostatically gating the graphene's surface.

The conductivity of graphene at low THz frequencies is dominated by intraband transitions and can be characterized by the Drude model. Strong surface plasmons are excited at the surface of graphene in this frequency regime. This leads to resonance conditions in the transmission or reflection spectrum of the proposed graphene metasurfaces that can be affected by the length of each graphene patch element. The strong interplay and coupling between the resonances excited by different polarized incident waves leads to the design of the aforementioned ultrathin and broadband polarization converters.

Moreover, we modulate in time the conductivity of an alternative graphene metasurface leading to the design of a new ultrathin non-reciprocal THz device that can provide strong non-reciprocity without the usual need of magnetic-bias. This device is composed by a loop of three identical elliptical graphene patches placed over a dielectric spacer backed by a gold substrate. Based on this symmetric configuration, we observe giant non-reciprocity in reflection between right-handed and left-handed circular polarized incident THz waves. The proposed time-modulated graphene metasurface scheme paves the way to a novel class of optimal and dynamically tunable compact non-reciprocal THz devices.