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Terahertz/infrared waveguide modulators using graphene metamaterials

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Active developement of terahertz (THz)/ infrared (IR) science and technology has created a growing demand for new electronic and quasi-optical devices. In particular, the promising opportunities for broadband high-speed terahertz communication require new techniques for real-time manipulation of radiation. Extrodinarily high carrier mobility [1] and pico-second-scale photocarrier generation and relaxation [2] have attracted attention to graphene as an active material for high-speed modulation solutions at various frequencies.

We study and classify the electromagnetic regimes of multilayer graphene/dielectric artificial metamaterials in the THz/IR range. Placed inside a hollow waveguide (Fig. 1), they provide high-speed modulation of radiation and offer novel concepts for terahertz modulators and tunable filters.

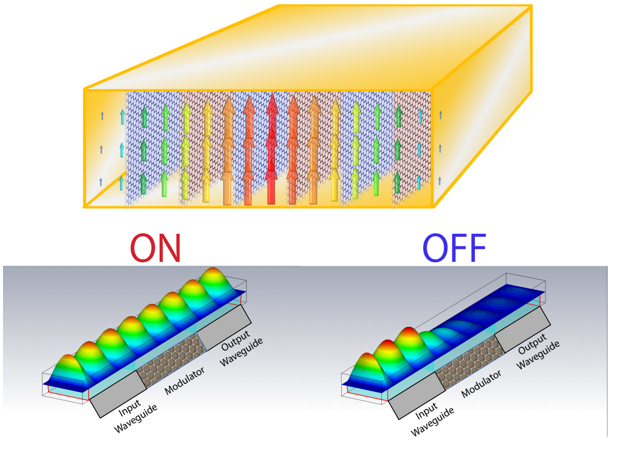

Fig. 1: Above: Graphene metamaterial inside a hollow waveguide. The arrows show the TE_{10} mode profile. Below: Electric fields in graphene/CsBr metamaterial modulator in the ON- and OFF-states. The modulating section is coupled to input/output NaCl-filled waveguides.

We demonstrate an efficient, compact and ultrasensitive modulation at high-THz frequencies around the CO_2 laser emission line (30 THz) and analyse three examples of resulting tunable devices. The first one is a modulator with excellent ON-state transmission and very high modulation depth: > 38 dB at 70 meV graphene's electrochemical potential (Fermi energy) change (Fig. 1). The second one is a modulator with extreme sensitivity towards graphene's Fermi energy - a minute 1 meV variation of the latter leads to > 13.2 dB modulation depth. The third one is a tunable waveguide-based passband filter. The narrow-band cut-off conditions around the ON-state allow the latter to shift its central frequency by 1.25% per every meV graphene's Fermi energy change. We believe that graphene-dielectric multilayer composites will constitute a useful functional element for the THz-IR waveguide-integrated devices.

References

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