Plasmonic antenna coupling to hyperbolic phonon polaritons for sensitive and fast mid-infrared photodetection with graphene

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Mid-infrared wavelength (mid-IR) detectors are highly useful for a myriad of applications such as security, sensing, etc. In this work, we show the realization of a new concept room temperature ultrafast infrared photodetector that exceeds any commercial technology. It has a response time of <15 nanoseconds (setup limited), while at the same time showing excellent sensitivity: we extracted a noise-equivalent-power (NEP) down to 82 pw/√Hz at 6 µm (50 THz) [1]. Our approach consists in exploiting the efficient coupling of plasmonic antennas with hyperbolic phonon-polaritons (HPPs) in hBN for highly concentrate mid-infrared light into a graphene pn junction in order to overwhelm its low absorption and small photoactive area. We use a metallic bowtie antenna and H-shape resonant gates that besides concentrating the light into its nanogap, their plasmonic resonances spectrally overlap within the upper reststrahlen band of hBN (6-7 µm) [1,2], thus launching efficiently these HPPs and guiding them with constructive interferences towards the photodetector active area. Additionally, by having two different antennas orientation, it allows us to have sensitive detection in two incident polarizations (see Fig. 1a,b). The photocurrent is generated via the photo-thermoelectric effect in high-quality encapsulated graphene devices of mobility >15,000 cm^2/Vs, where light incident on a junction between *p*-doped and *n*-doped graphene leads to an increase in the temperature of the charge carriers in graphene, subsequently creating a photoresponse [1,3]. These experimental results are supported by a novel multiphysics model, which includes optical, thermal and electrostatic simulations that show excellent quantitatively agreement. Consequently, it reveals the different contributions to our photoresponse, thus paving the way for further improvement of these types of photodetectors even beyond mid-infrared range.

References

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Figures

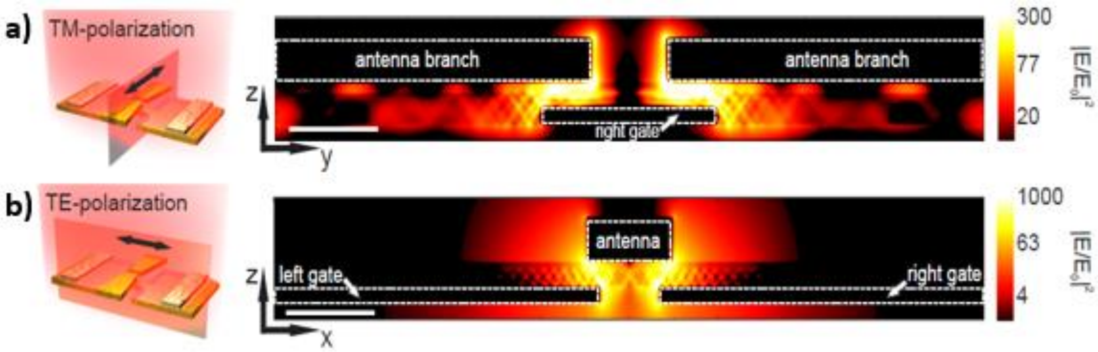

Figure 1: a) Cross section view of the simulated total electric field intensity normalized to the incident one along the antenna main axis when light is polarized parallel to the bow-tie antenna (TM-polarization) axis as indicated in the illustration on the left. The white scale bar corresponds to 250 nm. b) Same as a) but for light TE-polarization as shown in the schematic on the left.