When Metasurfaces Meet Photodetectors

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Abstract

Mid-infrared detectors are of critical importance for a variety of applications including thermal imaging, spectrometer, sensing and free space communication. High sensitivity, zero power consumption, fast response, simple CMOS-compatible fabrication processes, small footprint, wavelength and polarization selectivity are highly desired, while still being elusive so far especially at room temperature. In this talk, we will report a series of metasurface-mediated detectors. Non-centrosymmetric metallic nanoantennas are deployed to break the symmetry of local electromagnetic field and induce directional flow of hot carriers in graphene, leading to large unbalanced mid-IR photoresponse at room temperature without external bias. We demonstrate zero-bias uncooled mid-infrared photodetectors with three orders higher responsivity than conventional bulk photovoltaic effect (BPVE) and a noise equivalent power of $0.12\ \mathrm{nW\ Hz^{-1/2}}$. We further establish a scheme to realize configurable polarity transition by exploiting the vectorial and non-local photoresponse in hybrid metasurface of nanoantennas and graphene. By tuning the orientation of nanoantennas, polarization ratio (PR) values vary from positive (unipolar regime) to negative (bipolar regime), covering all possible numbers ($1 \rightarrow \infty/-\infty \rightarrow -1$). Polarization-angle perturbation down to $0.03°\ \mathrm{Hz^{-1/2}}$ in the mid-infrared range is demonstrated. We will also report on-chip filterless photodetectors in mid-infrared which solely responds to circular polarizations. We finally showcase how machine learning could enable full-Stokes photodetection and high-dimensional sensing of light's properties.