Graphene Photonics and Optoelectronics

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The richness of optical and electronic properties of graphene attracts enormous interest. So far, the main focus has been on fundamental physics and electronic devices. However, it has also great potential in photonics and optoelectronics, where the combination of its unique optical and electronic properties can be fully exploited, the absence of a bandgap can be beneficial, and the linear dispersion of the Dirac electrons enables ultra-wide-band tunability[1]. The rise of graphene in photonics and optoelectronics is shown by several recent results, ranging from solar cells and light emitting devices, to touch screens, photodetectors and ultrafast lasers [1]. Despite being a single atom thick, graphene can be optically visualized [2]. Its transmittance can be expressed in terms of the fine structure constant [3]. The linear dispersion of the Dirac electrons enables broadband applications. Saturable absorption is observed as a consequence of Pauli blocking [4,5]. Chemical and physical treatments enable luminescence [1,6]. Graphene-polymer composites prepared using wet chemistry [4-6] can be integrated in a fiber laser cavity, to generate ultrafast pulses, and enable broadband tunability [4,5]. Graphene's suitability for high-speed photodetection was demonstrated in an optical communication link operating at 10 Gbit s^{-1} [7]. However, the low responsivity of graphene-based photodetectors compared with traditional III-V-based ones is a potential drawback. By combining graphene with plasmonic nanostructures, the efficiency of graphene-based photodetectors can be increased by up to 20 times, because of efficient field concentration in the area of a p-n junction [8]. Additionally, wavelength and polarization selectivity can be achieved by employing nanostructures of different geometries [8]. Light-graphene interaction can be tailored by using microcavities [9]. Photodetection of far-infrared radiation (from hundreds of GHz to a few THz) is important for a variety of potential applications, ranging from medical diagnostics to process control, and homeland security. THz radiation penetrates numerous commonly used dielectric materials, otherwise opaque for visible and mid-IR light. At the same time, it allows spectroscopic identification of hazardous substances and compounds, through their characteristic molecular fingerprints. In this spectral region, due to the unavoidable doping, Pauli blocking does not allow detection exploiting the common photon-induced creation of charge carriers. Efficient THz detection in grapheme can be achieved exploiting the oscillating fields in a graphene field effect transistor [10]. This enables high-sensitivity, room temperature, large-area operation, not limited to a specific region of the THz range [10].

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