Can graphene photodetectors break the quantum efficiency limit?

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Abstract

Due to the unique properties of graphene, efficient photodetection based on the photo-thermoelectric (PTE) effect is possible [1]. The PTE mechanism involves the net movement of 'hot charge carriers' away from an interface between two regions with a different Fermi energy and therefore a different Seebeck coefficient (see Figure 1). These 'hot carriers' are created in a photoexcitation cascade where light excites charge carriers that rapidly share their energy with other charge carriers to form a hot-electron gas [2, 3]. In this process, a single absorbed photon can generate multiple hot electrons. This naturally leads to the question if the internal quantum efficiency (IQE) – the number of detected electrons in photocurrent per absorbed photon – can exceed unity. Devices based on the photovoltaic effect, in contrast, will always have IQE < 1. However, in the case of the photo-thermoelectric effect theory indicates that more than one charge carrier could be extracted per absorbed photon, i.e. IQE > 1 [4]. The aim of this project is to obtain a qualitative understanding of all relevant parameters that determine the IQE in order to assess the feasibility of obtaining IQE > 1.

We study high quality devices of BN-encapsulated graphene on local split-gates to tune the Seebeck coefficient independently in both regions. Using time-resolved photocurrent scanning microscopy we examine the temporal, spectral and spatial photocurrent response at different temperatures. From this, we aim to obtain the optimal parameters that would allow an IQE exceeding unity. At the moment we have clear indications that with optimized contact resistance (such as reported in [5]) this is possible. In the end, this can find applications in high-sensitivity and broadband photodetectors [6].

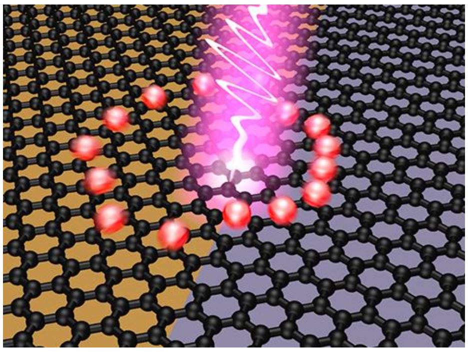

Figure 1: Light incident on graphene with a net flow of charge carriers due to the PTE effect.

References

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