Momentum alignment of photoexcited carriers in graphene

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A linearly polarized excitation is shown to create a strongly anisotropic distribution of photoexcited carriers in graphene (Fig.1a), where the momenta of photoexcited carriers are aligned preferentially normal to the polarization plane. This hitherto overlooked effect offers an experimental tool to generate highly directional photoexcited carriers which could assist in the investigation of “direction-dependent” phenomena in graphene-based nanostructures. The depolarization of hot photoluminescence (HPL) has been used with great success to study relaxation processes in conventional 2D systems [1, 2]. In such systems the alignment is due to the spin-orbit interaction for photoexcited holes [3], whereas in graphene, it is due to the pseudo-spin. Namely, the ratio of the two components of the spinor-like graphene wave function depends on momentum which influences the optical transition selection rules [4]. By comparing the depolarization of HPL from successive phonon replicas, the mechanisms of phonon-assisted relaxation of minority carriers in graphene can be studied by simple optical polarization measurements in contrast to a more sophisticated method based on intraband THz absorption, which is used to study carrier-carrier relaxation of the majority carriers [5]. Furthermore, studying the depolarization of HPL in a magnetic field (the Hanle effect) allows one to obtain momentum relaxation times of hot electrons. The effect of momentum alignment in graphene provides a contact-free method of characterizing energy and momentum relaxation. Our analysis of momentum alignment in the high frequency regime shows that a linearly polarized excitation allows the spatial separation of carriers belonging to different valleys (see Fig.1b), therefore opening the door to an optical means of controlling valley polarization (optovalleytronics) and valley-based quantum computing in graphene.

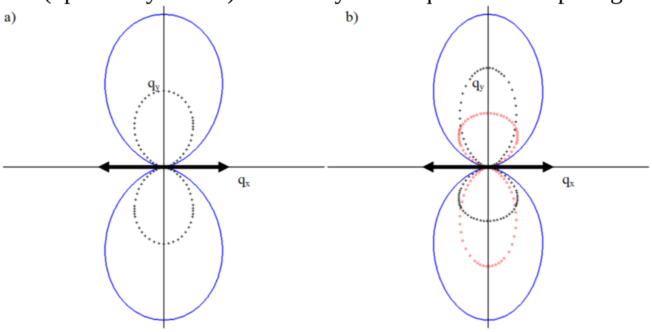

Fig. 1: The polar plots of the distribution function of photoexcited carriers: a) for an excitation energy $h\nu << \gamma$, where $\gamma \approx 3\text{eV}$ is the hopping parameter; b) for an excitation energy $h\nu = 0.6\gamma$. The bold arrows show the polarization vector of the excitation and the dotted lines show the separate contributions from each valley.

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