Towards THz emission from interlayer phonons in bilayer graphene

Since its discovery one decade ago, graphene has blossomed into one of the most interesting and thoroughly investigated research domains in condensed matter physics. Notwithstanding such a large effort, we are still far from developing a comprehensive understanding of its fascinating properties. In order to keep the peace with this quickly evolving domain, the European Commission declared graphene to be one of its principal research objective for the next decade starting an ambitious Graphene Flagship program.

The present project aims to insert itself into this positive trend by investigating quantum optomechanichal effects, coupling photo-emission and photo-transport properties in graphene bilayers. Interesting optical properties in this material have recently been demonstrated, leading for example to the controlled opening and tuning of a direct band gap by an applied perpendicular electric field, making of graphene bilayers an outstanding candidate for the realization of tunable light emitters in the terahertz and mid-infrared domain [1].

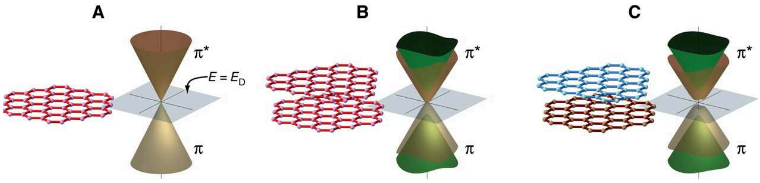

Figure 1: While the electronic structure of graphene monolayers (A) is characterized by a linear, massless dispersion near the Dirac point, in graphene bilayers (B) the inter-layer coupling makes the carrier massive. Breaking the symmetry between the two layers through electric fields or inhomogeneous doping it is possible to strongly tune both the optical and transport properties of the bilayer (C). Image from Ref. [2].

Our approach to enhance the emission properties of bilayer graphene consists in exploiting the coupling of the conduction electrons to the interlayer vibrational modes between graphene planes [4]. The importance of this coupling has recently been demonstrated by investigating electron transport properties in suspended few layer graphene devices [3]. In particular, we propose to apply a strong perpendicular electric field to create a charge imbalance between the electrons populations in the two planes of the bilayer. This will create an effective macroscopic electric-dipole moment between the planes vibrating in phase with the interlayer phonon mode resulting in a super-radiant enhancement of the emitted electromagnetic field.

An important advantage of the proposed approach as compared to the emission from optical-phonon modes in other materials, is that the life time of the optical phonons is usually limited by the decay into several acoustical phonon modes of comparable energy [5]. In bilayer systems the inter-layer vibrational mode is the only transverse mode available and is thus expected to have a much higher life time explaining for example its strong coupling to transport properties observed in [3]. The interlayer vibrational mode in graphene bilayer occurs at around a THz frequency in which efficient high power sources are actively sought for currently. Similar physics can also be explored in graphene based heterostructures that have been produced recently.

The project will consist in the theoretical modelling of the described emission process, both at the quantum and semiclassical level, and it will be performed between the laboratories of Southampton and Orsay. There candidate will also closely collaborate with the experimental groups in Orsay and Cambridge, that will observe the predicted effects. The candidate will be required to divide its time between England and France, and the studentship includes funds for both frequent travels and relocation.

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