Negative differential resistance in Van der Waals heterostructures due to moiré-induced spectral reconstruction

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The phenomenon of negative differential resistance (NDR) is a striking example of nonlinearities in physics; within a certain region of the current/voltage characteristic of a device, increase of applied voltage leads to decrease of the output current. We discuss theoretically electron transport in Van der Waals tunnelling transistors and show that NDR can be achieved in such heterostructures without the need for momentum-conserving tunnelling typically associated with high-quality exfoliated devices [1,2]. Instead, we exploit the formation of moiré superlattices at an interface between two two-dimensional crystals. Such superlattices arise due to the mismatch between lattice constants [3] and misalignment of crystallographic directions of the two neighbouring materials [4] and fold the electronic dispersion into minibands, opening mini gaps at the boundary of the superlattice Brillouin zone and leading to the appearance of Van Hove singularities in the electronic density of states. We simulate the tunnelling current in a Van der Waals transistors in which the source electrode is either (1) monolayer graphene highly aligned with underlying hexagonal boron nitride or (2) twisted bilayer graphene, with monolayer graphene as drain. We show that modifications of the electronic density of states of the source electrode due to the moiré can generate negative differential resistance across the tunneling junction. Our results should extend to general transistors with one or more electrodes containing superlattice-inducing interfaces.

References

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[2] Mishchenko et al., Nat. Nano., 9 (2014) 808–813
[3] Yankowitz et al., Nat Phys., 8 (2012) 382-386
[4] Li et al., Nat Phys., 6 (2010) 109-113

Figures

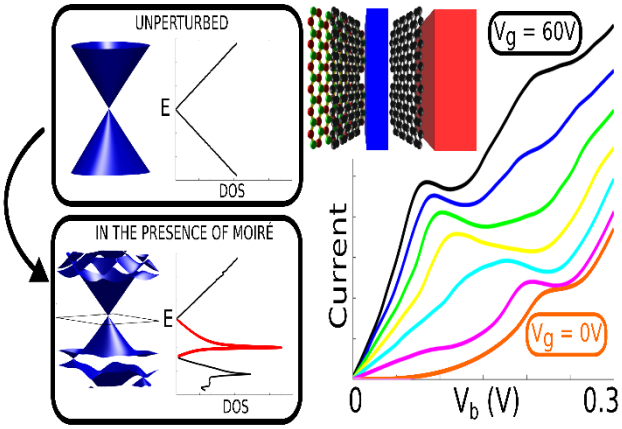

Figure 1: Folding of graphene conical dispersion due to hBN-induced moiré superlattice. Also shown is the corresponding density of states. (Right) Calculated current-bias voltage characteristics for a range of gate voltages. (Inset) Schematic of the modelled Van der Waals transistor.