Lattice parameter-scale moiré superlattices in near-30-degree twisted bilayer graphene

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When two-dimensional atomic crystals like graphene or monolayer transition metal dichalcogenides are stacked on top of each other, the difference between the lattice constants of neighbouring materials and misalignment between their crystallographic axes lead to formation of quasi-periodic moiré patterns. It is well established that when the moiré wavelength is large compared to the lattice constants of the individual crystals, the twisted heterostructure can be effectively considered a superlattice with a unit cell and Brillouin zone defined by the first harmonic of the moiré [1,2]. Here, we show that superlattice effects persist in twisted bilayer graphene with twists close to the maximum of 30 degrees, translating to periodicities on the scale of less than twice the lattice constant, although no superlattice of that size corresponding to the measured twist angle is possible in the case of rigid lattices and no evidence of mechanical deformations on the necessary scale is seen. Based on angle-resolved photoemission studies, we demonstrate effective intervalley Umklapp scattering of electrons in one graphene layer on the potential profile of the other which opens gaps in the electronic spectrum at energies closer to the Dirac points of the individual layers than the band gap due to cone anti-crossing, usually considered the dominant low-energy feature resulting from interlayer coupling.

References

[1] T. Ohta et al., Physical Review Letters **109**, 186807 (2012).
[2] J. Wallbank et al., Physical Review B **87**, 245408 (2013).