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## Band structure of hBN-graphene-hBN trilayer systems

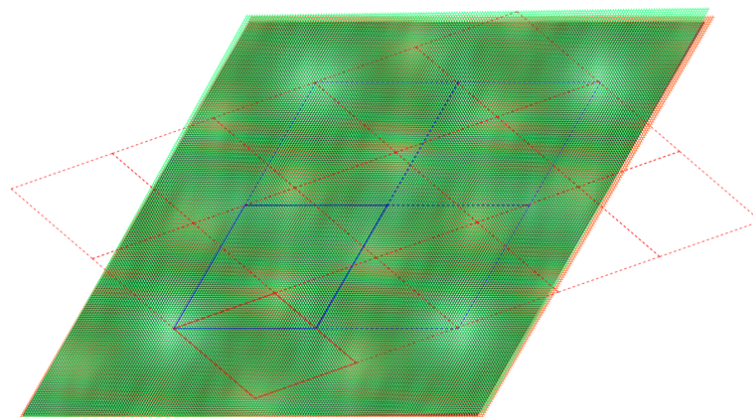
We study the electronic band structure of hBN-graphene-hBN trilayer system. Graphene is a two-dimensional materials of carbon atoms with honeycomb lattice structure and a gapless linear band structure. The hexagonal Born Nitride (hBN) is another two-dimensional material with honeycomb lattice, but with a slightly different lattice constant and an insulating band structure. When a graphene is stacked on a hBN, a small lattice mismatch gives rise to a moiré interference pattern, and the resulting superlattice potential breaks the graphene's Dirac cone into a series of minibands separated by energy gaps.<sup>1,2</sup> The interference pattern and the electronic structure sensitively depend on the twist angle  $\theta$  between the lattice orientations of the two materials.

In this study, we consider the hBN-graphene-hBN trilayer systems and investigate the electronic structures in various combinations of the twist angles. The system has two different moiré patterns depending on the twist angle of the top and bottom hBN layers with respect to the middle graphene layer. Generally, these two moiré patterns are incommensurate in arbitrary rotation angles, but quite often two moiré patterns are nearly commensurate, where we have an approximate super-superlattice period. In such the cases, we obtain the effective Bloch Hamiltonian and calculate the band structures. We show that, unlike the single moiré system, the double moiré patterns give rise to a series of higher-order gaps and also flat bands between the first-order gaps of the individual moiré patterns.

### References

- [1] C. R. Dean, A. F. Young, I. Meric, C. Lee, L. Wang, S. Sorgenfrei, K. Watanabe, T. Taniguchi, P. Kim, K. L. Shepard, and J. Hone, *Nat. Nanotechnol.* 5, 722 (2010).
- [2] J. Xue, J. Sanchez-Yamagishi, D. Bulmash, P. Jacquod, A. Deshpande, K. Watanabe, T. Taniguchi, P. Jarillo-Herrero, and B. LeRoy, *Nat. Mater.* 10, 282 (2011).

### Figures



**Figure 1:** Double moiré pattern in hBN-graphene-hBN trilayer system with the twist angles 0 and 0.893 degrees. Blue and red lines indicate the superlattice unit cells of individual moiré pattern