Measuring graphene's Berry phase at B = 0 T

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In quantum mechanics, the Berry phase is a geometrical phase picked up by wave functions along an adiabatic closed trajectory in parameter space.[1] It has become a central unifying concept with applications in fields ranging from chemistry to condensed matter physics. In condensed matter it has enabled the understanding of various low-energy properties of matter, among which electric polarisation, orbital magnetism, as well as topological and ultra-relativistic phenomena. Measuring the Berry phase is therefore of crucial importance in the search of new materials and new properties.
It is usually believed that measuring the Berry phase requires applying electromagnetic forces. This is because these forces allow realizing experimentally the adiabatic transport on closed trajectories which are at the very heart of the definition of the Berry phase.[1] Contradicting this belief, we demonstrate that the Berry phase of graphene can be measured in absence of any external magnetic field. [2] We observe edge dislocations in the Friedel oscillations [3] formed at a hydrogen atom chemisorbed on graphene (Fig. 1). These topological defects are direct consequences of the pseudospin rotation in intervalley back scattering and allow a direct determination of the Berry phase in the real space.
Our result generalize Friedel oscillations showing that together with the universal contribution which carries spectral properties they also contain information about the geometry of the band structure. This result bridges three important concepts in modern physics: the Berry phase, [1] Friedel oscillations [3] and topological defects in wave. [4]

References

[1] MV. Berry Proc. R. Soc. London Math. Phys. Eng. Sci. Eng. Sci 392, (1984) 45-57.
[2] C. Dutreix *et al.* Nature, 574 (2019) 219.
[3] J. Friedel, J. Phil. Mag 433 433, (1952)153.
[4] JF. Nye, MV. Berry, Proc. R. Soc. Lond. A 336 (1974) 165-190.

Figures

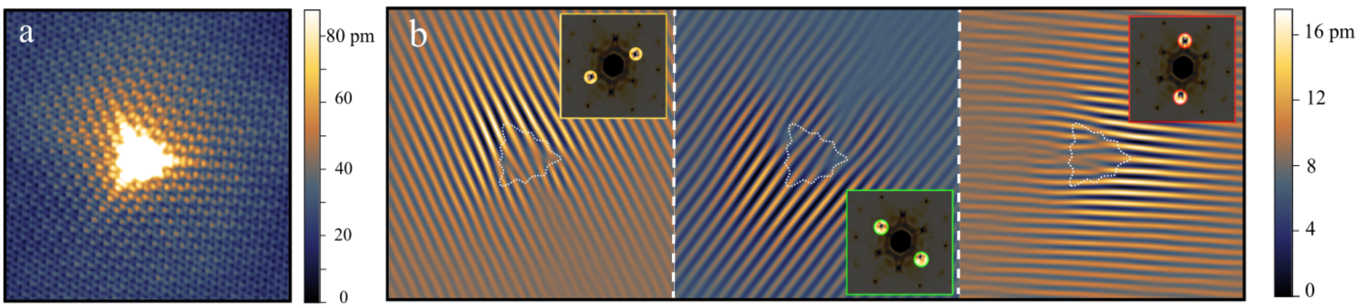

Figure 1: a) 10x10 nm² STM image of a hydrogen atom chemisorbed on graphene. b) Fourier filtered images highlighting the wavefrond dislocations measured in Friedel oscillations neat the adatom. The insets show the Fourier filters used.