Engineering topological superconductivity in twisted bilayer graphene

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Topological insulators have been the subject of an intense research effort, as they could host excitations with non-trivial braiding statistics like Majorana fermions or non-abelian anyons, quasiparticles proposed as a basis for fault-tolerant quantum computers [1,2].

We propose that twisted bilayer graphene (tBLG) Josephson junctions can realize such topological excitations. When the twist angle is significantly smaller than 1°, the superlattice consists of large (~µm wide) triangular domains with alternating Bernal (AB/BA) stacking order. In this system the domain boundaries allow valley-polarised 1D helical states with four gapless 1D states on each side of the triangular domains, propagating in opposite directions for valley K and K' [3,4].

In our Josephson junctions, the supercurrent persists deep into the quantum Hall regime, i.e. under magnetic fields breaking the time-reversal symmetry, ensuring s-wave pairing. We observe pockets of superconductivity in Landau levels at all magnetic fields below the critical field of the superconducting contacts, attributed to Andreev bound states propagating along 1D helical channels.

Our results show that tBLG is a particularly appealing system to engineer topological superconductivity. We provide evidence of the topological nature of the domain boundaries, a decisive step towards realizing exotic quasiparticles.

References

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