

Magnetically Tunable Bell-State Coherence and Spectroscopy in a Double Quantum Dot Embedded in Crossed Graphene Nanoribbons

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Abstract

Crossed graphene nanoribbon (GNR) junctions provide a compact platform for engineered localization and hybrid superconducting correlations. We show that the overlap of two quasi-1D GNRs at finite twist angle (θ) naturally forms an effective double quantum dot (DQD) capable of sustaining Bell-state dynamics. The system is modeled within a Bogoliubov–de Gennes tight-binding framework including interdot tunneling, Zeeman field B , Rashba spin–orbit coupling, and proximity pairing. From an initialized Bell state, we compute the time evolution and fidelity $F(t)$, revealing oscillatory regimes and coherence windows with sustained high fidelity. The landscape $F(t, B)$ demonstrates magnetic-field tunability and ridge-like optimal operating regions. For experimental relevance, we evaluate the spatial LDOS and tunneling spectra dI/dV . The overlap region shows two localized LDOS maxima consistent with the emergent DQD, while energy-resolved spectra exhibit symmetric subgap quasibound states. The phase diagram $dI/dV(V, B)$ displays smooth Zeeman evolution, consistent with the Bell-fidelity dynamics. Overall, the crossed-GNR junction functions as a graphene-native entanglement interferometer, highlighting crossed-nanoribbon DQD architectures as promising platforms for spin-topological graphene quantum devices.

References

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