Quantum devices based on complex materials and heterostructures

V. Brosco,[1] A. Coppo,[1] L. Chirolli,[2] N. Poccia[3,4] and U.Vool[5]

[1]Institute for Complex Systems Consiglio Nazionale delle Ricerche and Physics Department,"La Sapienza", Rome, Italy

[2]Quantum Research Center, Technology Innovation Institute, P.O. Box 9639 Abu Dhabi (UAE)

[3]Leibniz Institute for Solid State and Materials Science Dresden (IFW Dresden), Germany

[4]Department of Physics, University of Naples Federico II, Via Cintia, Naples, 80126, Italy

[5]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Abstract: Complex systems and materials provide promising pathways to innovative solutions for quantum technologies. Drawing on recent research, the talk explore some situations where complexity enables advanced functionalities.

Recent advances in creating van der Waals heterostructures hosting ultrathin electronic states and in fabricating hybrid Josephson nanostructures have opened new research avenues for understanding and controlling the exotic electronic properties and functionalities emerging in these hybrid systems.
The talk focuses on the potential offered by integrating twisted van der Waals heterostructures into superconducting quantum devices. Specifically, it shows how the d-wave nature of the order parameter in cuprate heterostructures significantly impacts quantum coherence, potentially enabling the realization of a qubit with inherent topological protection against charge-noise-induced relaxation and quasiparticle-induced dissipation, dubbed the flowermon [1]. Next, it presents a quantum device [2] comprising two twisted cuprate junctions integrated into a Superconducting Quantum Interference Device (SQUID) loop and threaded by an external magnetic flux. By adjusting the external flux and the twist angle, this device can be tuned into various regimes, each hosting distinct potential landscapes: a symmetric "twist-based" double-well potential, a "plasmonic" potential, and a "flux-biased" double-well potential. The critical flux at which the circuit enters the flux-biased regime is a special point where the spectrum exhibits a supersymmetric structure. This point marks a change in the symmetry properties of the excited state and leads to significant modifications in the system's coupling to external noise fluctuations and, consequently, in the decoherence rates.

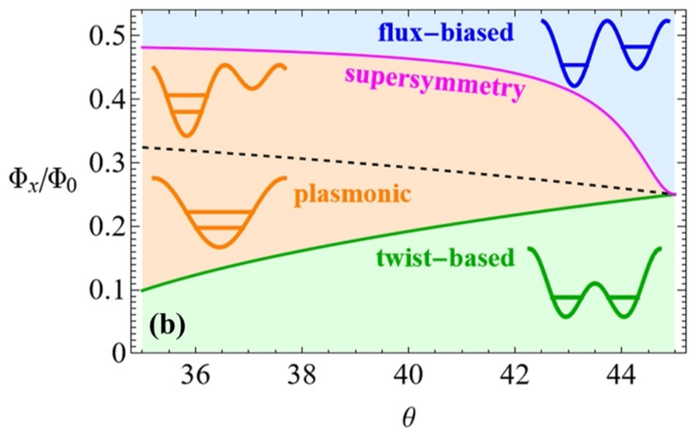

Fig. 1 Phase diagram of the twisted heterostructures SQUID device.

References

[1] V. Brosco, G. Serpico, V. Vinokur, N. Poccia and U. Vool, Phys. Rev. Lett. 132, 017003 (2024).

[2] A. Coppo, L. Chirolli, N. Poccia, U. Vool and V. Brosco, Appl. Phys. Lett. 125, 054001 (2024).