Towards Realistic Multilayer Quantum Circuits: Integrating Simulation with Experimental Data

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In this work, we introduce a comprehensive numerical framework developed to model three-dimensional multilayer superconducting devices, with a particular emphasis on nanobridge junctions and coplanar waveguide structures. In contrast to conventional modeling approaches that rely on simplified geometries or restrict the number of materials involved, our method captures the full physical layout and material complexity of multilayer superconducting architectures [1]. This enables a more faithful representation of realistic device behavior and offers researchers a flexible tool for the design and optimization of next-generation quantum circuits.

Our model allows for the precise calculation of critical currents, current–phase relationships, and energy gaps wherever these parameters play a defining role. To ensure reliability, we benchmark our simulations against experimental and published reference data, demonstrating strong agreement across a variety of material and geometric configurations [2].

The results reveal that employing multilayer superconducting films provides enhanced control over key device parameters, enabling engineers to tune circuit performance with greater precision. In the case of nanobridge junctions, the multilayer approach yields a marked increase in qubit anharmonicity relative to comparable monolayer designs—an effect that directly contributes to improved qubit isolation, reduced decoherence, and higher operational fidelity. Likewise, in coated multilayer microwave circuits, the model facilitates an in-depth exploration of the proximity effect and its influence on kinetic inductance, offering valuable insight into how layered superconductors can be engineered for optimal performance in superconducting quantum technologies.

References

[1] G. Colletta et al. Appl. Phys. Lett. 126, 142601 (2025)
[2] G. Colletta et al., in prepration

Figures

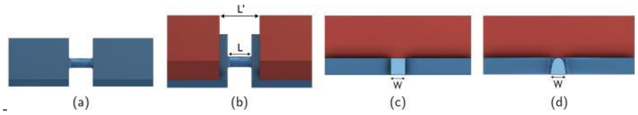

Figure 1: 3D design of the nanobridge junctions. (a) Planar nanobridge junction, (b) variable-thickness nanobridge (VTB) junction, (c) cross section of simplified VTB junction with rectangular edges, and (d) cross section of the VTB junction with realistically rounded edges. Colors are to indicate the presence of different materials.

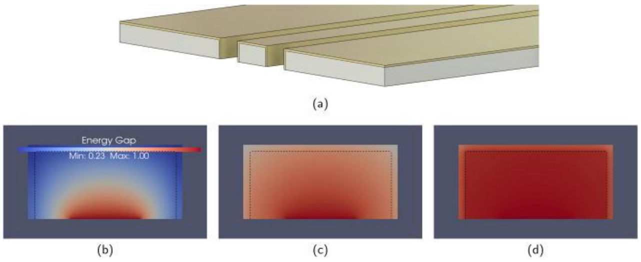

Figure 2: (a) 3D design (not to scale) of a multilayer CPW. Energy gap in the inner conductor of the CPW for (b) $\gamma = 10$, (c) $\gamma = 1$, and (d) . The dotted line was added to the images to indicate the separation between the niobium and encapsulating layer. Other parameters used were , and the thickness of the superconducting and normal metal is 200 and 20 nm, respectively. It is evident that the proximity effect is highly sensitive to the value of γ. As this parameter increases, the energy gap reduces even when the thickness of the encapsulating material is smaller than the coherence length.