Integration of Topological Insulator Josephson Junctions in Superconducting Qubit Circuits

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Abstract

The integration of semiconductor Josephson junctions (JJs) in superconducting quantum circuits provides a versatile platform for hybrid qubits and offers a powerful way to probe exotic quasiparticle excitations. Recent proposals for using circuit quantum electrodynamics (cQED) to detect topological superconductivity motivate the integration of novel topological materials in such circuits.

In this talk I describe the realisation of superconducting transmon qubits implemented with $(Bi_{0.06}Sb_{0.94})_2Te_3$ topological insulator (TI) JJs using ultrahigh vacuum fabrication techniques [1]. Microwave losses on our substrates, which host monolithically integrated hardmasks used for the selective area growth of TI nanostructures, imply microsecond limits to relaxation times and, thus, their compatibility with strong-coupling cQED. We use the cavity–qubit interaction to show that the Josephson energy of TI-based transmons scales with their JJ dimensions and demonstrate qubit control as well as temporal quantum coherence. Our results pave the way for advanced investigations of topological materials in both novel Josephson and topological qubits.

References

[1] Schmitt *et al.*, Nano Letters (2022), 10.1021/acs.nanolett.1c04055

Figures

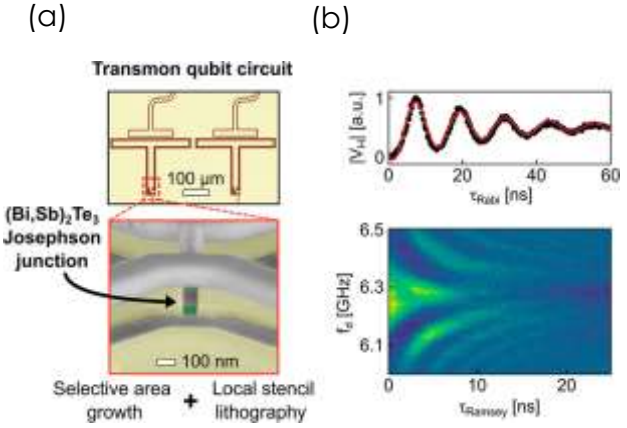

Figure 1: (a) Optical image (upper) of a niobium circuit showing a T-shaped transmon qubit island coupled to the bottom of a cavity resonator and tilted false-colour scanning electron micrograph (lower) showing the Josephson junction, comprising niobium (yellow), topological insulator (green), and the nanostencil (grey) used to shadow the junction region. (b) Rabi oscillations (upper) and Ramsey interference (lower) of the TI transmon showing coherent quantum control.