Topological phenomena in Josephson tunnel junction circuits

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Promising topological properties have been predicted in multi-terminal Josephson junctions [1], but so far they remain out of experimental reach due to lack of microscopic control over the normal weak link. Here we discuss an alternative approach based on two-terminal Josephson tunnel junctions [2,3]. In these circuits, topology naturally appears in the form of robust level crossings in the dispersion of charge states as a function of superconducting phase differences and charge offsets.
We first give a recipe for finding robust topological band crossings in simple Josephson circuits, and extend the discussion to more complex circuits with degeneracies in higher dimensions. We then present the results of a circuit-QED spectroscopy experiment of a three-junction circuit, the BiSQUID. We show that it simulates a Weyl semi-metal with robust linear band crossings in a unit cell of its three-dimensional parameter space.
This early-stage work is a first step showing that Josephson tunnel junction circuits are a promising platform to simulate topological properties inaccessible in condensed matter systems.

References
[1] R. P. Riwar, V. Nazarov, Nature Communications, 7 (2016) 11167
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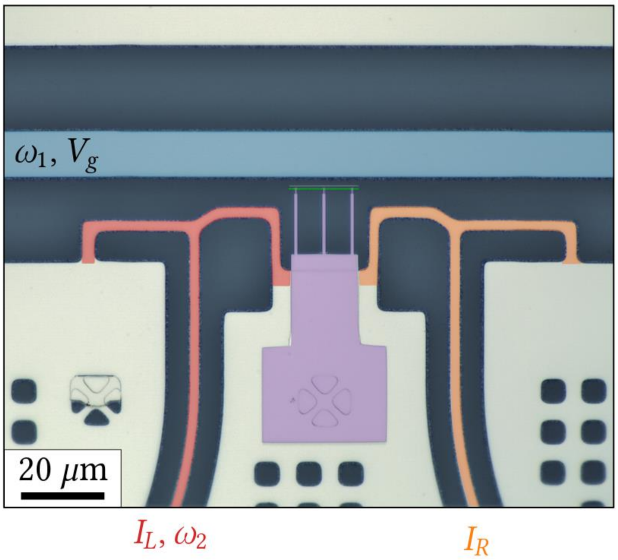

Figure 1: A BiSQUID circuit formed by three Josephson junctions in parallel is capacitively coupled to a CPW resonator. Two flux lines (red, orange) are used to control the magnetic fluxes in the BiSQUID loop and apply a second tone to excite BiSQUID transitions.

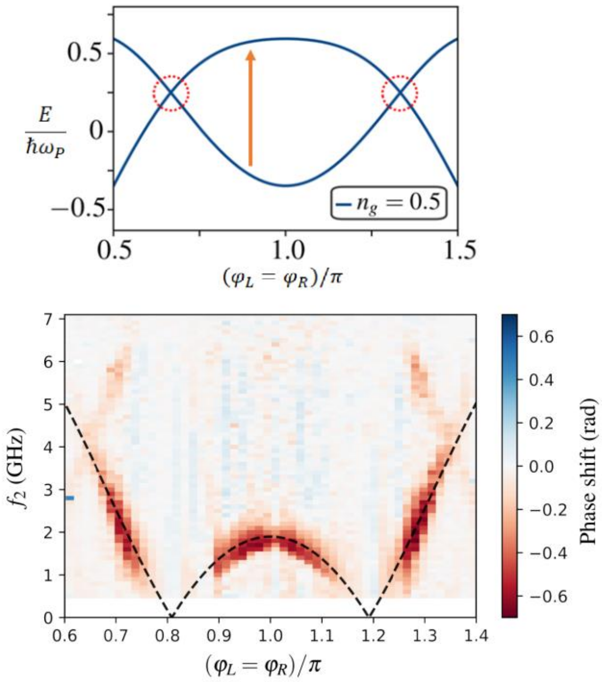

Figure 2: (top) Linear crossing of the first energy levels of a BiSQUID. Two Weyl nodes of opposite topological charges are highlighted with red crcles. (bottom) Two-tone spectroscopy of the first transition of the BiSQUID of Figure 1 showing the two topological band crossings.