

Quantum Coulomb drag mediated by cotunneling of fluxons and Cooper pairs

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Abstract

We predict two novel quantum Coulomb drag effects in systems of coupled resistively shunted ultrasmall Josephson junctions operating in the regime of macroscopic quantum coherence. In capacitively coupled junctions Fig.1, biasing one junction induces a finite voltage across the other due to cotunneling of magnetic flux quanta (fluxons).

Mutual capacitance promotes interaction and merging of instantons, rendering fluxon cotunneling the dominant transport mechanism over a broad parameter range. We derive the drag voltage and demonstrate its power-law scaling with temperature and bias current governed by dissipation. In the strong-coupling regime, the drag signal becomes comparable to the primary voltage, revealing collective quantum dynamics in the coupled phase space.

Exploiting phase-charge duality, we further predict a dual drag effect for two Josephson junctions connected in series Fig.2 in the Coulomb blockade regime. There, cotunneling of Cooper pairs generates a finite current in an unbiased junction when a voltage is applied to the other. We establish the corresponding scaling relations and identify experimentally accessible regimes.

Our results reveal new manifestations of nonlocal quantum transport in superconducting nanocircuits and open perspectives for experimental observation of quantum drag phenomena in circuit quantum electrodynamics architectures.

References

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Figures

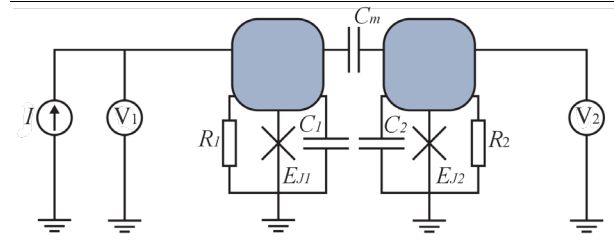


Figure 1: Two capacitively coupled resistively shunted ultrasmall Josephson junctions.

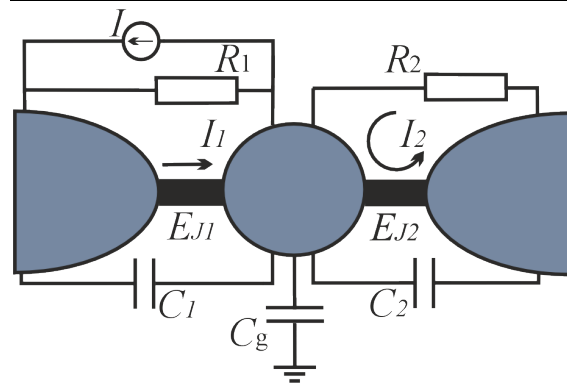


Figure 2: Series configuration of ultrasmall Josephson junctions in the Coulomb blockade regime.