Mean-field theory of first-order quantum superconductor-insulator transition

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Recent experimental studies on strongly disordered indium oxide films have revealed an unusual first-order quantum phase transition between the superconducting and insulating states (SIT). This transition is characterized by a discontinuous jump from non-zero to zero values of superfluid stiffness at the critical point, contradicting the conventional "scaling scenario" typically associated with SIT. In this paper, we present a theoretical framework for understanding this first-order transition. Our approach is based on the concept of competition between two fundamentally distinct ground states that arise from electron pairs initially localized by strong disorder: the superconducting state and the Coulomb glass insulator. These ground states are distinguished by two crucially different order parameters, suggesting a natural expectation of a discontinuous transition between them at $T = 0$. This transition occurs when the magnitudes of the superconducting gap Δ and the Coulomb gap E_C become comparable. Additionally, we extend our analysis to low non-zero temperatures and provide a mean-field "phase diagram" in the plane of $(T/\Delta, E_C/\Delta)$. Our results reveal the existence of a natural upper bound for the kinetic inductance of strongly disordered superconductors.