Critical States in the Two-Dimensional Quantum Percolation Model

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Abstract

We present a numerical study of the two-dimensional quantum percolation model, revealing that the transition from localized to delocalized states is mediated by a non-ergodic extended critical phase. By analyzing level spacing statistics and participation entropy, we identify two distinct quantum phase transitions: a Berezinskii–Kosterlitz–Thouless (BKT) transition at lower occupation probability, separating the localized and critical phases, and a power-law-type transition at higher probability, marking the onset of full delocalization. The critical phase is characterized by non-ergodic, multifractal eigenstates, as evidenced by the scaling of the participation entropy and the generalized fractal dimension of the wavefunctions. At high occupation probabilities, we find that the fractal dimension saturates at the classical percolation value, indicating that the quantum states extend over the fractal backbone of the percolating cluster. Our results establish that the 2D quantum percolation model belongs to a distinct universality class from the 2D Anderson model.

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