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The truncated U(1) Abelian Higgs model and implications for its quantum simulation

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We have proposed a concrete experimental setup for quantum simulating the $(1 + 1)$-dimensional Abelian Higgs model in J. Zhang *et al.* (2018), where the Hamiltonian in the electric field representation can be implemented on a multi-leg ladder with a single atom in each rung. The finite-size scaling of the energy gap can be measured and its universal behavior can be extracted at large enough spin truncations. However, the O(2) limit of this representation is always gapped for any finite spin-S truncation, and the dynamics of charges cannot be measured directly. We now study the charge representation of the O(2) model in detail with tensor renormalization group applied to the Lagrangian and level spectroscopy applied to the Hamiltonian. We find that there is an infinite-order Gaussian transition for spin-1 truncation, and there are Berezinskii–Kosterlitz–Thouless transitions for $S \geq 2$ truncations. We find universal functions relating the mass gap, the gauge coupling, and the spatial size in the smallest spin truncations, which do not exist in the field representation. Possible experimental realizations are discussed.

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