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Truncation effects in dual representations of the O(2) model

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The classical O(2) model is the zero-gauge-coupling limit of compact scalar quantum electrodynamics in Euclidean spacetime. We obtain two dual representations of the O(2) model, where the field quantum numbers on the plaquettes determine the charge quantum numbers on the links according to Gauss's law. Taking the time continuum limit, we study the Hamiltonians in the two representations with a truncation to "spin S", where the quantum numbers have an absolute value less or equal to S. In the infinite-S limit the spectra of the two Hamiltonians are identical however for quantum simulations, truncations are needed. The field representation is always gapped for finite spin truncations, while the charge representation preserves the gapped-to-gapless transition even for the smallest spin truncation $S = 1$. We show that the essential singularity in the correlation length for the $S = 1$ truncation is different from that for $S \geq 2$ truncations, where there are real Berezinskii–Kosterlitz–Thouless transitions. Using the ansatz for the scaling of the energy gap, the fidelity susceptibility, and the derivative of the entanglement entropy with respect to the coupling constant, we can extract the location of the infinite-order transitions with high accuracy.

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