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Topological entanglement swapping in spin-ladder systems

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We study how quantum measurements can transform quantum phases in spin ladder systems through an entanglement swapping protocol. Consecutive Bell measurements are performed between the legs of two independent ladders, followed by uniform post-selection of the measurement outcomes. We analyze the resulting phase realized in the unmeasured outer legs.

Our analysis is based on topological indices protected by the D_2=Z_2×Z_2 spin rotational symmetry as well as the lattice translation symmetry. We find that these indices remain unchanged through the measurement process, leading to a nontrivial inheritance rule. Namely, the output state is topological if only one of the ladders is initially topological, while it becomes trivial if both are.

To illustrate this, we explicitly construct post-measurement states using matrix product states (MPS), in which the rung singlet (trivial) and Haldane (SPT) phases are represented by a product of singlets and a valence bond solid state, respectively. The MPS results are consistent with the index characterization and further reveal that the correlation length increases after measurement, indicating enhanced fluctuations.

Finally, we perform a field-theoretical analysis using bosonization. By identifying the locking positions of bosonic fields associated with string order parameters, we determine the resulting phase and confirm consistency with both the index argument and MPS analysis. Interestingly, the post-measurement correlation length is approximately equal to the sum of those before measurement.

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