Detailed phase-diagram analysis of the two-leg ladder by entanglement entropy

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We investigate the ground-state properties of a frustrated spin-1/2 Heisenberg two-leg ladder in the presence of a transverse magnetic field. An anisotropy parameter a, acting on both intra-leg and diagonal exchange interactions, is introduced and varied continuously from zero (the Ising limit) to unity (the full Heisenberg limit) to explore the emergence of different quantum phases. The system is studied using the density matrix renormalization group (DMRG) method implemented within the ITensor framework. By analyzing the von Neumann entanglement entropy and local magnetization, we map out the ground-state phase diagram and identify five distinct phases: three gapped phases, namely a rung-singlet phase, a Haldane phase, and a fully ferromagnetic phase, as well as two gapless phases. The nature of these phases is further characterized through the calculation of spin–spin correlation functions and the extraction of the central charge.

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