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Quantum Phase Transition in the 3-Leg Spin Tube

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Recently some quantum spin systems on tube lattices, so called spin nanotubes, have been synthesized [1,2]. It would be possibly a new type of low-dimensional magnet towards a fruitful application in the nanoscience and technology, like the carbon nanotube. As a first step of theoretical study on the spin nanotube, we investigate the $S = 1/2$ three-leg spin tube, which is the simplest one, using numerical diagonalization, density matrix renormalization group calculation of finite clusters and a finite-size scaling technique.

The spin gap, which is one of the most interesting quantities reflecting the macroscopic quantum effect, was revealed to be open for any finite rung exchange couplings, in contrast to the three-leg spin ladder system which is gapless. In the previous study [3], we also found a quantum phase transition caused by an asymmetric rung interaction. When one of the three rung coupling constants is changed, the spin gap vanishes very rapidly. In the present study, estimating the critical exponent of the spin correlation function and the central charge of the conformal field theory, we reveal that the quantum phase transition belongs to the same universality class as the Berezinskii-Kosterlitz-Thouless transition. The phase diagram in the ground state is also presented by the recently developed level spectroscopy method [4] applied to the low-lying excitations of finite-size systems.

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