Critical Phenomena in the vicinity of the SU(3) symmetric tri-critical point of a spin-1 chain

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I investigate phase transitions and critical phenomena by dealing with a Hamiltonian

$$\widehat{H} \equiv \cos\phi \sum_i \left[\cos\theta\, \widehat{\boldsymbol{S}}_i \cdot \widehat{\boldsymbol{S}}_{i+1} + \sin\theta \left(\widehat{\boldsymbol{S}}_i \cdot \widehat{\boldsymbol{S}}_{i+1}\right)^2\right] + \sin\phi\, \widehat{H}_{\text{trimer}}, \quad (1)$$

with two parameters ϕ and θ. The first term of the right side is the bilinear biquadratic (BLBQ) model, where $\widehat{\boldsymbol{S}}_i$ is the spin operator with $S = 1$ at site i. The second term $\widehat{H}_{\text{trimer}}$ is a Hamiltonian whose ground state is the singlet state of three adjacent spins (trimer state) with the long-range order [1]. We already worked [2] in the case of the SU(3) symmetric case ($\theta = \pi/4$, changing ϕ), and then specified the critical point $(\phi, \theta) = (0.22339\pi, \pi/4)$.

Here, we investigate the phase transitions in the vicinity of this critical point, by expanding into not SU(3) symmetric cases ($\theta \neq \pi/4$). To tackle these problems, we numerically diagonalize the Hamiltonian Eq. (1). We then discuss the numerical results based on the conformal field theory (CFT) and perturbative renormalization group [3]. As a result, we firstly verify that the critical point found in Ref. [2] is the tri-critical point among the Haldane phase, the trimer liquid (TL) phase, and trimer phase (Figure 1). Secondly, we find that the critical phenomena belong to the Berezinskii–Kosterlitz–Thouless (BKT)-like universality class, in the cases of TL–Haldane phase transition and TL–trimer phase transition. This universality class can be described by the CFT with central charge $c = 2$ and scaling dimension $x = 2/3$. Thirdly, as for the Haldane–trimer phase transition, the phase boundary is illustrated with self-dual sine-Gordon model [4] with massive excitation, which means that there occurs the first-ordered phase transition.

Our numerical results can be applied to experiments and quantum simulations of ultracold atomic systems in an optical lattice. Also, these atomic systems are expected to be applied to quantum information engineering. Therefore, our results will be a part of a basic theory in realizing quantum information processing in the future. These results are published on arXiv [5], and under review now.

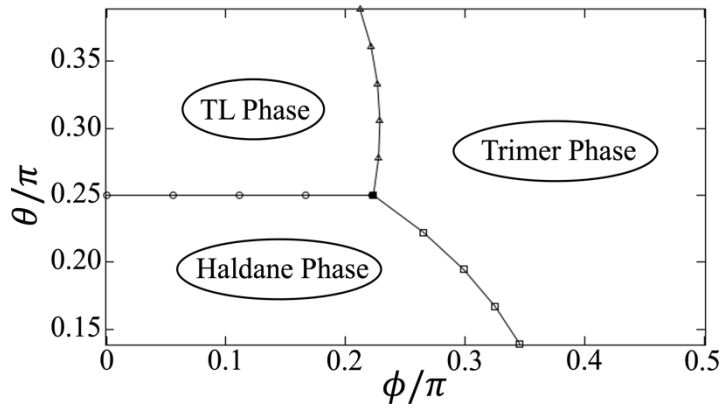

Figure 1: Phase diagram in the vicinity of the SU(3) symmetric tri-critical point.

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