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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
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The present thesis investigates phase transitions and critical phenomena in the random transverse-field Ising models by means of a real-space renormalization-group method. The analysis is intended to examine the presence of infinite-randomness fixed points in the models in a renormalization-group picture. Infinite-randomness fixed points are concerned with peculiar critical phenomena. There have been conjectures of the presence of the fixed points in some cases. The thesis mainly examines such two cases: the two- and three-dimensional Ising spin glasses in transverse fields and the one-dimensional Ising spin glass with the power-law interaction in a transverse field.

The main result of the present thesis is that we find evidence of the presence of infinite-randomness fixed points in the above two cases. However, we do not directly tackle the latter case. Instead, we introduce and analyze the hierarchical model which is expected to show similar critical phenomena. The result leads to a picture that the presence of an infinite-randomness fixed point is not influenced by frustration, which usually produces an essential difference between random ferromagnets and spin glasses.

Our renormalization-group procedure is introduced in the thesis and demonstrated in the transverse-field Ising model, which is the Ising model in a magnetic field traversing the Ising axis. The scheme is a kind of the block-spin transformations. We divide the system into blocks and define appropriate block Hamiltonians. We keep only the lowest-lying energy eigenstates of the block Hamiltonians and ignore the others. The whole Hamiltonian is reconstructed only with the remaining states, and the renormalized Hamiltonian is obtained. We employ a particular partition which results in preserving the form of the Hamiltonian of the transverse-field Ising model. The resulting values of the transition point and the critical exponents α and ν agree with the exact solutions. We generalize this promising method to higher dimensions. In the two-dimensional case, the system is renormalized in two directions: first in the horizontal direction and then in the vertical direction. In the three-dimensional case, the system is renormalized also in the third direction. This generalization also succeeds in yielding accurate results of the critical exponent ν.

One of the main targets in the thesis is the random transverse-field Ising models, where coupling constants J and transverse fields Γ are random variables. In the one-dimensional case, the transition point is analytically calculated under our renormalization-group scheme, and the result agrees with the exact solution. Indefinite growth is numerically found in the variance of the distributions of $\log \Gamma - \log J$. The growth demonstrates the presence of an infinite-randomness fixed point. This observation also leads to the evaluation of the critical exponent ν, which reproduces the exact value.

In two- and three-dimensional cases, we investigate the Ising ferromagnet in a transverse field and the Ising spin glass in a transverse field. A spin glass has ferromagnetic and antiferromagnetic interactions randomly, which generate frustration. In the random ferromagnet in a transverse field in two and three dimensions, the presence of an infinite-randomness fixed point is confirmed by observing the unlimited growth of the variance. In addition, the critical exponent ν is evaluated, and the resulting values are consistent with the previous results estimated by another approach. Also in the Ising spin glass in a transverse field in two and three dimensions, we find evidence of the presence of an infinite-randomness fixed point. We also evaluate ν in the spin glasses, and the resulting values are in good agreement with the corresponding values in the random ferromagnets. This result suggests that the two cases might belong to the same universality class.

The other main target is the one-dimensional Ising spin glass with the power-law interaction in a transverse field. As mentioned above, we investigate the hierarchical model instead, where similar critical phenomena are expected to be found. In the analysis of the corresponding pure model, we demonstrate that our method can be qualitatively reliable if the range of interactions is short. In the analysis of the spin-glass case, the renormalization-group scheme numerically finds the growth of the variance of $\log \Gamma - \log J$ in the vicinity of the estimated transition points. The rapid growth is found if the range of interaction is short. Our method concludes that critical phenomena in the short-range region are governed by an infinite-randomness fixed point. As the range of interaction becomes long, the growth slows down. Above a particular range of interaction, the clear growth is not confirmed, which is consistent with a previous study of the power-law interacting system by means of another approach. This agreement supports the validity of our results. Our method, moreover, shows a characteristic difference in the variance between the disordered-phase side and the ordered-phase side. This finding might be a clue to a further understanding of the power-law systems with randomness.