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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Quasicrystal systems have attracted considerable interest since its discovery. An important feature is that the system does not have translational symmetry but rotational symmetry (e.g. 10-fold and 8-fold) which should yield nontrivial electric properties in the metallic quasicrystals. Recently, interesting low-temperature properties have been observed in the quasicrystal $Au_{51}Al_{34}Yb_{15}$ and its approximant $Au_{51}Al_{34}Yb_{14}$. In the former compound, a quantum critical state is realized, where the specific heat and magnetic susceptibility exhibit power-law behavior with a nontrivial exponent at low temperatures. In contrast, the approximant with a translational symmetry shows conventional heavy fermion behavior. These findings suggest that electron correlations and quasiperiodic structure play a crucial role in stabilizing quantum critical behavior in the quasicrystal. Motivated by these, we study the repulsive Hubbard model on the Penrose lattice.

Firstly, we study the local correlation effect in the Penrose lattice by combining real-space dynamical mean field theory (RDMFT) and continuous-time quantum Monte Carlo (CTQMC) method. Analyzing the local quantities such as double occupancy, renormalization factor and density of states, we clarify that there is a single Mott transition and the quasiparticle weight strongly depends on the site and its geometry in the metallic state close to the Mott transition point. Moreover, we find a temperature dependent distribution of local quantities characteristic of the Penrose lattice. This behavior originates from the local isomorphism, which indicates that the quasiperiodic system holds high geometrical regularity even if there is no translational symmetry. Furthermore, we discuss in detail how the open boundary condition affects low-temperature properties in the system.

Secondly, we develop a numerical method to study effects of short-range intersite correlations. Although spatial correlations in homogeneous systems have been treated by means of extensions of DMFT, it is in general not clear how to treat intersite correlations in inhomogeneous systems. On the other hand, diagrammatic extensions of DMFT are more suitable to treat such systems. Therefore, we extend a dual fermion approach to the real-space description. By using the real-space dual fermion approach, we study how nonlocal correlations affect local quantities and clarify that the critical value of the Mott transition is lowered by taking antiferromagnetic fluctuations into account in a periodic system. Furthermore, the Mott transition point obtained in the homogeneous system is close to the

crossover point obtained by means of QMC. Similar behavior appears in the half-filled Hubbard model on the square lattice under an open boundary condition. Therefore, we conclude that the real-space dual fermion approach can take intersite correlations into account correctly in both homogeneous and inhomogeneous systems. This new method allows us to study intersite electron correlation effects in various other inhomogeneous systems such as cold atoms in a trapping potential, nanosystems, topological insulators and quasiperiodic lattices.

Thirdly, we apply the real-space dual fermion approach to the Penrose-Hubbard model and study how intersite electron correlations affect Mott physics in the quasiperiodic system. Computing the double occupancy at each site, we clarify that the Mott transition point appears at a relatively low Coulomb interaction compared to the crossover point obtained by the RDMFT and lattice QMC method since antiferromagnetic fluctuations lower the density of states at Fermi level sufficiently to form the Mott insulator. This fact is consistent with results obtained by the real-space dual fermion approach in homogeneous lattices. We clarify that the site-dependence of local quantities is enhanced by taking local and short-range correlations into account.

Our study clarifies how local and nonlocal electron correlations affect the local quantities in the quasiperiodic system and offers new powerful method for investigating low temperature properties of strongly correlated electron systems on inhomogeneous lattices.