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Quantum magnetism of SU(6) fermions in an optical lattice

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Ultracold fermions with an enlarged spin symmetry of SU(N) in an optical lattice offer novel possibilities of quantum simulation. Recent theories for an SU(N) Hubbard model predict novel quantum magnetisms, which is conceptually important from the viewpoints of deeper understanding of a strongly correlated quantum many-body system. At the same time, the SU(N) Hubbard model is a computationally difficult problem due to a large number of spin-components. In this paper, by working with ultracold two-electron atoms of ytterbium, we study an SU(N=6) Fermi Hubbard model. By developing an all-optical means of singlet-triplet oscillation (STO) we successfully detect nearest-neighbor spin correlations in various lattice geometries. This enlarged spin symmetry of SU(N) is also a powerful tool to lower the temperature of atoms in an optical lattice, known as a Pomeranchuk cooling effect, confirmed by our antiferromagnetic spin correlation measurements. We extend our study of the SU(N) Hubbard model to a plaquette lattice configuration which has a novel four-body entangled state of SU(4)-singlet as the ground state. Our STO measurements for the SU(6) fermions show the realization of this SU(4)-singlet state. Furthermore, we study the quantum magnetism in an open dissipative system where a controlled two-body dissipation is introduced to the Fermi Hubbard system. The STO signals show the sign-reversal, which indicates the dynamical change from the antiferromagnetic spin correlation in the absence of the dissipation to the ferromagnetic spin correlation in the presence of the dissipation, realizing the negative-temperature quantum magnetism.