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Ultracold ytterbium atoms in an optical lattice

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The species of ytterbium (Yb) is very attractive for the study of a quantum gas because it offers many interesting possibilities. The two valence electrons result in singlet and long-lived triplet states connected by extremely narrow intercombination transitions which are useful for probing and manipulating the gas. The existence of rich varieties of isotopes of five bosons (^{168}Yb, ^{170}Yb, ^{172}Yb, ^{174}Yb, and ^{176}Yb) and two fermions (^{171}Yb and ^{173}Yb) will allow us to study various interesting quantum gases. In this talk, I report our recent experiments on quantum degenerate Yb atoms loaded in an optical lattice. For bosonic isotopes, we successfully create a Mott insulator state, which will open many interesting applications such as an optical lattice quantum computation, optical lattice clock, and quantum simulation of condensed matter physics. We also study the Bose-Fermi mixtures by a photoassociation technique, which reveals the site occupancy both in attractively- and repulsively-interacting mixtures. The photoassociation technique is also applied to measure the double occupancy of the fermions to investigate the role of the interaction in the formation of a Mott insulator state. In addition, the Bloch oscillation for the Fermi-Fermi mixture is studied to reveal the effect of the strong attractive interaction between the two fermions. Furthermore, the BEC in optical lattices is studied in detail by high-resolution laser spectroscopy using the extremely narrow intercombination transition. The future plan of our research includes the work towards optical lattice quantum computing, improved performance of optical lattice clock by spin-squeezing, and exploration of novel quantum phases by exploiting optical tuning of inter-atomic interaction.