【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Exploration of new quantum condensed phase by exploiting orbital and spin degrees of freedom of ultracold atomic gases in an optical lattice

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Research Project Number : 18H05228 Researcher Number : 40226907
Keyword : quantum electronics, cold atom, quantum simulation, optical lattice

【Purpose and Background of the Research】

The researches using the quantum gases have been quite active. Among them, especially interesting is quantum simulation of quantum many-body system described by so called Hubbard model using cold atoms in an optical lattice which is the periodic potentials for atoms (See Fig. 1). The cold atoms in an optical lattice are well described by the Hubbard model which consists of hopping term and on-site interaction term. This Hubbard model is an important one which describes strongly correlated electron system such as itinerant magnetism and unconventional superconductivity.

Under this background, we aim at the significant advancement of research on physical properties of quantum condensed phases by exploiting novel orbital degrees of freedom which can be realized by non-standard optical lattice, and novel spin degrees of freedom of high spin symmetry offered by two-electron atoms.

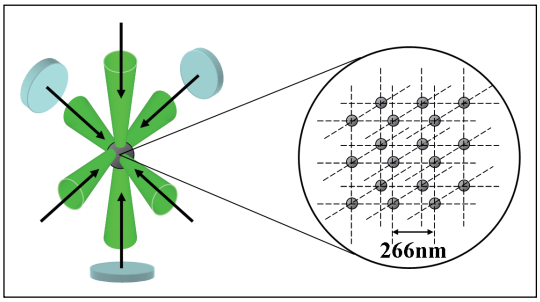

Figure 1 Optical lattice

We mainly exploit ytterbium (Yb) atomic system which possess SU(N=6) symmetry, and carry out unique experiments by constructing a Lieb optical lattice which possess flat-band and two-orbital systems of localized and itinerant characters. In addition, we develop a high-resolution imaging and controlling technique to realize a unique quantum simulator.

【Research Methods】

We plan to perform the following four research topics:

"study of quantum magnetism and superfluidity realized by flat band of optical Lieb lattice", "study of two-orbital system with localized and itinerant characters", "study of SU(N) quantum magnetism", and "New possibilities on unique orbital degrees of freedom".

【Expected Research Achievements and Scientific Significance】

Our research which focuses novel multi-orbital and highly-symmetric spin degrees of freedom is quite unique, only possible by two-electron atomic system which we have been developing. We expect significant advancement of quantum simulation research as well as condensed matter theory and computational science, which will give us an important guideline of material synthesis.

【Publications Relevant to the Project】

・T Tomita, S Nakajima, I Danshita, Y Takasu, and Y Takahashi, "Observation of the Mott insulator to superfluid crossover of a driven-dissipative Bose-Hubbard system", **Sci. Advances,** **3**, 2017, e1701513 (1-8).

・S. Taie, H. Ozawa, T. Ichinose, T. Nishio, S. Nakajima, and Y. Takahashi, "Coherent driving and freezing of bosonic matter wave in an optical Lieb lattice", **Sci. Advances,** **1**, 2015, e1500854(1-6).

【Term of Project】

FY2018-2022

【Budget Allocation】

144,600 Thousand Yen

【Homepage Address and Other Contact Information】

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