【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : New stage of research of novel quantum condensed phase developed by ultimate control and measurement of ytterbium quantum gases in an optical lattice

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Research Area : Quantum Electronics
Keyword : Atomic physics, laser cooling, optical lattice, quantum information

【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. Here, we use the word of “quantum simulation” in the same meaning as Richard Feynman first used the word to represent the simulation of one quantum many-body system by using another quantum many-body system with high controllability. The cold atoms in an optical lattice is well described by the Hubbard model which consists of hopping term and on-site interaction term. Under this background, in this Grant-in-Aid for Scientific Research(S), we aim at the significant advancement of research on physical properties of quantum condensed phases by loading ultracold two-electron atoms the research of which has been led by our group.

【Research Methods】

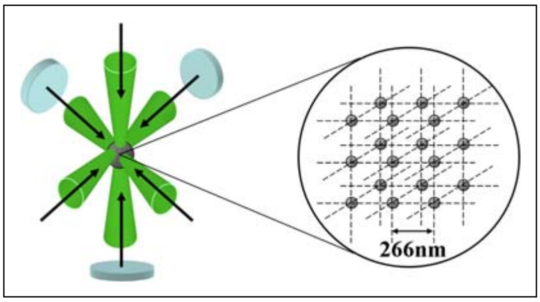

Figure 1 Optical Lattice

We will implement the Hubbard model of ytterbium(Yb) atom quantum gases, and will study “ realization of Fermi superfluidity of Cooper pairs with different electronic orbits and the realization of topological superfluids by introducing the spin-orbit interaction”, “SU(6) quantum magnetism using fermionic isotope of ^{173}Yb”, “Counterflow superfluidity of bose-fermi mixture”, “magnetism induced in a Lieb lattice”, “Anderson-Hubbard model using quantum gas mixture”. In addition, by realizing the ultra-high-resolution in situ imaging, we develop a completely new possibility in the study of the quantum condensed phases.

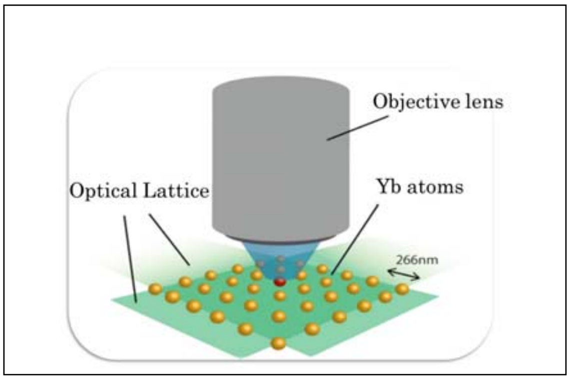

Figure 2 High-Resolution imaging

【Expected Research Achievements and Scientific Significance】

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】

- ”An SU(N=6) Mott insulator of an atomic Fermi gas realized by large-spin Pomeranchuk cooling”, S. Taie, S. Sugawa, R. Yamazaki, and Y. Takahashi, **Nature Physics**, **8**, 825(2012.9.23)
- “Interaction and filling induced quantum phases of dual Mott insulators of bosons and fermions”, S. Sugawa, K. Inaba, S. Taie, R. Yamazaki, M. Yamashita, and Y. Takahashi, **Nature Physics.7**, 642-648(2011.6.26)

【Term of Project】 FY2013-2017

【Budget Allocation】 165,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://yagura.scphys.kyoto-u.ac.jp/