【Grant-in-Aid for Specially Promoted Research】

Science and Engineering (Chemistry)

Title of Project : Addressing Quantum Many-Body Dynamics by Ultrafast Coherent Control with Attosecond Precision

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Research Project Number : 16H06289 Researcher Number : 10241580
Research Area : Physical Chemistry, AMO Physics
Keyword : Ultrafast coherent control, Attosecond, Quantum many-body problem, Quantum simulator

【Purpose and Background of the Research】

The quantum many-body problem governs a variety of physical and chemical functionalities ranging from superconducting and magnetic materials to drug molecules. However, it is impossible to calculate stationary eigenstates of a quantum many-body system with more than 30 particles even with the "post-K" supercomputer planned to be completed by 2020 in Japan. The nonstationary dynamics is even more difficult to calculate.

In this research project, we will develop a novel "ultrafast quantum simulator" that can simulate the quantum many-body dynamics for more than 1000 particles within one nanosecond without approximations.

【Research Methods】

In real bulk solids and liquids, a wave function delocalized over many atoms and molecules is localized extremely fast due to thermal fluctuations. It is thus difficult to observe the dynamics during this localization even with our ultrafast coherent control with attosecond precision.

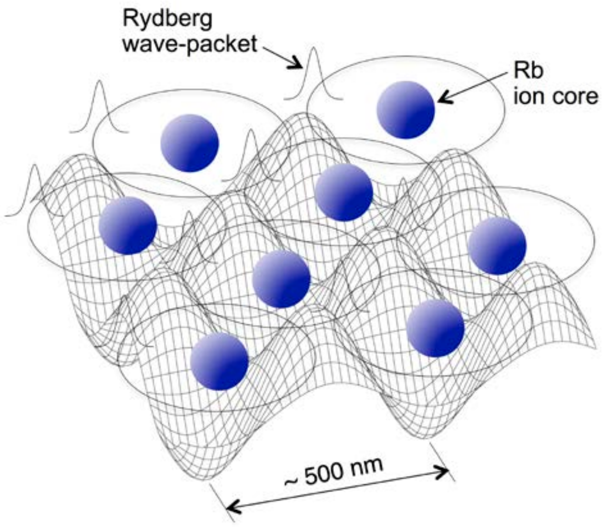
We therefore combine our coherent control with attosecond precision and a strongly-correlated ensemble of ultracold Rb Rydberg atoms (see Fig. 1), which is used as a model system of solids and liquids, to observe and control spatio-temporal evolutions of its many-body wave function. The precise and arbitrary assembly of the atoms is implemented with a new atom-trap technique based on advanced photonics and developed with Hamamatsu Photonics K.K..

【Expected Research Achievements and Scientific Significance】

The ultrafast quantum simulator will simulate the quantum many-body dynamics around the quantum-classical boundary for more than 1000 particles without approximations. Those simulations should allow us to better understand the boundary and the emergence of the physical and chemical functionalities mentioned above.

We anticipate that this ultrafast quantum simulator will develop into a large-scale simulation platform for the design of functional matter such as superconducting and magnetic materials and drug molecules in the future.

Figure 1 Ultrafast quantum simulator
(K. Ohmori, Found. Phys. **44**, 813 (2014))



【Publications Relevant to the Project】

・"Ultrafast Fourier transform with a femtosecond laser driven molecule," K. Hosaka and K. Ohmori *et al.*, Phys. Rev. Lett. **104**, 180501 (2010).
・"Strong-laser-induced quantum interference," H. Goto and K. Ohmori *et al.*, Nature Phys. **7**, 383-385 (2011).
・"All-optical control and visualization of ultrafast two-dimensional atomic motions in a single crystal of bismuth," H. Katsuki and K. Ohmori *et al.*, Nature Commun. **4**, 2801 (2013).

【Term of Project】 FY2016-2020

【Budget Allocation】 426,400 Thousand Yen

【Homepage Address and Other Contact Information】

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