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

Broad Section B

Title of Project : Study for the violation mechanism of fundamental symmetry using the cold atom/molecular interferometer with optical lattice

SAKEMI, Yasuhiro
(The University of Tokyo, Graduate School of Science, Professor))

Research Project Number : 19H05601 Researcher Number : 90251602

Keyword : Fundamental symmetry, EDM, Optical lattice, Cold molecule, Baryon generation

【Purpose and Background of the Research】

In the Standard Model (SM) of elementary particle physics, the fundamental discrete symmetries of charge conjugation (C), parity (P) and time reversal (T) play a significant role, and advance our knowledge about different interactions. Of these, the combined CP symmetry are the least well understood, and they hold valuable clues for unraveling the secrets of nature. All subatomic particles are postulated to possess an intrinsic property known as a permanent electric dipole moment (EDM) due to their spin. The EDM of an atom is a combination of those of each constituent particle and also CP-violating interactions between the particles.

Paramagnetic atoms such as Fr, which have a single valence electron in their outer shell, are sensitive to subtle signals associated with CP violations in the leptonic sector, i.e., the EDM of the electron. Since an electron is a point particle with a non-zero spin, it may possess an intrinsic EDM. However, the electron EDM is predicted to be very small. If the e-EDM was identified, it could be used to indirectly investigate particles with masses of tera electron Volts or higher, which are beyond the reach of even planned high-energy particle colliders. The mass hierarchy of super-symmetry (SUSY) particles could also be studied.

【Research Methods】

The EDM for Fr atoms will be measured by atomic interferometry. In this experiment, we will use quantum optics techniques such as laser cooling and trapping in an optical lattice to achieve longer interaction times.

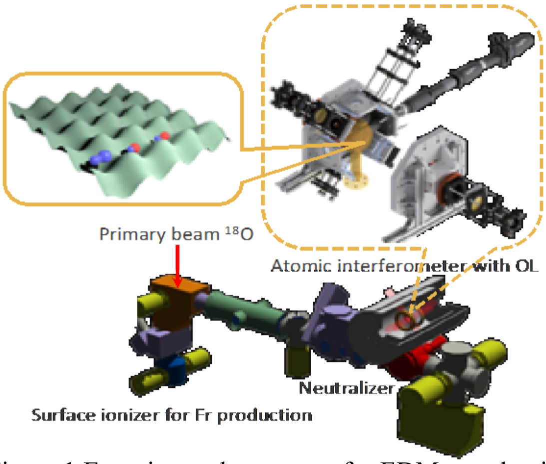

Figure 1 Experimental apparatus for EDM search with optical lattice interferometer

Low-energy Fr ions will be produced by nuclear fusion reactions at RIKEN AVF cyclotron, and will be neutralized, rapidly decelerated and trapped by laser cooling in a magneto-optical trap (MOT). They will then be transferred to an optical lattice equipped with electric field plates (Figure 1). The spin precession of the Fr atoms will be measured using the Ramsey resonance method. We will try to realize the cold polar-molecule: Fr-Sr in the optical lattice to achieve the higher EDM measurement accuracy ~10^{-30}ecm.

【Expected Research Achievements and Scientific Significance】

Although the standard model succeeds in explaining various phenomena, the number of parameters possessed in the theory is unnatural. Then aiming at a more fundamental understanding, it is necessary to pursue the origin of conservation law and fundamental symmetry. In this project, by controlling the atoms/molecules to an extreme quantum state, the quantum correction effects from SUSY is amplified, and ultra-precision measurement technique of the EDM will be established. Furthermore, information on the mass hierarchy of heavy SUSY particles of 10 TeV or more will be obtained.

【Publications Relevant to the Project】

・Correlation Trends in the Hyperfine Structures of ^{210,212}Fr B.K.Sahoo, D.K. Nandy, B.P. Das, and Y. Sakemi
Phys.Rev. A91 (2015) 042507
・Effective multiple sideband generation using an electro-optic modulator for a multiple isotope magneto-optical trap A.Uchiyama, K.Harada, and Y.Sakemi et al. Review of Scientific Instruments 89 (2018) 123111

【Term of Project】 FY2019-2023

【Budget Allocation】 154,200 Thousand Yen

【Homepage Address and Other Contact Information】

https://sites.google.com/cns.s.u-tokyo.ac.jp/fundamental-symmetry-group
sakemi@cns.s.u-tokyo.ac.jp