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Muonium at J-PARC: from fundamental to application

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In this contribution, we will present recent activities at J-PARC by using muonium from the fundamental physics to applied science, especially, on muonium hyperfine structure measurement, muon g-2 and ultra slow muon microscope.
1) Muonium hyperfine structure measurement
Muonium is the bound system of a positive muon and an electron. Among the various spectroscopic measurements, ground state hyperfine structure measurement under external magnetic field is rather attractive, since they provide the information of the internal consistency of QED and the most precise value of muon mass, which is important parameter for muon g-2 expereiment. The latest experiment at Los Alamos obtained the remarkable precision value (120ppb for magnetic moment). However, the main uncertainty came from the luck of statics. In this measurement, quasi DC muon beam was adopted. To overcome above statics limit, use of the intense pulsed muon beam obtained J-PARC MUSE H line is ideal.
2) Muon g-2 measurement with muonium ionization
One of the indications for New Physics (NP) up to now is in the muon anomalous magnetic moment (g-2); there is 3.3σ discrepancy between the SM prediction and measurement by the E821 experiment at BNL with an accuracy of 0.54 ppm. One of the other windows to NP is the muon electric dipole moment (EDM); having the CPT symmetry, the EDM violates CP, which is necessary for the baryon-antibaryon asymmetry while strongly suppressed in SM.
The J-PARC muon g-2/EDM experiment aims to measure the muon g-2 and EDM with an accuracy of 0.1 ppm and a sensitivity of 10-21 e ⊠cm, respectively, to cast light on NP. To achieve the world best accuracy, high intensity beam at J-PARC MUSE and novel technique of the ultra-cold muon beam, which are obtained thermal muonium ionization by intese laser systems. The ultra-cold beam enables muons to be stored and detected in the magnetic field with no electric focusing, resulting in no need to choose the magic momentum of 3.094 GeV/c used for decades and minimizing dimensions of the stored magnetic field and its systematics.
3) Ultra slow muon microscope with muonium ionization
The Ultra Slow Muon Microscope (USMM), under construction at the U-line of the Muon Facility in J-PARC/MLF, will be the first experimental instrumentation in the world possessing two novel muon sources with unique capabilities: an ultra slow muon beam for depth profiling from the surface to the interior of a material, across interfaces, with nanometer resolution near surface, and a muon micro-beam for probing the interior of a material with a resolution of several micrometers at the stopping position. The new spatial imaging method, USMM, is developed for studies of local functional properties and their dynamical aspects near surface and buried interfaces which play key roles in materials and life sciences, such as electron and spin density of states, charge, spin transportation, defects and vacancies in catalytic reaction and so on.

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