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# Laser Spectroscopy of RI atoms stopped in Superfluid Helium

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We are developing a new nuclear laser spectroscopic technique to measure nuclear spins and moments of exotic radioisotopes (RIs). In this technique, we use superfluid helium (He II) as a stopping material of energetic RI beams produced in the projectile-fragment separators such as BigRIPS at RIKEN RI Beam Factory. Stopped RI atoms are subjected to in-situ laser spectroscopy in He II. The characteristic features of atoms in He II, e.g. high stopping efficiency for accelerated ion beams, enables us to measure the nuclear spins and moments of the low yield RIs of various elements. We call this method "OROCHI (Optical RI-atom Observation in Condensed Helium as Ion-catcher)."

So far, we have demonstrated the feasibility of OROCHI to deduce the nuclear spins and moments with stable Rb, Cs, Ag and Au isotopes introduced into He II by laser sputtering of sample materials [1]. In a series of the experiments, we observed the hyperfine (Cs and Rb atoms) and Zeeman (Cs, Rb, Ag and Au atoms) spectra using double resonance spectroscopy. From the hyperfine and Zeeman resonance frequencies, we successfully deduced the nuclear spins and magnetic dipole moments, respectively. Note that we can produce large spin polarizations in Cs (90%), Rb (50%), Ag (85%) and Au atoms (85 %) with optical pumping technique in He II. We are going to observe the hyperfine resonance of stable Ag and Au isotopes in the next experiment.

In parallel to the development without an accelerator, experiments with accelerated beams of $^{85}$Rb and $^{87}$Rb ions (energy: both 66 MeV/u) have been performed at RIKEN. We have observed the Zeeman resonances of introduced Rb isotopes, not only the primary $^{85}$Rb (ground state, $I^{\pi}=5/2^{-}$) but also the radioactive $^{84}$Rb (ground state, $I^{\pi}=2^{-}$) and $^{84m}$Rb (isomer state, $I^{\pi}=6^{-}$) produced by the projectile fragmentation with RIPS separator. The nuclear spin values of $^{84,84m,85}$Rb have been obtained from their Zeeman frequencies. The beam intensity of the introduced Rb isotopes is typically $10^4$ - $10^5$ ions/s in both experiments. The typical yield required for OROCHI is estimated to be $10^3$ ions/s with the present setup. This required yield is dominantly limited by the background counts on the photon detector due to huge stray laser light. We are planning to reduce the required yield to as small as 10 ions/s after the improvement of the setup with reducing the stray laser light.

In this presentation, we will discuss the details, present status and the future prospects of the OROCHI, in particular the highlight data of the recent experiments with ion beams of Rb isotopes.

[1] T. Furukawa et al., Hyp. Int. 196, 191 (2010): T. Furukawa et al., PRL 96 095301(2006).