Measurement of the hyperfine structure of ^{197}Au atom in superfluid helium

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We have developed a new laser spectroscopic technique called Optical Radioisotope atom Observation in Condensed Helium as Ion-catcher (OROCHI) for investigating the structure of exotic nuclei.[1)] In this method, we observe atomic Zeeman splitting (ZMS) and hyperfine splitting (HFS) by using optical pumping and laser-microwave (MW) double resonance spectroscopy in superfluid helium (He II) to derive nuclear spins and electromagnetic moments. The characteristic optical properties of atoms in He II, for example, blue-shifted and considerably broadened absorption spectra, enables us to apply the optical pumping technique to several elements. Recently, we performed a series of on-line experiments by using energetic (up to 66 MeV/u) $^{84\text{-}87}$Rb beams from Riken Projectile-fragment Separator (RIPS), and confirmed the feasibility of the OROCHI method.[2)] Furthermore, we succeeded in producing a large atomic spin polarization (>80 %) of ^{197}Au by means of optical pumping in He II by the laser light of the fourth harmonics of a LD-pumped pulsed Nd:YLF laser (263.5 nm, 3 kHz). Subsequently, we plan to measure the spins and moments of neutron-deficient Au isotopes possessing interesting structures.[3)]

As the first step, we measured the HFS of a stable ^{197}Au atom in an off-line experiment. Fig. 1 shows the experimental apparatus. An open-topped cubic quartz cell in a cryostat is fully filled with He II. The produced Au atoms are introduced into He II by using laser sputtering of the sample material with two pulsed lasers[4)]. We observed the intensity of Laser Induced Fluorescence (LIF) by means of a photomultiplier tube (PMT) through a monochromator for wavelength selection, and performed the laser-MW double resonance spectroscopic measurements (MW power: typically 1 W).

Fig. 2 shows an HFS resonance spectrum of ^{197}Au in He II. In fact, the observed HFS resonance frequencies were shifted because of the Zeeman interaction with the applied magnetic field. Then, we derived the HFS with the zero-magnetic field effect from two HFS resonance frequencies measured by employing opposite polarization directions of the pumping laser, σ^+ and σ^-, respectively, for cancelling the shift due to the Zeeman effect. The deduced HFS in this study was consistent with the literature value of the HFS of ^{197}Au in vacuum (with an accuracy of 0.5 %). The obtained value was slightly different from the literature value as well as the values for ^{133}Cs and ^{85,87}Rb.[1)] The shift is due to the pressure from surrounding helium atoms. However, the slight shift can be neglected in the discussion regarding the structure of nuclei.

The successful HFS measurement indicates the feasibility of future measurements for neutron-deficient nuclei of Au by using the OROCHI method. In the near future, we plan to propose experiments with exotic Au isotopes.

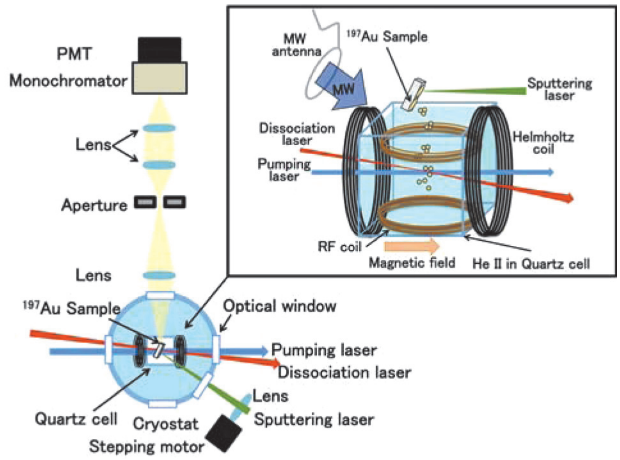

Fig. 1. Experimental apparatus.

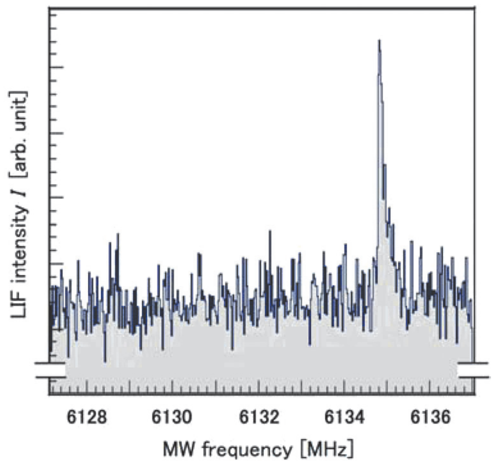

Fig. 2. HFS resonance spectrum of ^{197}Au in He II with σ^+ polarized pumping laser light.

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References

1) T. Furukawa et al.: Hyp. Int. **196**, 191(2010).
2) T. Furukawa et al.: Nucl. Instrum. Meth. B **317**, 590 (2013).
3) H.-J. Kluge and W. Nörtershäuser : Spectrochim. Acta Part B **58**, 1031(2003).
4) T. Furukawa et al. : Phys. Rev. Lett. **96,** 095301 (2006).