Isotope shift measurement of ^{190}W for the study of shape transition in neutron-rich tungsten isotopes

M. Mukai,[*1] Y. Hirayama,[*2] Y. X. Watanabe,[*2] P. Schury,[*2] T. Hashimoto,[*3] S. C. Jeong,[*2] H. Miyatake,[*2] J. Y. Moon,[*3] T. Niwase,[*4] M. Reponen,[*5] M. Rosenbusch,[*6] H. Ueno,[*6] and M. Wada[*2]

In theoretical calculations, it is predicted that tungsten isotopes undergo a shape transition around the neutron number $N = 116$.[1,2] The nuclear shape evolution of tungsten has been investigated up to ^{190}W ($N = 116$) in terms of the properties of the first 2^+, 4^+ excited states[3] and K-isomers[4] via γ-ray spectroscopy using relativistic ions produced in fragmentation reactions. However, owing to its refractory nature, effective research utilizing laser spectroscopy for the study of the nuclear structure evolution has not been conducted beyond stable nuclei. Thus, to investigate the ground state shape evolution with the help of theoretical calculations, we performed isotope shift measurement of ^{190}W via in-gas-cell laser ionization spectroscopy[5–7] at the KEK Isotope Separation System (KISS).[8] We report the preliminary measurement and analysis results.

The KISS facility is an argon-gas-cell-based laser ion source combined with an ISOL, designed to produce otherwise difficult-to-access nuclides by multi-nucleon transfer (MNT) reactions. Neutron-rich tungsten isotopes were produced in MNT reactions using an ^{136}Xe beam (30 particle nA, 10.75 MeV/nucleon) impinging upon a target foil of 10 μm in thickness. The target wheel, divided into eight segments, includes seven pieces of ^{nat}Ir foils and one piece of ^{nat}W foil. These targets were utilized for the efficient production of ^{190}W and ^{186}W, respectively. The target-like fragments were stopped and neutralized in a gas cell pressurized to 75 kPa with purified Ar gas.[8] The neutralized tungsten atoms were transported by gas flow and ionized by element-selective laser resonance ionization at the gas cell exit. The W atoms were resonantly excited by laser irradiation at $\lambda_1 = 260.7165$ nm ($5d^46s^2\ ^5\mathrm{D}_0 \rightarrow J = 1^\circ$),[9] followed by non-resonant excitation to continuum states by laser irradiation at $\lambda_2 = 308$ nm from an XeCl laser. The post-accelerated ions ($E = 20$ keV/q) were mass separated using a dipole magnet with a mass resolving power of $m/\Delta m \sim 900$. After being thermalized in a gas cell cooler-buncher (GCCB),[10] the ions were analyzed in a multi-reflection time-of-flight (MRTOF) mass spectrograph[11] for isobaric identification and efficient ion counting of stable or long-lived tungsten isotopes.

The resonance spectra for each isotope were measured by varying the wavelength of the first-step laser and recording the ion yield. Figure 1 shows the measured resonance spectra of ^{186}W and ^{190}W. The spectra were fitted using a combination of a constant ion count background and a Voigt function. Both isotopes were measured under the same gas cell conditions; therefore, the fitting was performed with common Gaussian and Lorentzian widths. The best-fitted curves are shown in Fig. 1 as red solid lines. We will derive the changes in mean square charge radius from the determined isotope shifts and discuss the shape transition in neutron-rich tungsten isotopes.

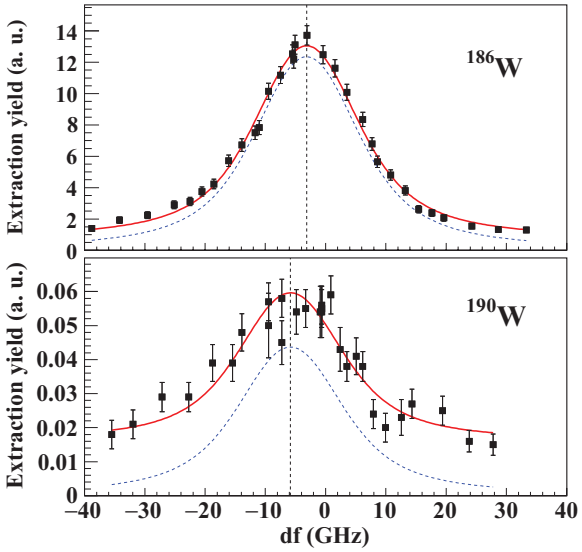

Fig. 1. Resonance spectra of ^{186}W (top) and ^{190}W (bottom). The horizontal axis indicates the detuning frequency of the first step laser from 1149881 GHz. The black points with error bars represent the experimental data. The red solid line represents the best-fitted curve to the experimental data, consisting of a constant background and a Voigt function (blue dotted line). The vertical black dotted lines indicate the positions of the resonance peak determined through fitting.

*1 Department of Applied Energy, Nagoya University
*2 Wako Nuclear Science Center (WNSC), IPNS, KEK
*3 Rare Isotope Development Team, Institute for Basic Science
*4 Department of Physics, Kyushu University
*5 Department of Physics, University of Jyväskylä
*6 RIKEN Nishina Center

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