In-gas-jet laser ionization spectroscopy at KISS

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We developed the KEK Isotope Separation System (KISS)[1)] to study the nuclear properties of neutron-rich isotopes with neutron numbers around $N = 126$. To study the nuclear structures at KISS, we measured the hyperfine structure (HFS) of ^{199}Pt and ^{196,197,198}Ir to determine the magnetic dipole moment and the change in charge radius using the in-gas-cell laser ionization spectroscopy technique.[2)]

The present resolution of $\Gamma = 12$ GHz (FWHM) in the HFS spectra measured by the in-gas-cell laser ionization technique was governed by pressure broadening (typically $\Gamma_p = 10$ GHz in FWHM), Doppler broadening ($\Gamma_D = 1.1$ GHz), and laser bandwidth ($\Gamma_L = 3.4$ GHz). To improve the resolution, the in-gas-jet (collinear) laser ionization technique was successfully established by the KU Leuven group[3)] to obtain precise laser spectroscopy. In the case of in-gas-jet laser ionization technique, Γ_p and Γ_D were drastically reduced to 0.05 and 0.3 GHz owing to the spectroscopy in low-pressure and low-temperature gas jet, respectively. Γ_L can be improved to be 0.1 GHz by applying a narrow-band laser system. Finally, the evaluated resolution will be $\Gamma = 0.35$ GHz in FWHM.

To determine the electromagnetic moments and isotope shifts with higher precision, we have been developing an in-gas-jet laser ionization spectroscopy technique at KISS. We developed and installed a Laval nozzle to obtain a gas jet with uniform velocity distribution,[3)] S-shaped pseudo-radio frequency quadrupole (S-RFQ) for the production and transportation of laser-induced singly charged ions by collinear laser spectroscopy, and a new narrow-band laser system. The designed Mach number of the Laval nozzle is 6.3, and the expected diameter and velocity of the gas jet are approximately 4 mm and 538 m/s, respectively. The laser system consists of a pumping laser of Nd:YAG (EdgeWave, 355 nm, 60 W), narrow-band seed laser (TOPTICA, DLC DL Pro HP), and dye-amplifier (Sirah).

Figure 1 shows the HFS spectra of ^{198}Pt ($I^\pi = 0^+$) and ^{194}Pt ($I^\pi = 0^+$) measured using the in-gas-cell and in-gas-jet laser ionization techniques, respectively. No HFS was observed due to $I^\pi = 0^+$ of both isotopes. Therefore, the widths measured by both techniques are the intrinsic resolutions of the techniques. The widths obtained using the in-gas-cell and in-gas-jet laser ionization techniques were 12.5(5) and 0.6(1) GHz in FWHM, respectively. Thus, we significantly improved the resonance width by applying the in-gas-jet laser ionization technique. The gas-jet velocity was deduced to be 537(5) m/s from the Doppler shift of the HFS spectra of ^{194}Pt measured by the in-gas-jet collinear. The gas-jet velocity was significantly consistent with the designed value of 538 m/s. From the measurements, we confirmed that the experimental equipment used in this study was successful.

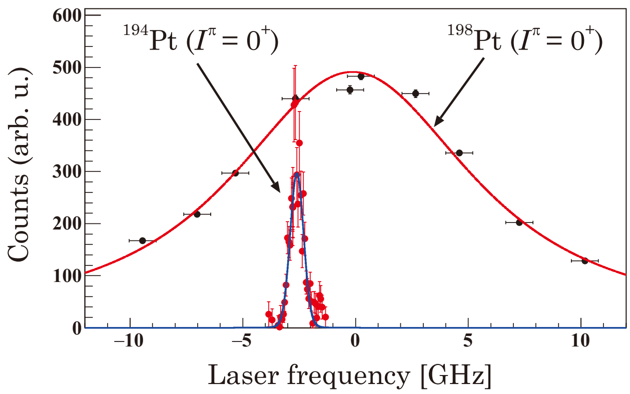

Fig. 1. HFS spectra of ^{198}Pt ($I^\pi = 0^+$) and ^{194}Pt ($I^\pi = 0^+$) measured using the in-gas-cell and in-gas-jet laser ionization techniques, respectively, under the gas cell pressure of 80 kPa (background gas-pressure 50 Pa). For the in-gas-cell laser ionization spectroscopy, the ionization scheme in Ref. 2) was used. We used the combination of $\lambda_1 = 225.000$ nm and $\lambda_2 = 355$ nm for the in-gas-jet laser ionization spectroscopy. Horizontal axis shows the deviation from each λ_1 of the applied ionization schemes. Horizontal uncertainties stemmed from wavemeters were 0.6 and 0.06 GHz for the in-gas-cell and jet spectroscopy, respectively.

However present width of 0.6 GHz is broader than our expected width of 0.35 GHz owing to the Doppler broadening effect. To achieve the expected width, we will optimize the background gas-pressure to create a gas jet with uniform velocity distribution.[3)] Despite the present width of 0.6 GHz, we could measure the electromagnetic moments and isotope shift more precisely. The feasibility study by simulating the ^{199}Pt HFS spectra was performed and reported in this progress report by H. Choi.[4)]

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