Performance of a resonant Schottky pick-up in the commissioning of Rare RI Ring[†]

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The Rare RI Ring is a storage ring dedicated to the measurement of the masses of unstable nuclei to study their nuclear structure and nucleosynthesis[1]. We employ the isochronous mass spectrometry method aiming at a relative mass precision of 10^{-6}. For such high-precision measurement, reaching the isochronous condition in the ring up to a precision of 10^{-6} is essential. As a monitor for the tuning of the isochronous field, we adopt a resonant Schottky pick-up. Figure 1 a) shows the resonant Schottky pick-up installed in the ring. When the beam passes through the resonant Schottky pick-up, an electromagnetic field is induced in the resonant cavity. Figure 1 b) shows the magnetic field induced at the resonance frequency f_{res}. The change of magnetic flux is detected by a pick-up loop inside the cavity. Similar resonant Schottky pick-ups have been used at GSI[2] in Germany and IMP[3] in China. From the results of an offline test, we obtained $f_{\mathrm{res}} = 171.43$ MHz, shunt impedance $R_{\mathrm{sh}} = 161$ kΩ, and unloaded quality factor $Q_0 = 1880$[4].

In June 2015, we commissioned the Rare RI Ring using a Kr beam with an energy of 168 MeV/u. In the commissioning, we successfully observed the signals of a single Kr ion in the Schottky spectrum, as shown in Fig. 2. The upper part of Fig. 2 is a spectrogram of Kr. In this plot, the horizontal and vertical axes are the resonance frequency and time, respectively. The frequency shift is considered to be caused by the momentum change due to the interactions with the residual gas in the ring. The vacuum was still of the order of 10^{-5} Pa without the baking procedure. The lower part of Fig. 2 is a zoomed FFT spectrum in a frame of 32 ms. The frequency width is 224 Hz at FWHM; therefore, the frequency resolution is 1.29×10^{-6}. The measured signal power is $P = -68.9$ dBm, where P is obtained by integrating the peak in the Schottky spectrum after subtracting thermal noise background. For comparison, we calculated the expected signal power P_{cal} by using the following equation which represents the signal power of a single ion with charge q[2]: $P_{\mathrm{cal}} = 1/8(qef)^2 R_{\mathrm{load}}$, where e = elementary charge, f = revolution frequency, and R_{load} is calculated from the equation $R_{\mathrm{load}} = R_{\mathrm{sh}}/Q_0 \times Q_{\mathrm{load}}$. Taking into account the gains of two amplifiers and transmission losses, P_{cal} = -66.1 dBm. The observed Schottky signal power P is in good agreement with the expected P_{cal}. In conclusion the performance of the resonant Schottky pick-up is sufficient in terms of sensitivity and resolution.

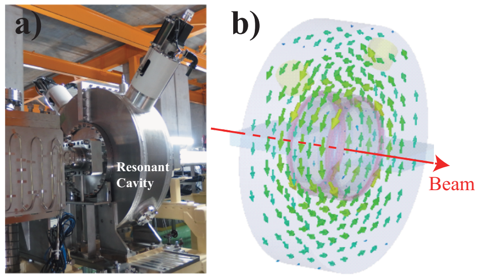

Fig. 1. a) A photograph of the resonant Schottky pick-up. b) Magnetic field in the resonant cavity induced by the beam.

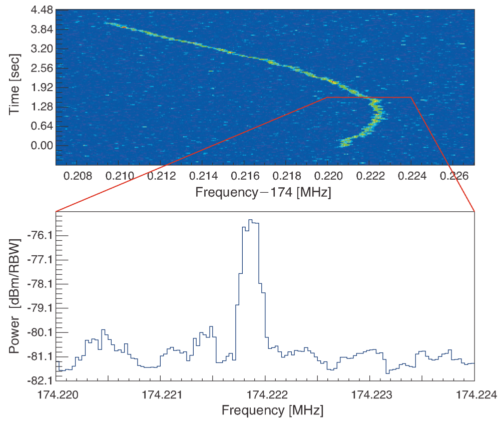

Fig. 2. Upper: A spectrogram of a single ^{78}Kr ion. Lower: A zoomed FFT spectrum in a frame of 32 ms.

References

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† Condensed from the article in Proceedings of HIAT2015, Yokohama, Japan

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