A compact Schottky cavity detector at the Rare-RI Ring

T. Yamaguchi,*1 K. Takiura,*1 K. Nishimuro,*1 G. Hudson-Chang,*2 T. Ohnishi,*3 A. Ozawa,*4 F. Suzaki,*5 T. Uesaka,*3 M. Wakasugi,*6 Y. Yamaguchi,*3 A. Yano*4 and the R3 Collaboration

We report a new Schottky cavity detector, fabricated by Saitama University, that was recently implemented in the Rare-RI Ring facility (R3) and successfully tested with heavy ions via a machine study conducted during a beam time in June 2024.

A Schottky detector is a general beam diagnostic device for ring accelerators used to measure the revolution frequencies of stored ions non-destructively. It consists of a resonant cavity to induce electromagnetic fields with an inherent eigenmode created by the periodic passage of a high-energy beam. The electromagnetic power picked up by a magnetic coupler in the cavity is amplified and processed via a fast Fourier transform to produce a frequency spectrum, namely the Schottky spectrum. Because the Rare-RI Ring is isochronous, an observed peak in the Schottky spectrum correlates directly to the mass-to-charge ratio of the stored ion.

Previously, we developed a pill-box type Schottky detector, similar to the one installed at the storage ring ESR at GSI,[1] where the cavity is separated from the ring vacuum by a ceramic gap. That detector was successfully used for isochronous tuning and evaluations. The design, simulations, offline tests, and results of its commissioning have been published as a series[2] that now extends to this report.

The purpose of the present work is two fold: to increase the single-ion sensitivity and to realize broadband measurements with multiple Schottky detectors. The new cavity is made from copper and has a rectangular box shape with a width of 520 mm, height of 260 mm, and length of 200 mm. It has been installed in the R-MD3 vacuum chamber at R3 next to the previous Schottky detector. Whereas the ceramic gap embedded in the previous detector causes dielectric loss of electromagnetic fields, the present cavity, positioned directly in the vacuum, should provide maximum sensitivity.

From offline tests, a resonant frequency of approximately 500 MHz, loaded Q-factor of 7×10^3, and shut impedance of 3 MΩ are obtained. The coupling β factor between the cavity and subsequent external electronics is adjusted to be around unity. Two tuners can adjust the resonant frequencies by one harmonic of a typical revolution frequency of approximately 3 MHz.

An online beam test was performed with a primary beam of $^{124}Xe^{54+}$ and an energy of 155 MeV/nucleon. Figure 1 illustrates a typical Schottky spectrum, where the horizontal axis indicates frequency, with a span of 1 MHz, and the vertical axis indicates time, ranging from 0 to 200 ms. The clear signal from a single Xe^{54+} ion is visible. The signal amplitude is approaching 16 dBm. Measurements with a time range down to 10 ms were also successful, which indicates an improvement in the sensitivity of more than an order of magnitude compared to that of the original detector. The results suggest that, in addition to beam diagnostics, the present Schottky detector would also enable mass measurements of short-lived single rare ions, providing an alternative to the existing time-of-flight detector system.

A detailed analysis of data from the commissioning experiment is ongoing and will be published in the near future.

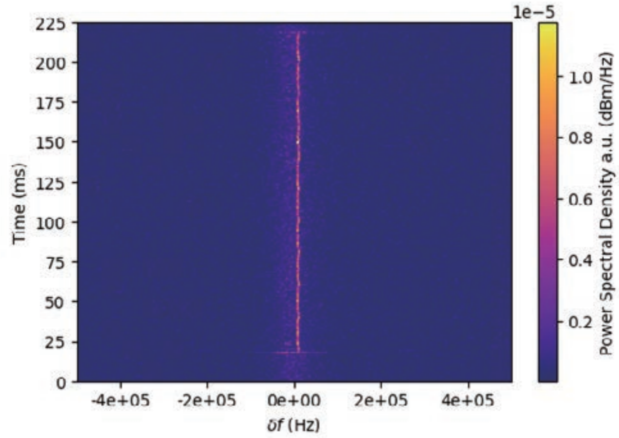

Fig. 1. Typical Schottky spectrum for a single ion of $^{124}Xe^{54+}$ at 155 MeV/nucleon.

References
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*1 Department of Physics, Saitama University
*2 Department of Physics, University of Surrey
*3 RIKEN Nishina Center
*4 Institute of Physics, University of Tsukuba
*5 ASR, Japan Atomic Energy Agency
*6 Institute for Chemical Research, Kyoto University

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