Concept of isomer filtering at the Rare-RI Ring facility

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Nuclear isomers are an intriguing physics case for probing specific states of spin, shape, and shell configurations. Many isomers have been discovered at RIBF via the conventional decay spectroscopy technique. If an isomer beam is available, studies on direct reactions will provide alternative data to extend our knowledges of nuclear interactions.

Heavy-ion storage ring is key to the realization of an isomer beam. At the storage ring ESR at GSI/FAIR, Darmstadt, cooled ions with tiny different mass-to-charge ratios (m/q) have been spatially isolated by a fine-controlled mechanical scraper toward pure isomer beam.[1)] However, the cooling technique inevitably requires a lengthy process which is inapplicable to short-lived nuclei.

The Rare-RI Ring (R3) is dedicated to precise mass measurements of short-lived exotic nuclei. Such nuclei can be injected one-by-one and stored without background. The m/q separation of stored ions can be controlled by changing storage time under a precise isochronous condition. Therefore, R3 could be selectively extracted an isomer of interest from many unwanted species, working as an in-flight filtering mechanism. This study focuses on its feasibility.

Figure 1 shows the concept of isomer beam production at R3. One target ion identified at BigRIPS arrives at the kicker position, where it may be either in the ground or isomeric states, but is injected into R3 at the same timing because the m/q difference is excessively small. In the mass measurement mode, shown at the middle, after a storage time of approximately 1 ms, the relative time difference between the ground and isomeric states increases to distinguish each m/q unambiguously, while still in the same time window of kicker waveform for extraction. Whether the ion is in the ground or isomeric state becomes clear afterwards through the mass value analysis (mass tagging mode).[2)] In the isomer filter mode, shown at the bottom, a sufficiently long storage time of approximately 10–50 ms makes the relative time difference sufficiently to be well separated in a different time window of the kicker waveform. Thus, by adjusting the kicker timing only the isomer can be extracted as a beam.

We evaluated the applicability of the isomer filter mode, the specification of which depends on the excitation energy (E_x) of isomeric state. Note that a typical injection energy of R3 is 180 MeV/nucleon, the revolution time is approximately 360 ns, and the effective flat-top duration of the kicker magnetic field is approximately 100 ns. To extract only the isomer, a storage time of 30 ms is sufficient, implying the relative time difference of 180 ns corresponds to a half revolution. For instance, it is possible to extract ^{79m}Zn ($E_x = 942(10)$ keV,[3)] $T_{1/2} > 200$ ms).

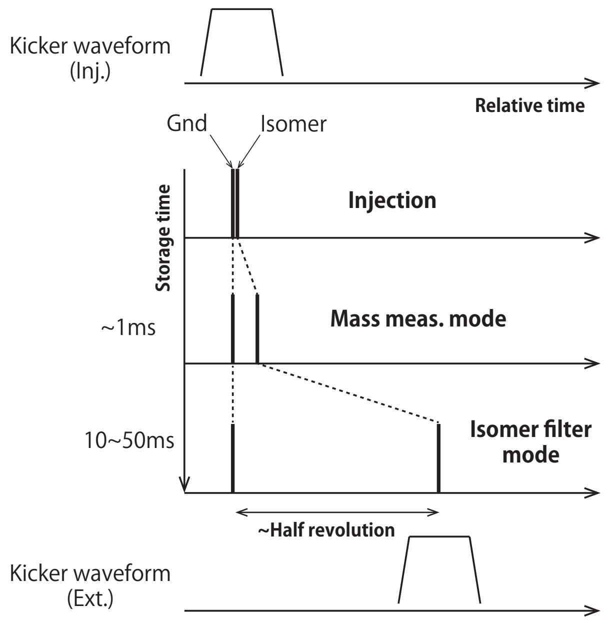

Fig. 1. Concept of isomer beam production. Only an isomer is extracted by increasing storage time.

To further expand the scope, the degree of isochronism (ΔTOF/TOF) should be improved to be 1 ppm for better resolving power, while the current value is 3 ppm. For better extraction performance, the charging method of the kicker must also be renewed, such that the kicker flat-top is approximately 50 ns as well as shorter rise and fall times are available. After such an upgrade is realized, an isomer beam in the $A = 100$ region will be provided in 10 ms storage time for $E_x =$ 1 MeV and in 50 ms storage time for $E_x = 200$ keV.

The first candidate for the isomer physics experiment is total cross section measurements. It can be performed with a beam intensity of 1 cps, which is currently being conducted in R3. Once the beam intensity reaches 10 cps by upgrading the kicker charging method, the isomer beam will be used for investigating the shape of nuclei by giant dipole resonance measurements of super-deformed states and de-excitation γ-ray measurements.

References

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