

Research Facility Development Division Instrumentation Development Group

1. Abstract

This group develops the core-experimental instruments at the RI Beam Factory. Three projects are currently going on. SCRIT is the world's first experimental facility for electron scattering of unstable nuclei and was constructed off the main beamline of RIBF. The first physics result was demonstrated in 2017. After years of developments and improvements, the world's first electron scattering experiment with online-produced radioactive isotopes has been successfully conducted in 2022. An upgrade of the electron beam power that drives RI beam production is currently underway. The Rare-RI Ring is an event-by-event-operated heavy ion storage ring for precise mass measurement of extremely rare exotic nuclei. It is currently accepting applications for experimental proposals and has already conducted PAC-approved experiments and published its first physics results. In 2022, we confirmed that the new capacitors of the kicker-magnet system worked well during long-time test. Thus, the problem in the operation has been solved so far. More improvements are currently underway to achieve more precise mass measurements and stable operation. The compact heavy-ion storage ring RUNBA is an R&D machine for the development of beam recycling techniques for nuclear reaction research on rare elements. This is currently under construction and some of the critical components of the ring are currently undergoing technical development.

All instrumentations are designed to maximize the research potential of the world's most intense RI beams, and dedicated RI Beam Factory equipment makes the experimental challenge possible. The experimental technique and experience accumulated in this group provide opportunities for new experimental challenges and form the basis for the future development of the RIBF.

2. Major Research Subjects

- (1) SCRIT Project (electron scattering off unstable nuclei)
- (2) Rear RI Ring Project (precise mass measurement)
- (3) RUNBA project (Beam recycling techniques)

3. Summary of Research Activity

We are developing beam manipulation techniques to carry out the above projects. These are high-quality slow RI beam generation technology (SCRIT), beam cooling and stopping technology (SCRIT) and beam accumulation technology in a storage ring (Rare RI Ring, RUNBA). The technical know-how accumulated in the project will play a major role in the next generation of RIBF. The current status and future plans for SCRIT and Rare-RI Ring are described in the respective sections.

In 2022, we successfully conducted the world's first electron scattering experiment with online-produced unstable nuclei, which is ^{137}Cs isotopes, through years of the developments and improvements. We are in the process of power upgrading of the electron beam from the RTM, which is the driving for RI production, and expanding the nuclei that can be accessed. The Rare RI Ring is an event-by-event based mass measurement system, designed specifically for extremely low-producing isotopes. We carried out PAC-approved experiments and successfully measured the masses of $^{74,76}\text{Ni}$, ^{122}Rh , $^{123,124}\text{Pd}$ and ^{125}Ag for the first time. To improve mass resolution and efficiency, the first-response kicker system and optical tuning system are being improved. To ensure stable operation, the new capacitors were tested with a kicker magnet system with good results. According to the future plans of Nishina center, a beam re-cycling technique is under development. Beam recycling technology allows the circulation of RI beams to be maintained in a storage ring with a thin internal target until a nuclear reaction occurs. In order to establish beam recirculation, the increase in energy width and emittance needs to be compensated for using a fast feedback system. We have demonstrated the possibility of compensation in an analytical way and found the properties of EDC and ADC devices necessary for compensation. To develop these new technologies, a compact heavy ion storage ring (RUNBA) connected to ISOL (ERIS) is under construction at the SCRIT facility. Under a research cooperation agreement with ICR in Kyoto University, technical development of the main components required for RUNBA *i.e.* the charge breeder, energy dispersion corrector, angular diffusion corrector and internal target system are underway. We developed the prototype devices for EDC and ADC devices, and further improvements are ongoing. Furthermore, we also developed the simulation code based on the analytical model, and evaluated the performance of RUNBA.

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List of Publication & Presentations**Publication****[Review Article]**

M. Wakasugi, Y. Abe, Y. Ito, T. Ohnishi, R. Ogawara, K. Kuze, S. Takagi, K. Tsukada, H. Tongu, Y. Maehara, and Y. Yamaguchi, "Recycled-Unstable-Nuclear Beam Accumulator (RUNBA) for developing beam recycling technique toward the study of nuclear reaction for rare RIs," J. Part. Accl. Soc. Jpn. **19**, 25 (2022).

Presentations**[Domestic Conferences/Workshops]**

小川原亮 (口頭発表), 「RI-RI 反応実験を目的としたビームリサイクル技術開発用蓄積リング (RUNBA) の動作原理」, 日本物理学会 第 77 回年次大会, オンライン, 2022 年 3 月 15-19 日.

小川原亮 (口頭発表), 「ビームリサイクル技術開発を目的とした重イオン蓄積リング RUNBA の動作原理」, 第 19 回日本加速器学会年会, オンライン, 2022 年 10 月 18-21 日.