

High Current Proton Beam Extraction for Neutron Production Using RFT-30 Cyclotron

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1. Introduction

RFT-30 cyclotron has been developed not only for the production of radioisotopes (RIs) and their applications, but also for proton beam utilization to various research fields including material science, bio science, and so on. RFT-30 cyclotron has been regularly operated since 2013, and research on the production of radioisotopes has been performed using this cyclotron. ^{18}F , which is the most widely-used positron emitter, has been produced regularly since 2015. In 2018, mass-production of ^{89}Zr is successfully achieved. In addition, long-term proton irradiation for the production of ^{68}Ge , which is one of the typical generator RIs, was also performed. We are also trying to carry out the test production of $^{64,67}\text{Cu}$, ^{57}Co , and ^{44}Sc .

In addition, proton beam extracted from RFT-30 cyclotron has also been utilized for neutron production and utilization including a soft error rate test of semiconductors, fast neutron measurement, neutron shielding material test, and so on. Now we are trying to extract high current proton beam in order to obtain high-flux neutrons enough for the neutron imaging. Proton beam extraction experiment with the average beam current of 100 μA has been performed.

2. Methods and Results

2.1 Cyclotron Operation for Proton Beam Extraction

Proton Beam extraction experiment was performed using the RFT-30 cyclotron of Korea Atomic Energy Research Institute (KAERI) and its beamline 1-2, of which main purpose is proton and neutron beam user service (Fig. 1).

Negative hydrogen ions were produced from multi-cusp ion source installed on the top part of the RFT-30 cyclotron and injected to the main vacuum chamber. Then they were accelerated up to 30 MeV by the electric field produced by RF system and extracted outside the main vacuum chamber after passing through the carbon stripper foil, which convert negative hydrogen ions (H^-) into protons (H^+) by stealing two electrons from negative hydrogen ions. Extracted proton beam was controlled by X-Y steering magnets and three quadrupole magnets, and finally transported to the end of the beamline. Beam current was measured by a Faraday cup installed at the beamline and a current meter connected to the Faraday cup.

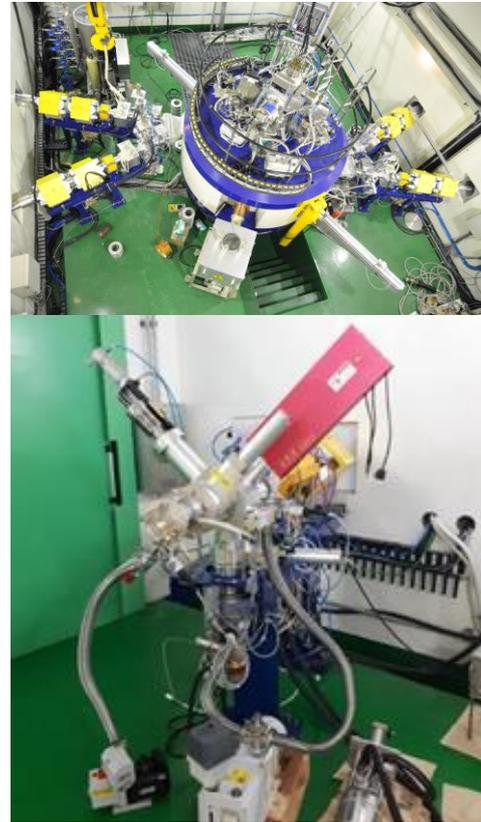


Fig. 1. Photo of RFT-30 cyclotron and the beamline 1-2 for high-current proton beam irradiation and neutron production.

2.2 Measurement of Proton Beam Current

Beam current data were monitored and recorded using a cyclotron control PC. The graph of measured proton beam current is shown in Fig. 2. Because two electrons are stripped from negative hydrogen ions when they pass through the carbon stripper foil, the beam current measured at the carbon stripper foil was as twice as the beam current measured at the Faraday cup.

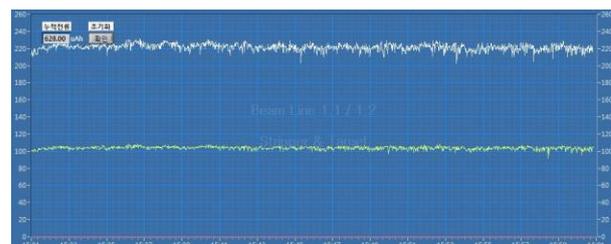


Fig. 2. Beam current graph measured at the carbon stripper foil (white) and the target Faraday cup (yellowish green).

Proton beam with the current of more than 100 μA was stably extracted for more than 8 hours.

2.3 Measurement of Neutrons Produced by the Proton Beam Irradiation

Neutrons were produced by the proton irradiation of a Be target with the thickness of 3.5 mm. Al degrader with the thickness of 2.0 mm was placed in front of the Be target so that the beam energy entering the Be target was ~ 20 MeV and the proton beam would be stopped in the Be target. Proton beam current was 1 μA and RF duty was 20% in order to produce pulsed beam. Fig. 3 shows the neutron pulse measured by a He-3 detector. Pulse width of produced neutrons was 2 ms and Pulse period was 10 ms.

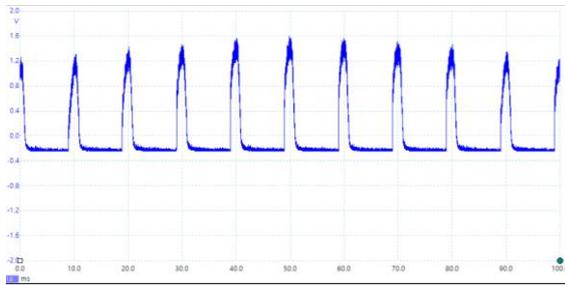


Fig. 3. Neutron pulse measured by a He-3 detector when the proton beam hit the Be target.

3. Conclusions

In order to pursue good neutron image quality and short acquisition time, sufficient neutron flux should be guaranteed. Here we showed that stable long-term (> 8 hours) and high current ($> 100 \mu\text{A}$) proton beam irradiation can be performed using RFT-30 cyclotron. If we irradiate this high current proton beam onto a proper TMRS (Target-Moderator-Reflector-Shielding) system, high neutron flux enough to obtain the neutron image with good quality and short acquisition time can be produced.