Present Status of the CYRIC Accelerator Facility

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The CYRIC has a 930 cyclotron (K=110 MeV) and a HM12 cyclotron. The 930 cyclotron is mainly used in the fields of science and engineering, for the purposes of research, education and university-industry collaboration. In contrast, the HM12 cyclotron is wholly used for the production of radioisotopes for positron emission tomography. Both the cyclotrons were not in operation from March in 2011 to October in 2012, because of the repair work on the accelerator facilities damaged by the Great East Japan Earthquake[1)]. In this report, we describe the operational status and improvements after restarting the joint use in 2012-2013.

The performance of the accelerator facilities is assessed by their availability and reliability. The availability is defined as the ratio of delivered beam time to the scheduled beam time. The reliability is measured according to the average operating time between failures. In 2012, the availability and reliability of the 930 cyclotron were 95.3% and 204 hours, respectively. The reliability was four times worse than that in the usual years. The lower value was due to initial failures occurring for a month after restarting the joint use. In contrast, for the HM12 cyclotron, we attained the availability of 99.9% and set the best record in the history of HM12 operation at CYRIC. The reliability was 155 hours. In 2013, the availability and reliability of the 930 cyclotron were 99.6% and 729 hours, respectively. These values were almost the same as that in the usual years. For the HM12 cyclotron, the availability was 99.8% and the reliability was 167 hours. We could maintain a good performance of the HM12 cyclotron also in 2013.

The 930 cyclotron has provided ion species from hydrogen to argon. Heavy ions delivered for the 930 cyclotron are produced using a 10 GHz electron cyclotron resonance ion source (ECRIS)[2)]. In these few years, improvements in beam intensity and energy and also new ion species were requested from joint use users. To realize the requests, we have introduced the so-called gas mixing method into the 10 GHz ECRIS[3,4]. In this method, a light gas such as helium for neon or lighter and oxygen for argon or heavier is added to ECR plasma. The light gas increases a confinement time of heavier ions. As a result, the production of high charge state ions can be enhanced. This improves the beam intensity.

Table 1 shows the beam intensities extracted from the ECRIS with and without the gas mixing method. We have successfully increased the beam intensities two to six times. Moreover, the beams of $^{84}Kr^{19+}$ and $^{129}Xe^{23+}$ have newly been observed with the intensities higher than 1 eμA, which is an indication of acceleratable beam current by the 930 cyclotron at CYRIC.

The beam energy accelerated by a cyclotron is proportional to the square of the charge state of ions. Thus, the beam energy can also be increased by increasing the charge state of ions. Table 2 shows the beam energies of ions provided for the join use, before and after introducing the gas mixing method. The range of beam energies has been enhanced two to three times for C and Ar ions. The ions of Kr and Xe have newly been provided for the joint use at CYRIC, owing to the gas mixing method.

For further enhancement of beam intensity, beam energy and variety of ions from the 930 cyclotron, we have some improvement plans for ECRIS including introduction of so-called an accel-decel extraction system and of a metallic sample insertion system.

References

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Table 1. Beam intensities from the 10 GHz ECRIS with and without the gas mixing.

Ion species	without gas mixing	with gas mixing
$^{12}C^{4+}$	16 eμA	55 eμA
$^{18}O^{5+}$	60 eμA	125 eμA
$^{40}Ar^{12+}$	1.2 eμA	7 eμA
$^{84}Kr^{19+}$	not observed	3 eμA
$^{129}Xe^{23+}$	not observed	1 eμA

Table 2. Beam energies before and after introducing the gas mixing.

Ion species	Previous	This work
$12C^{4+}$	70 MeV	140 MeV
$^{40}Ar^{12+}$	128 MeV	378 MeV
$^{84}Kr^{19+}$	not provided	451 MeV
$^{129}Xe^{23+}$	not provided	422 MeV