NEGATIVE HYDROGEN ACCELERATION IN THE CYCLONE-30 AT KIRAMS

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Abstract

Cyclone-30 accelerator was installed at the end of 2001. It has operated for production radioisotopes from October 2003 until now. This cyclotron is the first Cyclone-30 with the negative ion source, which can accelerate protons. Beams of H- generated in a multicusp ion source are injected to the inflector at the center of the cyclotron with especial design and accelerated in two 30° Dees powered by the RF system on its fourth harmonic modes. High intensity proton beams are needed for producing radioisotopes. Beams can be extracted by two carbon stripper systems at opposite sides of the cyclotron and transported to 4 target rooms by 4 beam lines. The H^- acceleration with stripping extraction is to minimize activation of the cyclotron and to allow for higher intensities. At present the extraction efficiency of 18~30MeV proton beams is 25~40% where a multicusp source can produce 5mA of negative H^- ions. The maximum extracted beam current is up to about 300uA. The production of the I-123 radiopharmaceutical from a new Xe-124 gas target system is employed. In addition, this cyclotron produces F-18, and Tl-201. This paper will describe the cyclotron facility and the status of the machine since its operation.

INTRODUCTION

The application of nuclear medicine is now well established in many hospitals and nuclear medical centers and there are increasing demands for radioisotopes in Korea. The first cyclotron with negative ion source at Korea Institute of Radiological & Medical Sciences (KIRAMS), Korea Atomic Energy Research Institute (KAERI) in Seoul is based on an IBA built Cyclone-30 cyclotron. This accelerator was installed and tested in 2003. Production radioisotopes have been in routine operation since the end of 2003.

The Cyclone-30 accelerator is a fixed field, fixed frequency cyclotron that accelerators negative ions(H^-) up to 30MeV. The energy of the extracted beam can vary between 15 and 30MeV by positioning of a stripper foil at the radius corresponding to the required energy.

LAYOUT OF THE CYCLOTRON FACILITIES

The cyclotron and target room' arrangements are illustrated in Figure 1. Beams can be extracted by two carbon stripper systems at opposite sides of the cyclotron and transported to 2 solid target room (Ga-67, Tl-201), 1 gas target room (I-123) and 1 liquid target room (F-18) by 4 beam lines. Since 2003, Tl-201, I-123, F-18 have been produced and delivered several hospitals every week in Korea. In near future, we will add to the Ga-67.

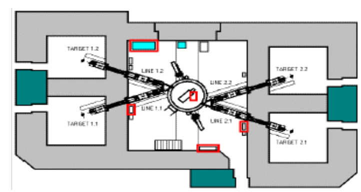

Figure 1: The cyclotron and target room' arrangements.

CYCLOTRON DESCRIPTION AND PARAMETERS

Magnet system

The main magnet assembly consists of the steel yokes and of two coils located symmetrically above and below the median plane. Each coil is made from water-cooled hollow conductor wound to form double-layer pancakes. Both are series connected and powered by a current regulated power supply unit. The magnet structure is a compromise between sector separated and compact cyclotrons. The magnet field is concentrated on four straight sectors with a narrow gap that reduces the electric power necessary to establish the magnet field. The sectors are separated by deep valleys that can accommodate the RF cavities.

- Number of pole sectors : 4
- Pole diameter : 3.0m
- Sector angle : 54 ~ 55 degrees
- Hill field : 1.7 Tesla
- Valley field : 0.12 Tesla
- Extraction radius : 0.5 ~ 1.4m
- DC power in the coil : 7.2kW
- Weight : 50 tons

RF System

The RF system provides an oscillating electric field that pulls the ions through acceleration gaps where they gain energy with each turn, until they reach the desired energy at the extraction radius. The RF system is essentially a high-power amplifier system that amplifies the sine wave of a small quartz oscillator to a large 25 or 40kW. RF power is then fed to two opposite pairs of the dees located inside the cyclotron. This powerful RF acceleration system is locked on a quartz oscillator to ensure perfect frequency stability. Two dees, located in opposite valleys, are brought to 50kV at a frequency of 65~66MHz. When the yoke is lifted, the dees split into a lower and upper part. The dees are made of solid cooper and are conduction cooled. The low capacitance of the dees and the special geometry of the resonators enable this voltage to be reached while with a power dissipation as low as 5kW per cavity. The dees are connected together and to four resonating cavities. Each dee is supported by a vertical stem, which is resonating on a quarter wavelength modes, the stem being itself connected to a resonating cavity. The two 30° dees operate in the fourth harmonic mode with respect to the particle revolution frequency. To prevent any phase mismatch and to simplify the RF system, they are connected at the center. The copper cavities are entirely located in the valley.

Axial Injection System

The axial injection system is a line from the ion generator output to the machine center that includes the following:

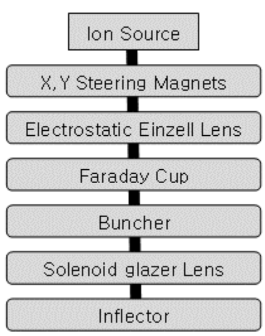

Figure 2: The axial injection system.

The H^- source is of multicusp design based on the method first used by Leung for production negative ions. The injector consists of a multipole volume ion source with three filament cartridges coupled to a triode accelerator. The source is operated with a filament power of 1kW. With a constant arc voltage, raising the filament current will increase the arc current and hence the plasma density. Typically, the H_2 gas flow is less than 15 st.cc/min. Under these conditions, with 9mm diameter extraction hole and source biased at 30kV extracted H^- beam is greater than 2.5mA inside a normalized emittance of 0.65π mm mrad. The accelerator is formed from three electrostatic grids separated by two insulators. The first grid is known as the plasma grid and contains the isolated extraction aperture, which is held at a few volts positive to the surrounding grid during operation. The second grid contains the electron trap in which the co-extracted electrons are removed from the beam. The third grid provides an earth plane for the extracted beam. Steering magnets that allow to move the beam sideways along two X and Y axes perpendicular to one another, and to the injection axis. Electrostatic Einzell Lens, which permits a weak focusing of low energy beams. It simply consists of a polarized section of the axial injection tube. Faraday cup, with a water-cooled cooper plate allowing stopping the beam and measuring the current. Bunchers used in the axial injection line to group the particles in order to prepare and to optimize the amount of the beam that can be accelerated. Solenoid Glazer Lens with a 1000 Gauss magnetic field serves to focus the beam. It provides strong beam focusing. Electrostatic Inflector delivers the beam accelerated down the injection line to the cyclotron's magnetic field. The inflector provides an electrostatic channel that twists and tilts as it guides the ions into the median plane of the machine.

Extraction System

The extraction of the beam is based on H^- ion stripping, when they are crossing a thin carbon foil, with more than 99% efficiency. The stripping foils are mounted on two stripping probes. The strippers are made of carbon foils or carbon fibers to allow partial interception of the beam and extraction of two beams at different energy levels or different current at the same time.

Control System

The Cyclone-30 and related equipment such as beam transport lines and solid target systems are controlled by SIMATIC programmable logic controller (PLC) from Siemens. The PC and the PLC are connected by a network link. The user interface application consists in windows that include both status indicators and commands. The user interface program does not act directly on the machine. When the operator selects a command, the request triggers programs built-in the PLC software. Similarly, the user interface builds its displays from signal processing executed by the PLC.

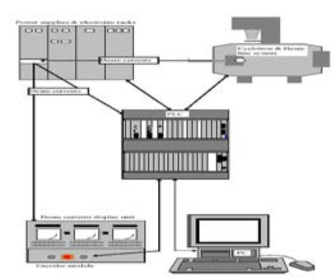

Figure 3: The control system

FACILITIES PERFORMANCES

The performance of the Cyclone-30 cyclotron has been improved during the first year operation of the cyclotron. Personnel have now been fully trained in the operation and some aspects of the machine maintenance. Regular weekly production of Tl-201, I-123 and F-18 radioisotopes made confidence for further activities with respect to the production of other radioisotopes.

REFERENCES

[1] IBA's Cyclone-30 Manual
[2] Leung. K. N, Ehlers. K. W and Bacal. M. ReV. Sci. Instrum, 54, 56 (1983)