THE DESIGN AND CONSTRUCTION OF STRIPPING PROBE SYSTEM FOR CYCIAE-100*

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Abstract

A 100 MeV H^- compact cyclotron is being constructed at China Institute of Atomic Energy (CYCIAE-100). 75 MeV - 100 MeV proton beams with 200 μA beam intensity will be extracted in dual opposite directions by charge exchange stripping devices. Two stripping probes with carbon foils are inserted radially in the opposite direction from the main magnet pole and the obtained two proton beams by charge exchange after stripping foil are transported into the crossing point in a combination magnet center separately under the fixed main magnetic field. Because of the large energy range of the extracted beam, the stripping probe system is the most critical and complicated device in the dual extraction of CYCIAE-100. In order to save the foil changing time, the structure of the foil changing system in the vacuum is adopted. The foil automatic changing machine is outside the magnetism yoke and 12 pieces foil can be changed in one time. The design and fabrication of the stripping probe system has been finished and it is going to the progress of installation and adjusting. The experimental verification on probe rod driving and foil changing system has been finished in 2010. The whole stripping extraction system will be installed in CYCIAE-100 in 2013.

INTRODUCTION

The project of Beijing Radioactivity Ion-beam Facility (BRIF) is being constructed at China Institute of Atomic Energy (CIAE). As a major part of the BRIF project, a 100MeV compact cyclotron (CYCIAE-100) will provide proton beam with an intensity of 200μA～500μA[1]. The extracted proton energy range is 75MeV～100MeV with the carbon foil stripping system in dual opposite directions and 7 target stations for CYCIAE-100 are being built for fundamental and applied research. At present, the construction of buildings for CYCIAE-100 and target stations has been finished and the installation and commissioning of the major components for CYCIAE-100 has been accomplished including the 416t main magnet, coil of 200000 ampere-turns, 200t high precision hydraulic equipment, large-scale high precision magnetic mapper, etc.

The foil automatic changing machine is outside the magnetism yoke and 12 pieces foil can be changed in one time [2]. The design and fabrication of the stripping probe system has been finished and it is going to the progress of installation and adjusting. The experimental verification on probe rod driving and foil changing system has been finished in 2010. The machining process was finished in the beginning of 2011 and the assembly for the whole part was finished in the temporary building in 2012. The design, machining and adjustment of the control system for stripping probe were finished in 2012. After the adjustment, the stripping probe system can work very well. The movement precision is better than 0.1mm, which satisfies the design requirement.

The stripping probe system is the major part of the extraction system for CYCIAE-100, and its function will directly affect the extracted proton beam quality and the operation of CYCIAE-100. Two stripping probes with carbon foil are inserted radially in the opposite directions from the hill gap region and the two proton beams after stripping are transported into the crossing point in a combination magnet center separately under the fixed main magnetic field. The combination magnet is fixed between the adjacent yokes of main magnet in the direction of valley region after the calculation for the stripping system of CYCIAE-100. Figure 1 shows the layout of the stripping probe of CYCIAE-100.

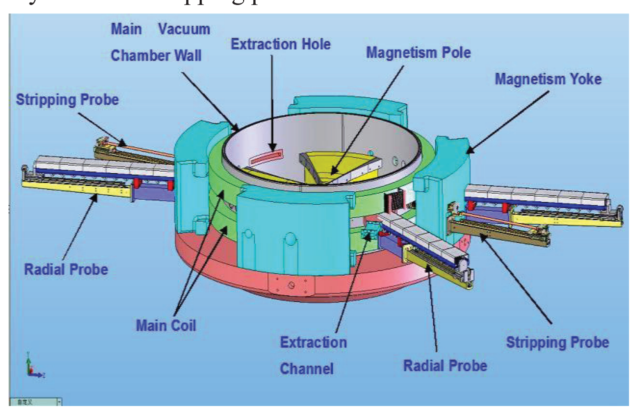

Figure 1: Layout of stripping probe of CYCIAE-100.

THE POSITIONS OF STRIPPING FOIL

The optical trajectories of the extracted beam are studied in details [3]. The positions of the stripping points for different energies are calculated with the code CYCTR. The main magnetic field used to calculate the extraction trajectories is assumed to have mid-plane symmetry for the CYCIAE-100 that is a compact isochronous cyclotron with 4 sectors. The extracted beam energy is chosen by the corresponding static equilibrium orbit, which is calculated with the code CYClOP [4]. The phase space distributions at the stripping foil are obtained from the multi-particle trackings by the code COMA [5]. The extracted beam parameters are given by the extracted optics calculation.

For CYCIAE-100, the outer radius of magnet yoke is 3.08 m and the combination magnet is located inside the yoke (R=2.75 m, θ=100º). Figure 2 shows the position of

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combination magnet and the extracted beam trajectories from the stripping foil to the combination magnet center for different energies. The red lines are the equilibrium orbits, corresponding the energies are from 20 MeV to 100 MeV and the circles R200 and R241 are the outer radii of the pole and the coil. Table1 shows the positions of stripping foil with the extraction energy between 70 MeV and 100 MeV.

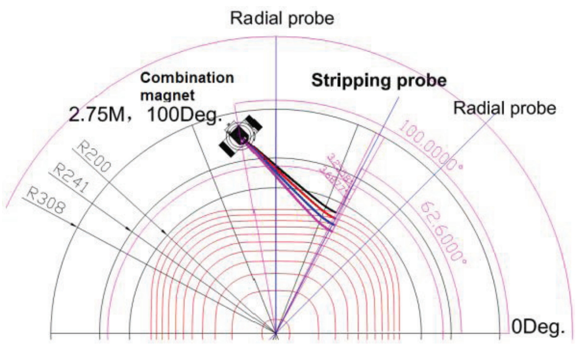

Figure 2: Position of stripping probe and combination magnet.

Table 1: Position of Stripping Foil with Different Extraction Energy with Code CYCTRS

Energy (MeV)	R (m)	θ (Deg.)
100	1.875	59.63
90	1.796	58.96
80	1.708	58.39
70	1.612	57.81

THE DESIGN OF STRIPPING PROBE SYSTEM

The stripping probe system is the most complex device among the individual devices for CYCIAE-100 and auto controlled precision is very high for different movements. In order to save the foil changing time, the structure of the foil changing system in the vacuum is adopted. The foil automatic changing machine is outside the magnetism yoke and 12 pieces foil can be changed in one time. According to the extraction design, the stripping probe can be moved in the radius direction and rotated in the azimuth direction and swing around the fix point. The minimal inserted position of the stripping probes is at R=160cm and the swaying angle is ±5 degree. The radial movement range of stripping probe is about 110 Cm. The precision requirement of the movement orientation for the stripping system is very high. In total 12 carbon foils are installed and can be replaced in the operation. Figure 3 shows the whole stripping probe system. The stripping probe is mainly consisting of 6 parts, i.e., foil exchanger, rotation driving, rotation support, rod motion, bellows and the base. In the process of designing, several schemes have been gradually determined, including the point selection under the vacuum condition, driving mode of the rod rotation and structural design of the foil exchange in the vacuum.

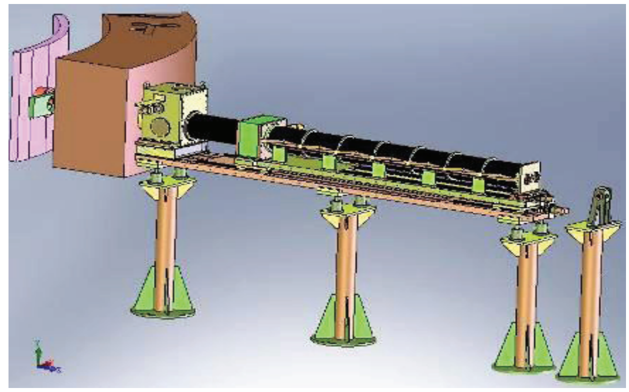

Figure 3: Main structural model of stripping probe.

In order to ensure the reliability, a test has been conducted for target changing before machining the whole device. A simple device is machined for the test. In order to shorten the machining time and reduce the costs, the cooling and driving systems have been omitted. The test has a good result, which indicates the design scheme is practical. The experimental verification on probe rod driving and foil changing system has been finished in 2010. Figure 4 shows the stripping foil exchanger.

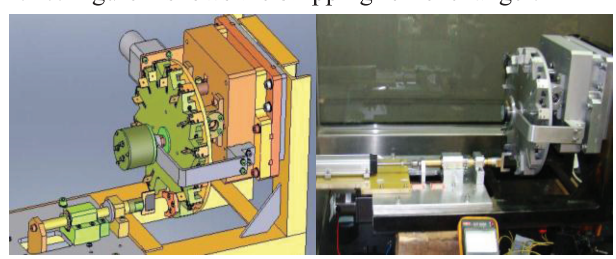

Figure 4: Stripping foil exchanger.

To achieve the required accuracy, the closed control loop is used in the design, as shown in Figure 5. The microprocessor MSP430F149 communicates with control computer through serial port, getting the position setting information from the control interface, and this information is then sent to the control circuit. Position feedback signal, read by a high precision potentiometer, is sent to the control circuit to control the servo motor driver MSE421 together with the position setting information, thus forming the closed control loop. The output signal from microprocessor is a digital signal, and an ADC is needed to change the digital signal to a voltage signal for the amplifiers. The DAC7631, 16bit, serial input, voltage output, guaranteed 15-bit monotonic performance is used in the design and ±2.5V reference voltages are got from the servo motor driver MSE421. The influence of mechanical errors can be eliminated through the closed loop in the design. High precision components are chosen, such as the servo motor with a small inertia, together with a 250:1 gear head. Servo motor driver MSE421 from Mclennan, the driving current, feedback factor can be

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adjusted easily by switch. Taking the fine regulating for example, the total length is 340mm with accuracy better than 0.1mm, error less than 0.03%.

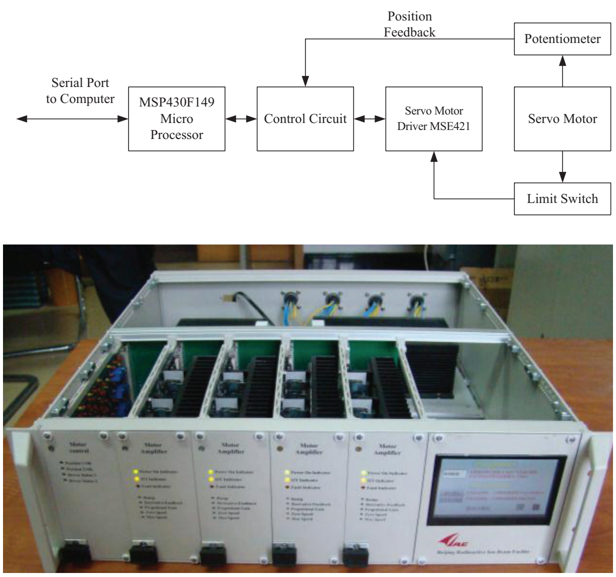

Figure 5: Layout of the Stripping Foil Control System.

The LWH400 position potentiometer from Novotechnik, the linearity is better than ±0.05%, repeatability is better than 0.01mm. In the design, high precision low noise amplifier OPA2227 is chosen, with an offset voltage of 100μV and temperature drift of 0.6μV/oC. In the design of PCB, weak signal should be well protected.

THE CONSTRUCTION AND ASSEMBLY OF STRIPPING PROBE SYSTEM

The machining process of the stripping probe system was finished in the beginning of 2011 and the assembly for the whole part was finished in the temporary building in 2012. The design, machining and adjustment of the control system for stripping probe were finished in 2012 too. After the adjustment, the stripping probe system can work very well. The movement precision is better than 0.1mm, which satisfies the design requirement. Figure 6 shows the whole stripping probe system stalled in the temporary building.

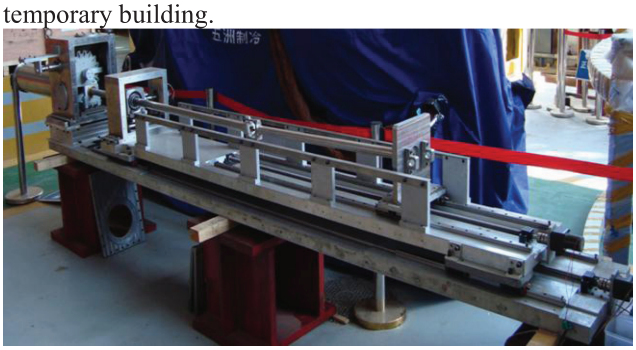

Figure 6: The stripping probe system installed in temporary building.

SUMMARY

For CYCIAE-100, 75 MeV - 100 MeV proton beams with 200 μA beam intensity will be extracted in dual opposite direction by charge exchange stripping devices. The CYCIAE-100MeV extraction system use two sets of stripping probes and can extract the beam from the symmetry direction to the 7 target stations. The stripping probe system is the most complex device among the individual devices and it includes the following parts: foil exchanger, rotation driving, rotation support, rod motion, bellows the base, and corresponding vacuum and control systems. The auto controlled precision is very high for different movements.

The foil changing system in the vacuum is adopted and 12 pieces foil can be changed in one time. The stripping foil thickness of 150 - 180 μg/cm^2 is adopted for CYCIAE-100 [6]. The design and the fabrication of the whole stripping system have been finished. The experimental verification on probe rod driving and foil changing system has been finished. The whole stripping extraction system will be installed in CYCIAE-100 in 2013. After the adjustment, the stripping probe system can work very well. The movement precision is better than 0.1mm and the precision of azimuthal movement is better than 0.01 degree, which satisfies the design requirement.

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