THE ASSEMBLY AND ADJUSTMENT OF THE SECOND STRIPPING PROBE SYSTEM FOR CYCIAE-100

Shizhong An[1], Lipeng Wen, Jiansheng Xing, Genshou Liu, Lei Cao, Yang Wang, Xiaoliang Fu, Yinlong Lv, Xiaotong Lu, Yiwang Zhang, Zhenguo Li, Gaofeng Pan, Tianjue Zhang,
China Institute of Atomic Energy, Beijing, 102413, P.R. China

Abstract

A 100 MeV H- compact cyclotron is under construction at China Institute of Atomic Energy (CYCIAE-100). The proton beams ranging from 75 MeV - 100 MeV with 200 μA beam intensity will be extracted in dual opposite direction by charge exchange stripping devices. The stripping probe system is the key part of extraction system for CYCIAE-100. The first stripping extraction system was installed in 2014 and it has satisfied all kinds of requirements for the proton beam extraction. The first 100MeV proton beam was got on July 4, 2014 and the beam current was stably maintained at above 25 μA for about 9 hours on July 25, 2014. The first RIB with ISOL system driven by 100 MeV proton beam was generated in 2015. The second stripping system was installed in 2015 after the assembly and adjustment. The beam commissioning based on the second stripping system will be finished and the extracted proton beam parameters will be measured in detail in this year.

INTRODUCTION

A 100 MeV H- compact cyclotron is under constructed in China Institute of Atomic Energy (CYCIAE-100) [1-3]. The machine is selected as the driving accelerator for the Beijing Radioactive Ion-beam Facility (BRIF). 75 MeV - 100 MeV proton beams with 200 μA - 500 μA beam intensity will be extracted in dual opposite direction by charge exchange stripping devices [3]. In total 7 target stations will be built based on CYCIAE-100 for the fundamental and applied researches. For CYCIAE-100, the diameter of main magnet is 6160mm, corresponding to 4000mm for the magnet pole. The magnet is 2820mm high with a total weight of 435 tons. The quality factor of the two rf resonators reach 9500, which is highest value among the existing compact cyclotrons in the world. Two identical 100 kW RF amplifiers have been adopted to drive two cavities independently. In order to reduce the beam losses caused by residual gas stripping process, a high-speed cryo-panel system is utilized to raise the vacuum to $5*10^{-8}$ torr level. By the end of 2013, all the sub-systems of the cyclotron are installed and assembled on site. The first stripping extraction system was installed in 2014 and it has satisfied all kinds of requirements for the proton beam extraction. The first 100MeV proton beam was got on July 4, 2014 [4] and the beam current was stably maintained at above 25 μA for about 9 hours on July 25, 2014. The first RIB with ISOL system driven by 100 MeV proton beam was generated in 2015. The operation stability have been improved and beam current have been increased gradually. 720 μA beam was got on the internal target at the beginning of this year. The effort for mA beam is continuing and 1135 μA beam was got on the internal target in June of this year [5]. Figure1 is the fresh photo of the cyclotron and its beam line.

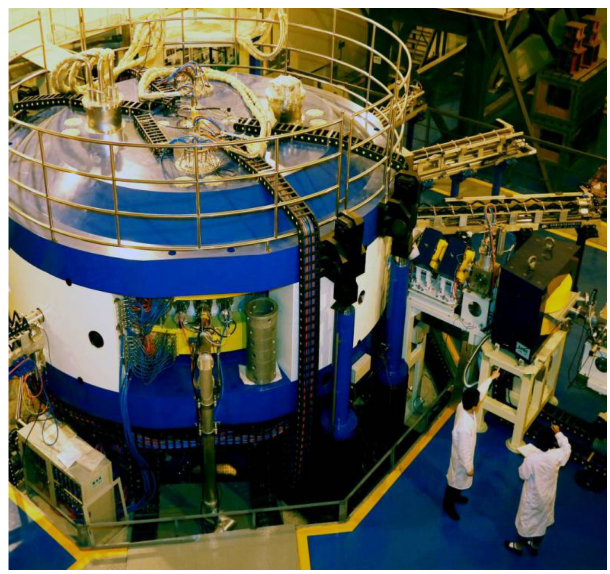

Figure 1: The 100 MeV compact cyclotron.

The second stripping system was installed in 2015 after the assembly and adjustment. After the debugging, 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. The beam commissioning based on the second stripping system will be finished and the extracted proton beam parameters will be measured in detail in this year.

THE DESIGN AND CONSTRUCTION OF STRIPPING PROBE SYSTEM

The stripping probe system is the key part of extraction system for CYCIAE-100. Two stripping probes with carbon foil 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

[1] szan@ciae.ac.cn

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transported into the crossing point in a combination magnet center separately under the fixed main magnetic field [6]. The combination magnet is fixed between the adjacent yokes of main magnet in the direction of valley region. 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. 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 stripping foil thickness of 150 - 180 μg/cm^2 is adopted for CYCIAE-100.

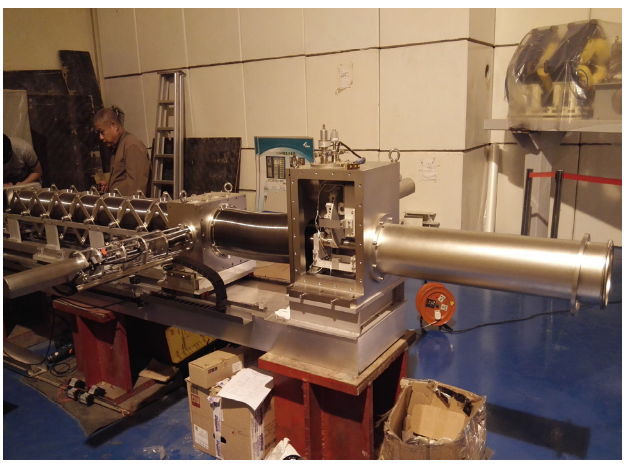

Figure 2: Main structural model of stripping probe.

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. 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. The length of stripping probe is 4752mm and the total weight is about 600 kg. Figure 2 shows the whole second stripping probe system and Figure 3 shows the stripping foil exchanger device.

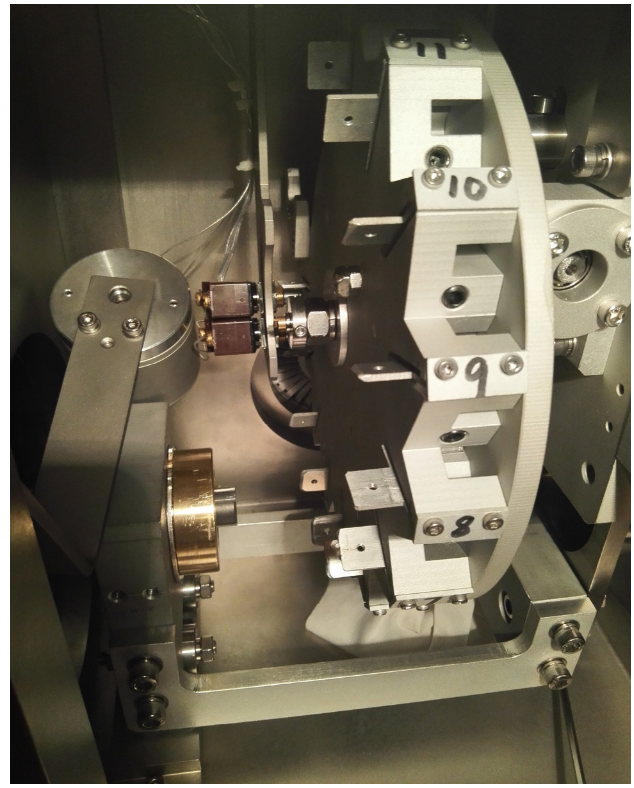

Figure 3: Stripping foil exchanger with 12 pieces foils.

To achieve the required accuracy, the closed control loop is used in the design, as shown in Figure 4. 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, 16-bit, 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 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%. 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 100 μV and temperature drift of 0.6 μV/oC. In the design of PCB, weak signal should be well protected.

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Siemens PLC STEP7 development environment is used in the second stripping probe system to control the main accurate positioning, interlock in the riot shaft closed motor and stripping of movement target four road safety chain effect. Compared with the analog comparator control, PLC with the digital signal control can reduce the errors of the control volume and has a more precise input and feedback. Motor swing caused by using analog circuit can be controlled effectively with PLC control system and connection circuit becomes simple. Logic control is more intuitive and the movement of stripping probes is easier to debug. After the adjustment for the second stripping probe system, the first one will be used PLC control too.

Figure 4: Layout of the stripping foil control system.

THE ASSEMBLY AND ADJUSTMENT OF THE SECOND STRIPPING PROBE SYSTEM

The machining process of the second stripping probe system was finished in 2015 and the assembly and adjustment was finished in 2015 and was installed afterwards. 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 5 shows the installed second stripping probe system. Figure 6 shows the control interface of the second stripping probe.

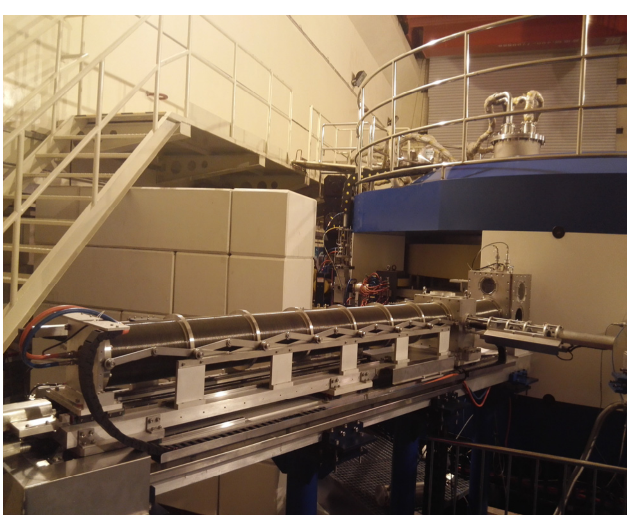

Figure 5: The installed second stripping probe system.

Figure 6: The control interface of the stripping probe.

SUMMARY

For CYCIAE-100, the second stripping system was installed in 2015. More design details for the second system are improved due to the experiment of the first one. The PLC digital control is used for the second system and it is much easier to debug and control the whole system. After the debugging, 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. The beam commissioning based on the second stripping system will be finished and the extracted proton beam parameters will be measured in detail in this year.

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