Collimator for Beam Position Measurement and beam collimation for Cyclotron

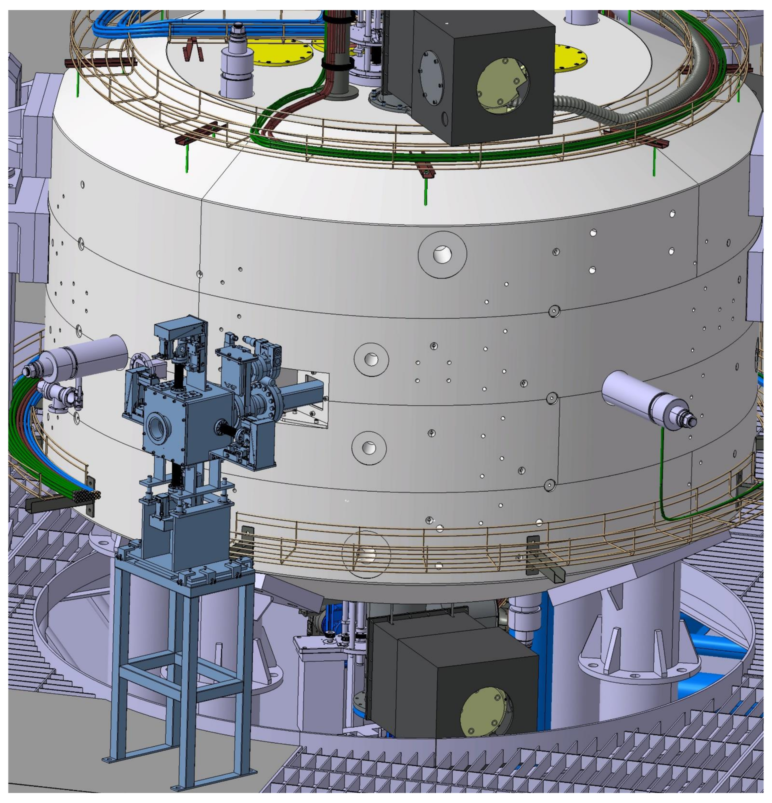
Lexing Hu [a, b], Yuntao Song [a], Kaizhong Ding [a], Kai Yao [c], Yucheng Wu [c], Juniun Li [a], Qingxi Yang [a], Yonghua Chen [c]
[a] Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, Anhui, China
[b] University of Science and Technology of China, Hefei, Anhui, China
[c] Hefei CAS Ion Medical and Technical Devices Co., Ltd, Hefei, Anhui, China

ABSTRACT :

In order to restrict the beam dispersion and diffusion at the extraction area of the cyclotron and to detect abnormal beam loss, a beam collimator system has been designed to collimate the beam and to measure its transverse positions. The collimator system is composed of a vacuum cavity, two pairs of beam targets, a set of driving and supporting mechanism, and a measurement and control unit. The beam target with the size determined by the diameter of the beam pipe, the particle energy and beam intensity, will generate current signal during particle deposition. Each pair of beam targets has bilateral blocks which forms a slit in either horizontal or vertical direction. Servo motor and screw rod are used so that the target can reciprocate with the repeatability of less than 0.1mm. The measurement and control system based on LabVIEW can realize the motion control and current measurement of the targets and then calculate the beam transverse positions.

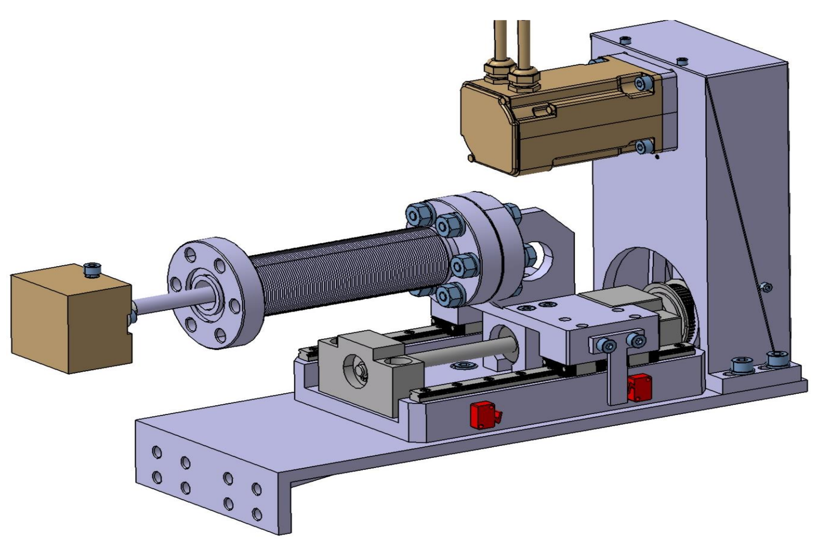
Introduction

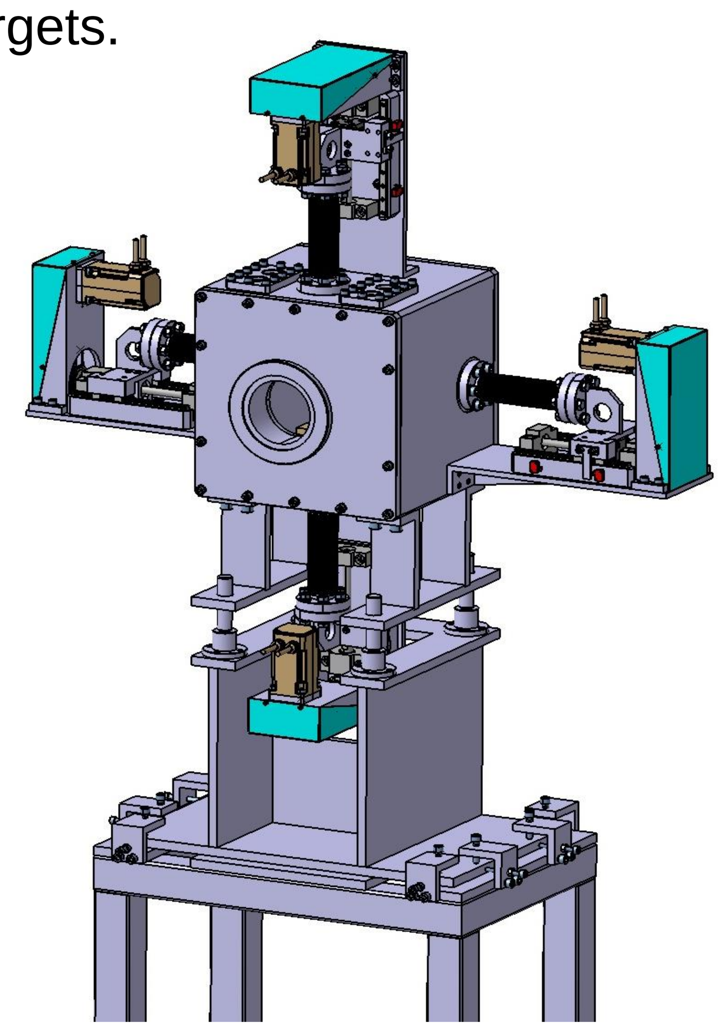
The project of superconducting cyclotron for proton therapy SC200 is under development at HFCIM (Hefei, China) and JINR, which will be able to accelerate protons to the energy 200 MeV with the maximum beam current of 400 nA.
The collimator has been developed to reduce beam diffusion at the extraction area of the cyclotron and to detect abnormal beam loss, and then to measure the beam positions in both horizontal and vertical directions.



Structural Design

The collimator system is composed of a support gantry, servo drive unit, a vacuum chamber, bellows, and tungsten targets.

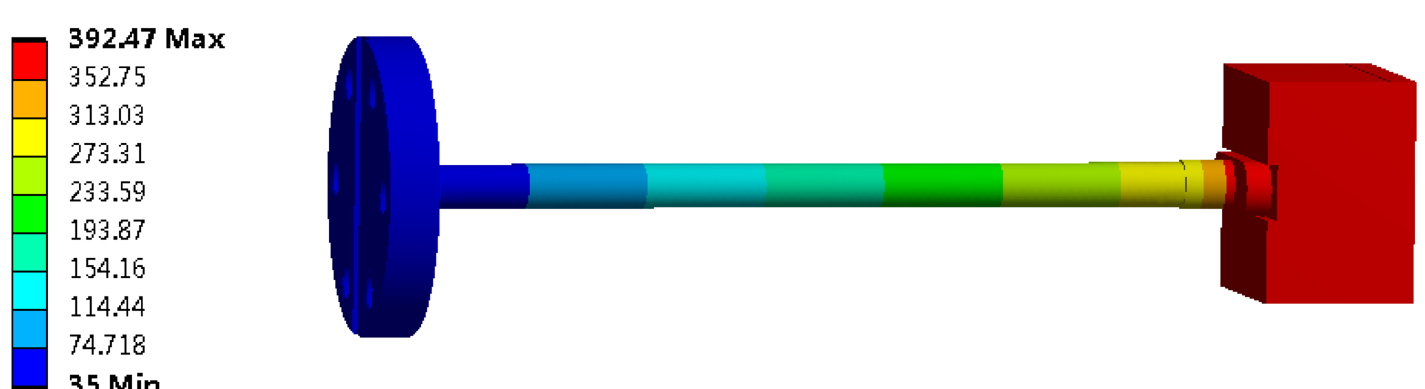




Characteristics:
- Compact;
- Remote operation;
- High measurement accuracy;
- High motion accuracy;
- High heat dissipation performance.

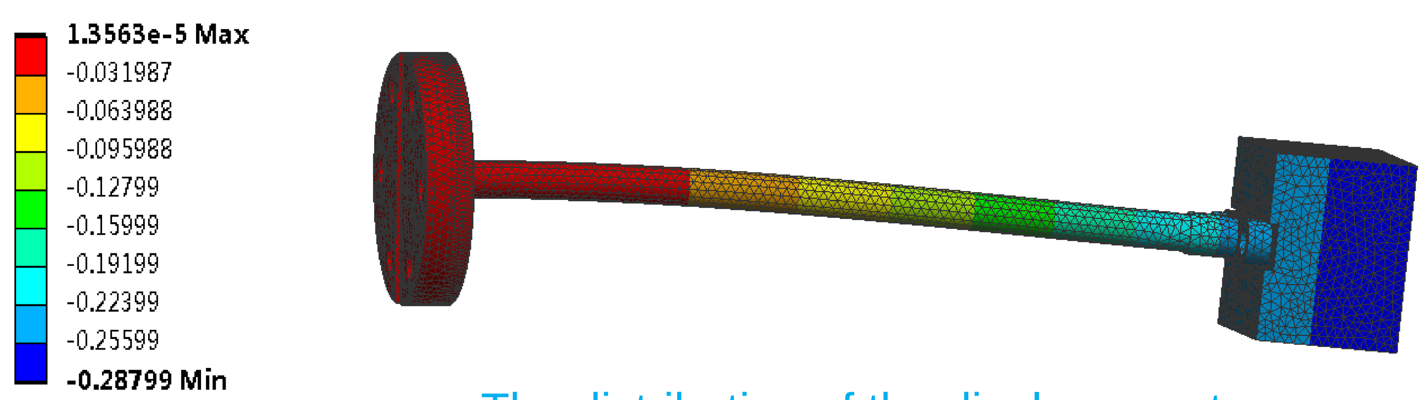
Thermal Structural Coupling Analysis

Thermal structural coupling analysis has been performed to provide guidance for the structural design and material selection of the collimator system.



The distribution of the temperature field

The material of the insulating block was replaced with alumina ceramic from peek to increase heat transfer capacity, and then to deduce the temperature of the target.



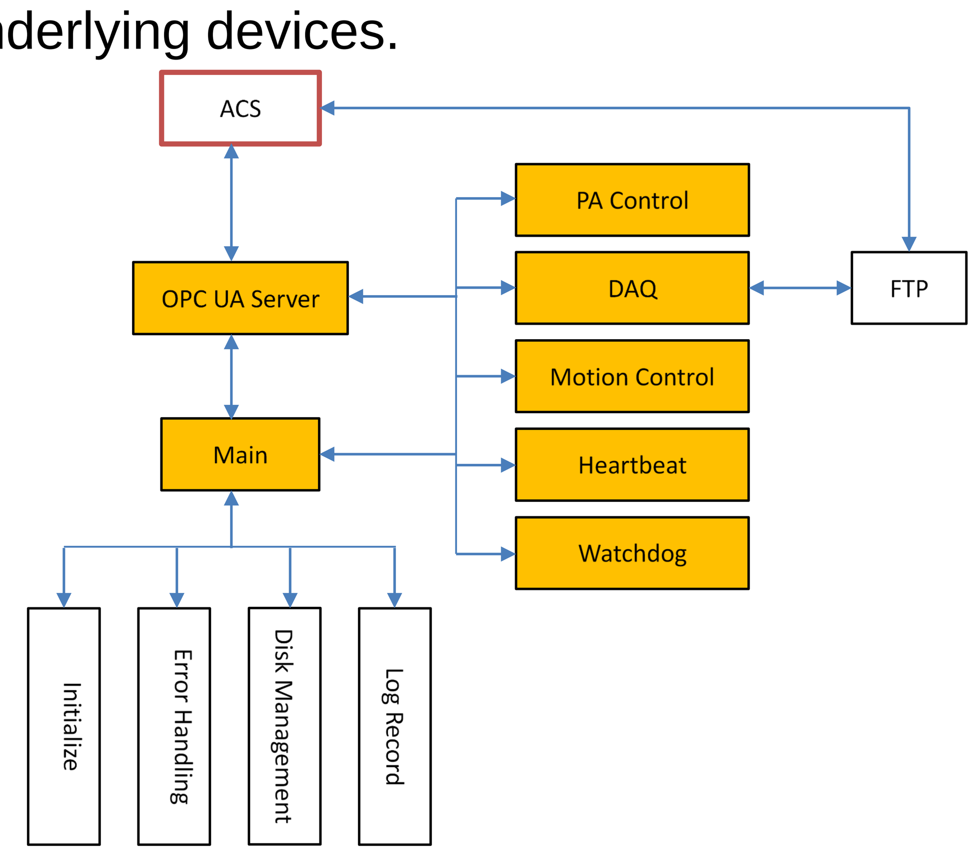
The distribution of the displacement

The maximum deformation is 0.288mm, and it can be eliminated by applying pre-stress.

Control System

The collimator control system is developed based on a distributed architecture, and the NI CompactRIO real-time controller is used as the server computer to realize the integrated control of the underlying devices.

Hardware architecture

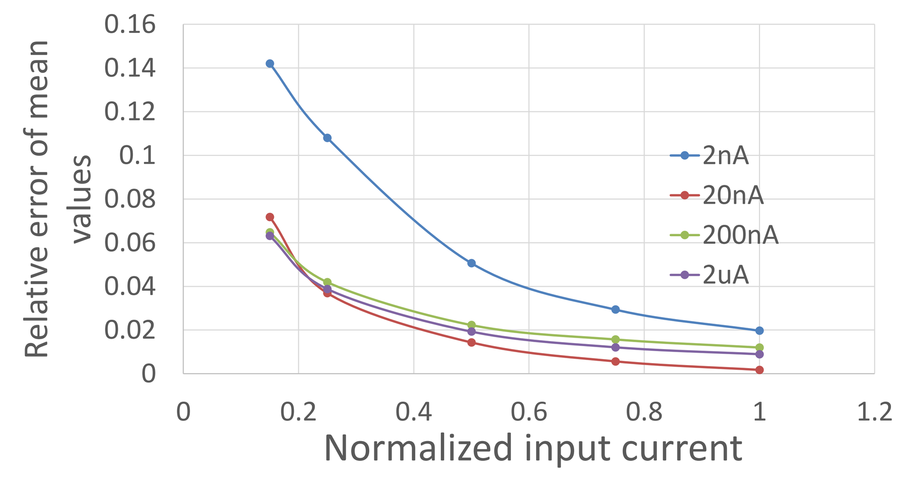


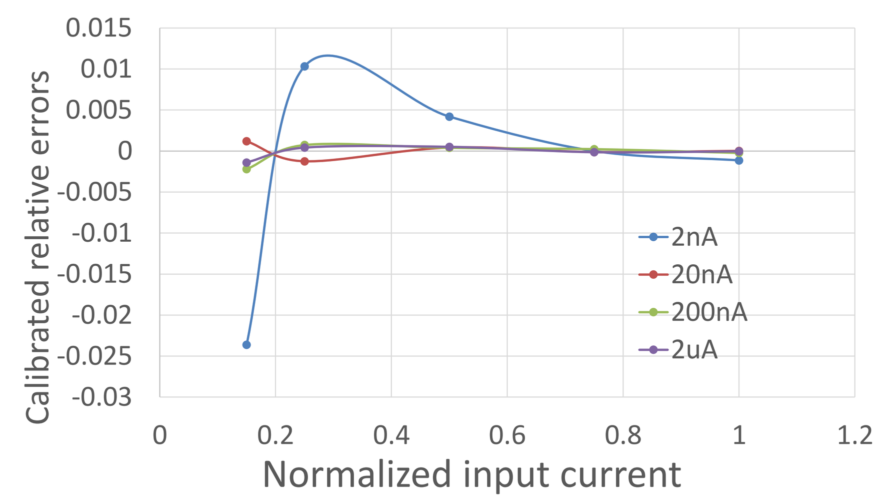
Software architecture

Four Keithley 6485 picoammeters are adopted to realize accurate measurement of the beam current, and four servo motors with EtherCAT communication port are equipped to achieve high precision motion control.

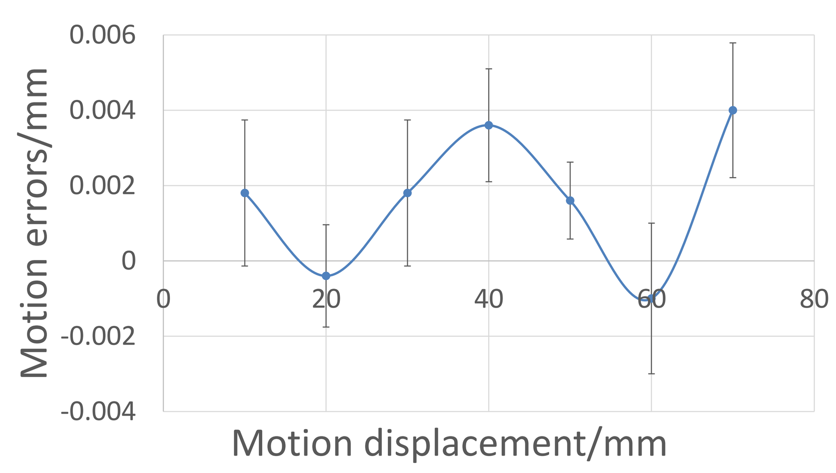
Testing and Calibration

Measurement accuracy: The insulation between the targets, the insulation to the ground must be greater than 100MΩ. The background noise should be measured. And the measurement accuracy can be calibrated by a high precision current source.





Motion accuracy: The repetitive positioning accuracy of the transmission unit has also been measured.



Test Results:
Insulation resistance between targets>2000MΩ;
Ground insulation resistance>1500MΩ;
Background noise<10^{-11}nA;
Measurement accuracy:±(1+5%rdg)nA;
Repetitive positioning accuracy:0.006mm.

Conclusions

The beam collimation system has been machined and assembled, and its key performance have also been tested, which have been proven to meet design requirements.

Item	Requirements	Results
Ground insulation resistance	100MΩ	2000MΩ
measurement accuracy	±(1+5%rdg)nA	±(1+5%rdg)nA
repetitive positioning accuracy	0.1mm	0.006mm

This work is supported in part by grants 1604b0602005 and 1503062029.