The Construction of the Inner Ion Source for SC200 Compact Superconducting Cyclotron

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Abstract The SC200 compact superconducting cyclotron is supposed to contribute on the proton therapy under the collaboration of the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) and the Joint Institute for Nuclear Research (JINR). The energy of cyclotron is 200Mev with the maximum proton beam current of ~400nA from the cyclotron outlet. The hot cathode Penning Ionization Gauge (PIG) type proton source will be used in the cyclotron. The purpose of the article is to introduce the inner ion source from the design, simulation and dedicated test. Through the analysis and bench experiment results, the ion source shows a good performance which can provide enough protons to reach the cyclotron beam current. The lifetime of filament can reach more than 50 hours and the source operates at least 1h continuously. A layer-to-layer intensity modulation of the scanned beam is realized with the filament current and the arc voltage that need to vary the extracted beam current between maximum and zero. For the research the request for higher flexibility, in particular for faster beam intensity modulation. In order to explore capabilities of the machine for such research mode, a real-time control system of the arc power supply for ion source has been developed and will also be presented.

Introduction

Hot cathode Penning inner ion source is applied in 200 MeV superconducting cyclotron accelerator proton therapy system to produce accelerated proton. The penning ion source produces plasma by heating cathode which will release thermo electron. The proton of plasma will be extracted and then be accelerated to form proton beam [1]. Since the parameters of structure were confirmed one year ago, we have finished the whole process of SC200 hot cathode penning inner ion source: design of structure, analysis and calculation, processing and assembling, testing on the test-bed. Now, we have realized our goal.

Design of Structure

The fundamental structure of SC200 inner ion source includes three parts: cathode filament, anode arc chamber, anti-cathode, as shown in Fig.1. The axial magnetic field constrains these primary thermo electrons to move along the magnetic field lines preventing them from directly moving to the anode [2]. In order to avoid structural deformation caused by over-heated filament and arc chamber, we need to use deionized water for cooling. For the proton extracted slit in the side of anode chamber, we design it into plane to extract beam more efficiently. Anti-cathode is a floating anti-cathode without power.

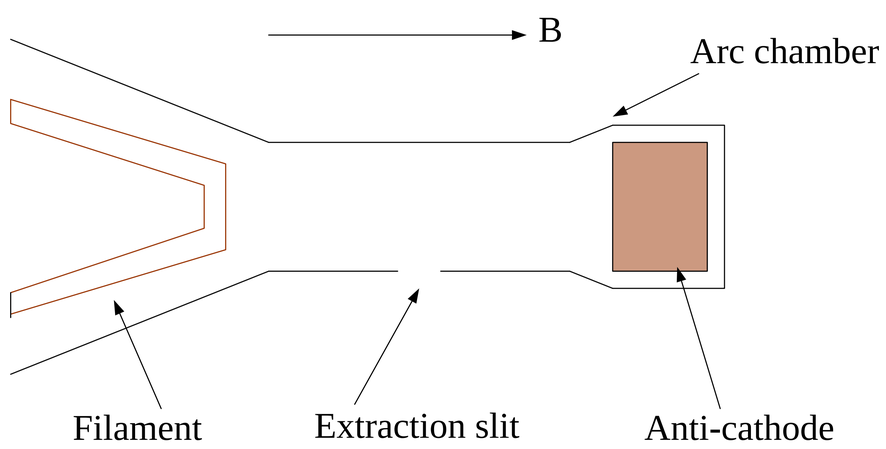

Figure 1. Fundamental structure of SC200 inner ion source

Analysis and Calculation

After finishing the initial design of structure, we need to do various simulation analysis to ensure the reasonableness and practicability. Results are shown in Fig. 2. Figure 2(a) is the thermal distribution result without water cooling. Figure 2(b) is the thermal distribution result with water cooling, temperature set at 301K. Besides, the filament will be acted upon by Lorentz force in magnetic field which direction is parallel to the source axial, once being passed about 200 amp dc through it. The current is 200A and magnetic field is 3T. The maximal deformation value is 0.006mm, and maximum intensity at the bottom is 29MPa.

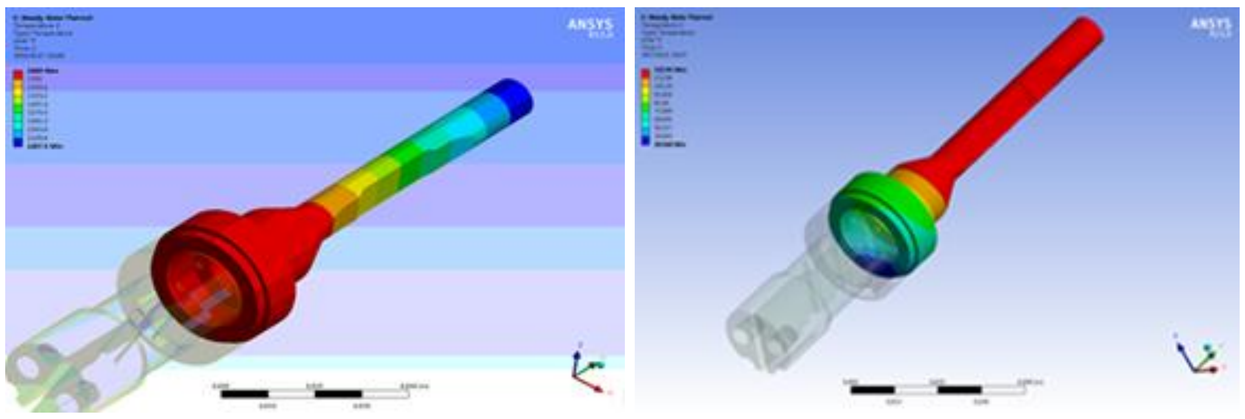

Figure 2 . (a) (b)

Experiment and Test

We established a testbed to carry out experiment so as to verify the proper functioning of ion source. The structure is shown as below Fig. 3. After 4-month we get the intensity of beam current is more than 100μA. Keep beam intensity of 100μA, with the condition of one-hour working and half-an-hour rest, we test the lifetime of filaments. The total lifetime of filament for beam extraction is over 50 hours, which meets the requirements of design.

Conclusion

The hot cathode Penning inner ion source plays a very important role for the whole proton superconducting cyclotron system. The results obtained on our testbed confirm that the structure and operation state of the designed ion source is suitable for long pulses at high beam current. All these works are finished by ourselves besides treatment control system, that will be tested on Nov 2017.

[1] J.R.J.Bennett, IEEE Trans. Nucl. Sci, **19,**48-68 (1972). [2] R. J. Jones and A. Zucker, Rev. Sci. Instr **25**, 563-566(1954).