The Latest results of LAPECR3 ion source at IMP

Y. Cao, J. Q. Li, L. T. Sun, X. Z. Zhang, L. L. Wang, T. L. Yin, H. Wang, B. H. Ma and X. X. Li
Institute of Modern Physics, Chinese Academy of Sciences

A high charge state all permanent Electron Cyclotron Resonance Ion Source (ECRIS) LAPECR3 (Lanzhou All Permanent magnet ECR ion source No.3) has been successfully built at the Institute of Modern Physics (IMP) since 2012. LAPECR3 was designed for the Heavy Ion Medical Machine (HIMM) project. More than 120 eμA of C^{5+} ion beam has been extracted from the LAPECR3 ion source using CH_4 and C_2H_2 gas, and the emittance was less than 75 π*mm*mrad when the working gas was C_2H_2. The corresponding experimental results will be presented in detail in this paper.

Introduction

Lanzhou All Permanent ECR ion source no. 3 (LAPECR3) has been designed and built as the ion injector of the Heavy Ion Medical Machine (HIMM) project.[1] The ion source can provide high quality and high intensity C^{5+} ion beam for the cyclotron injector in HIMM project. The ion source features a compact structure, small size and low cost, which is suitable as a commercial device.

Since 2013 many experiments were carried out on LAPECR3 with CH_4 and C_2H_2 as the working gas. More than 100 eμA C^{5+} ion beam can be easily obtained in both cases. But the beam emittance couldn't satisfy the requirement of HIMM using CH_4 gas while the beam emittance was better than 75 π*mm*mrad when work gas was C_2H_2 gas.

LAPECR3 ion source and the low energy beam line

LAPECR3 ion source is a high charge state ECR ion source that can produce high intensity C^{5+} ion beam. The magnetic rings of the ion source are all 24-segmented rings, which can provide the injection magnetic field peak up to 1.8 T, the extraction field peak 0.96 T, and 1.14 T radial magnetic field at the inner wall of a 50 mm diameter plasma chamber. The low energy beam line was designed using the Trance3D program and assumed 100% beam neutralization as a start. LAPECR3 ion source and the low energy beam line are shown in Fig. 1. In addition, two Allison _type emittance scanners are mounted on both the horizontal and the vertical directions behind the dipole. [2]

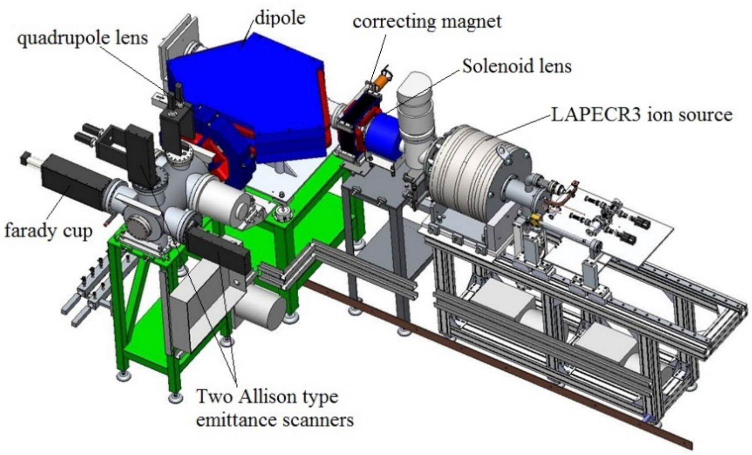

Fig.1. LAPECR3 ion source and the low energy beam line

The results and discussions of experiments

In privious experiments, C^{5+} ion beam was optimized using CH_4 gas and extraction voltage was 22.3 kV which was demanded for HIMM project. Microwave power was fed into the ion source from the 14.5 GHz microwave generator. With an extraction electrode of 8 mm diameter, more than 100 eμA C^{5+} ion beam was extracted from the LAPECR3 ion source at 500 W microwave power, and the total drain current was more than 4 emA. So the performance of the ion source was good enough to extract high intensity C^{5+} ion beam to meet the requirements of HIMM. But the emittance of C^{5+} ion beam was more than 120 π*mm*mrad that is much larger than the required value, 75 π*mm*mrad, and the distortion of the emittance phase in vertical direction was great as shown in Fig. 2. This distortion might be due to the magnetic aberrations and the space charge effect of ion beams. The space charge of ion beams and magnetic aberrations lead to large ion beam envelopes and distortions which deteriorate the beam quality so that the emittance grows singularly. This results is similar to the results of the simulation using TRACK code, as shown in Fig. 3. [3]

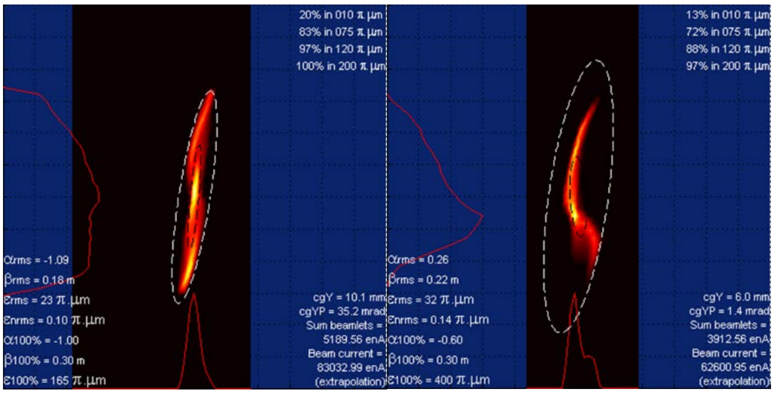

Fig. 2. Measured phase space distributions of C^{5+} ion beam using CH_4 gas

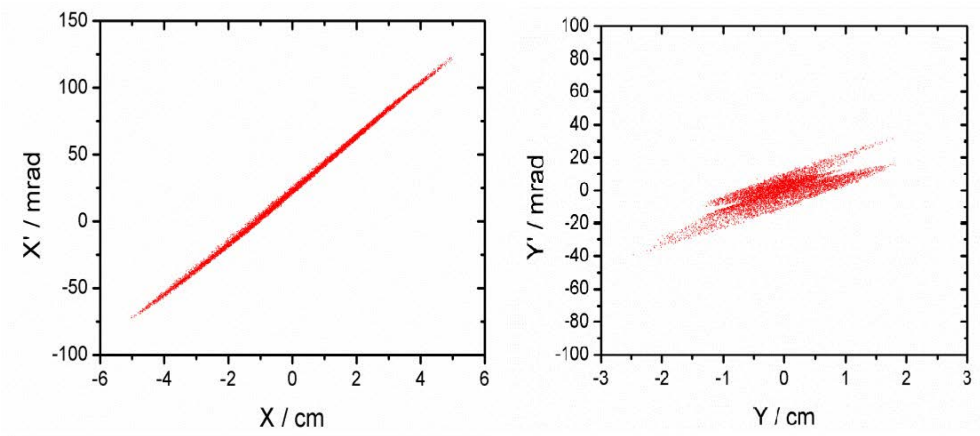

Fig. 3. Simulated phase space distributions of C^{5+} ion beam by TRACK code

In order to be better satisfy the demand of HIMM project, many experiments had been done using C_2H_2 gas, and good results were obtained. When C^{5+} ion beam was optimized using C_2H_2 gas, more than 100 eμA could be obtained more easily while the total drain current was less than 2 emA in the best case. Moreover, the quality of C^{5+} ion beam was improved to a large extent, and the beam emittance was less than 75 π*mm*mrad which fully satisfies the requirement for HIMM. Fig. 4 shows the emittance phase distribution when 120 eμA C^{5+} ion beam was gotten with the total drain current of about 2.3 emA, and microwave power was 180 W. In addition, the distortion of the emittance phase in the vertical director still presented, which might be mainly led by the magnetic aberrations of the beam line.

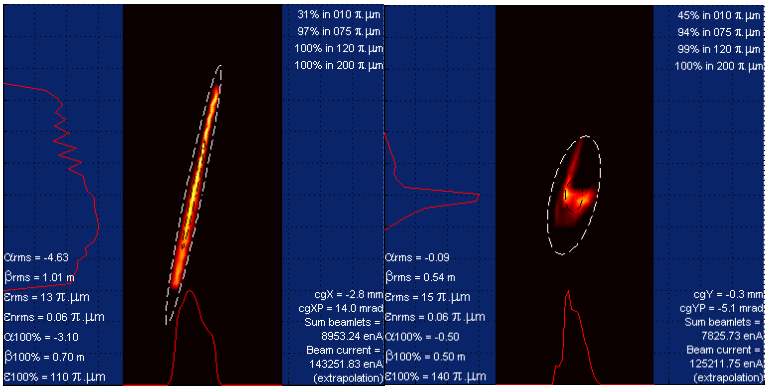

Fig. 4. Measured phase space distributions of C^{5+} ion beam using C_2H_2 gas

The stability of C^{5+} ion beam has been tested. Fig. 5 shows the curves of the beam current of C^{5+}, drain current and high voltage in 24 hours. We can see in these curves that C^{5+} ion beam is very stable, and its stability is better than ±2% in 24 hours. Furthermore, C^{5+} ion beam kept very good stability even in a 120-hour test. On the other hand, carbonic pollution has to be considered during long-term operatin. After the ion source was run for more than three weeks, some carbon contaminant was found in the plasma chamber and the bias voltage plate as shown in Fig. 6. This might affect the performance of the ion source and C^{5+} ion beam will be unstable. So, it is important that the ion source is tested for long time in the future.

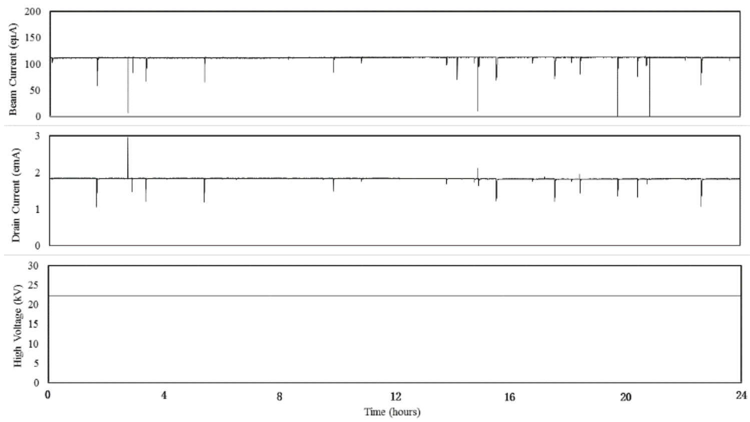

Fig. 5. The curves of the beam current, the drain current and high voltage in 24 hours

Fig. 6. The photo of the bias voltage plate

Conclusion

Good results have been acquired from LAPECR3 in the recent experiments. More than 100 eμA of C^{5+} ion beam could be extracted, and the beam emittance was less than 75 π*mm*mrad when C_2H_2 gas was used. But carbonic pollution is serious for the plasma chamber with C_2H_2 gas, so long term stability of C^{5+} ion beam need be further tested in future. It is very important that long term stable high intense C^{5+} ion beam can be provided to meet the requirements of HIMM project.

Reference

[1] Y. Cao, J. Q. Li, L. T. Sun, X. Z. Zhang, et al. Rev. Sci. Instrum. 85, 02A960 (2014).
[2] Y. Cao, H. W. Zhao, L. Ma, Z. M. Zhang and L. T. Sun, Rev. Sci. Instrum. 75, 1443 (2004)
[3] V. N. Aseev, P. N. Ostroumov, E. S. Lessner, B. Mustapha. Proceedings of PAC 2005, Knoxville, USA, 2005, P2053-2055.