8 - 18 Summary of Ion Source Group Work in 2022

Sun Liangting, Lu Wang, Guo Junwei, Zhao Huanyu, Li Jibo, Feng Yucheng, Qian Cheng, Zhang Wenhui, Yang Yao, Liu Yuguo, Wu Qi, Ma Hongyi, Li Libin, Zhang Xuezhen and Zhao Hongwei

Ion Source Group are taking the responsibilities of high performance ion sources development, low energy ion beam application research, and ion source routine operation for the accelerators at the IMP campus. This paper will give a general scope of the progress of the work in the group.

Ion Sources in Routine Operation. On the campus of IMP in Lanzhou, there are the HIRFL heavy ion complex that are composed of HIRFL, CAFe-2 and LEAF. Three ECR ion sources working in parallel for HIRFL,*i.e.* the 28 GHz SECRAL-II and 14.5 GHz LECR3 serving as the injector ion sources for SFC cyclotron, and 18 GHz LECR4 serving as the injector ion source for SSC-linac. In 2022, these three ion sources contributed in total 7 735 h beam time for HIRFL, and 53% of the beam time is made with SECRAL-II. One of the highlights in the annual operation work is the successful implementation of afterglow mode to the high intensity heavy ion beam operation of CSRm. The 18 GHz LECR5 ion source is used to deliver high intensity highly charged medium mass ion beams for CAFe-2, which is dedicated to the synthesis of super heavy elements. One of the highlights of LECR5 on-line operation is the production of highly charged ion beams with refractory materials such as CaO and so on. Thanks to the successful development of high temperature inductive heating oven, long-term reliable delivery of Ca^{14+} beam is applicable (Fig. 1). The 28 GHz SECRAL-I ion source is temporarily borrowed and used at LEAF to produce highly charged ion beams for the experimental investigations. In 2022, totally more than 3 500 h beam time has been made. One of the highlights of LEAF operation is the successful acceleration of 50 pμA carbon ion beams with the energy spread within ±3‰.

Ion Sources Development. After the hybrid superconducting ECR ion source called HECRAL (Hybrid superconducting Electron Cyclotron Resonance ion source in Lanzhou) had been developed in 2021, we have made tremendous efforts on the ion source performance improvement. By the injection of more microwave power and better plasma cooling, obvious ion source performance enhancement has been made. Typically, more than 2.0 emA O^{6+}, 0.54 emA Ar^{12+}, 110 eμA Xe^{30+} have been extracted that are similar to the performance a superconducting ECR ion source can make at 18 GHz. The successful production of high intensity highly charged ion beams demonstrated the success of HECRAL. FECR (the First 4^{th} generation ECR ion source) was under intense development this year. After totally 8 rounds of test with the 1/2-length Nb_3Sn prototype, many fundamental issues have been well studied and addressed. We can then move on to the full -sized cold mass development, which is more challenging in terms of sextupole coil fabrication, precise and safe coils assembly to the cold mass structure, and quench protection. In 2022, the main effort was on the safe assembly of the Nb_3Sn sextupole coils to the cold mass. We have completed totally 4 rounds of assembly (Fig. 2) coil damage during the assembly process revealing that the assembly of the full-length cold mass is much more complicated compared to the 1/2-length one. More detailed work is taken by the team to realize a successful FECR cold mass assembly.

New Platform Design and Setup. An Electromagnetic Isotope Separator (EMIS) system has been successfully developed at IMP. This platform is aiming to produce intense isotopic ion beams, separate the isotopes via the electromagnetic separator, enrich and collect the isotopes at the collector region. The performance of the separator was tested by separating the Xe isotopes with the natural abundances. With a 2.45 GHz ECR ion source, a total beam current of 15 mA was produced and separated by the EMIS system. According to the beam spectrum scanned at the isotope collector plane, this system can provide the designed ion beam separation at high beam currents.

New Development and Applications. LECR5 ion source for the SESRI (Space Environment Simulation and Research Infrastructure) 300 MeV accelerator was used for routine operation. Intense ion beams from H_2^+ to Bi^{32+} have been used for routine operation. High reproducibility, high reliability and high beam quality are the main features of this room temperature ion source, which owes to the careful design of the ion source and the precise assembly. A compact 2.45 GHz ECR ion source and the LEBT system (Fig. 3) was developed for the PREF (Proton Radiation Effect Facility) accelerator. This ion source is to produce 10 mA hydrogen ion beam at the repetition rate of 1 20 Hz for the injector RFQ. Ion beam extraction was successfully made with the test bench and beam quality check is under preparation before its on-site installation. The ion source front end for HIAF project is on track for the readiness in 2023. As the 45 GHz ion source for HIAF is not ready yet, HECRAL as discussed in the previous section has been discussed to be used as the baseline ion source to deliver intense heavy ion beams for the early commission of HIAF. At the meantime a 3^{rd} generation ECR ion source 28 GHz SECRAL-IV is under consideration to be used as the injector to deliver more intense heavy ion beams typically Bi^{31+} and U^{35+}. Other

conventional parts for the ion source front end are mostly fabricated or in the stock waiting for quality check.

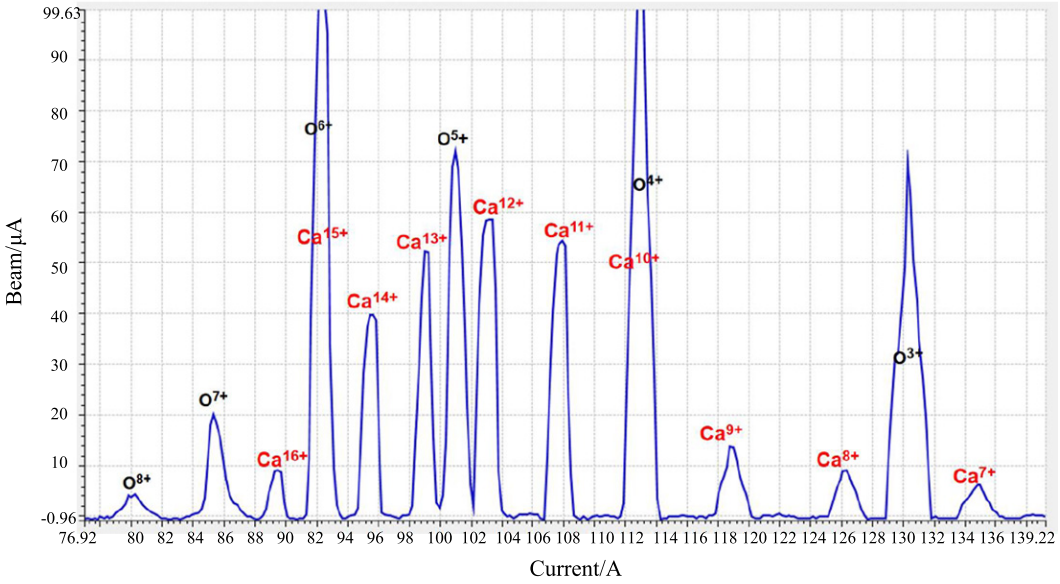

Fig. 1 (color online) Production of Ca^{14+} beam with LECR5 ion source at CAFe-2 facility.

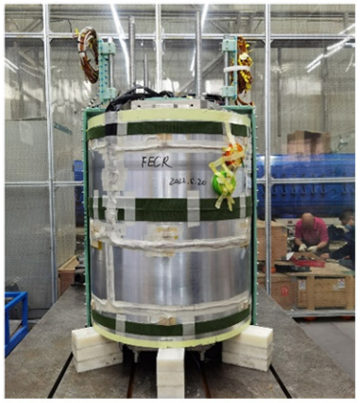

Fig. 2 (color online) The picture of the assembly for FECR full-length cold mass.

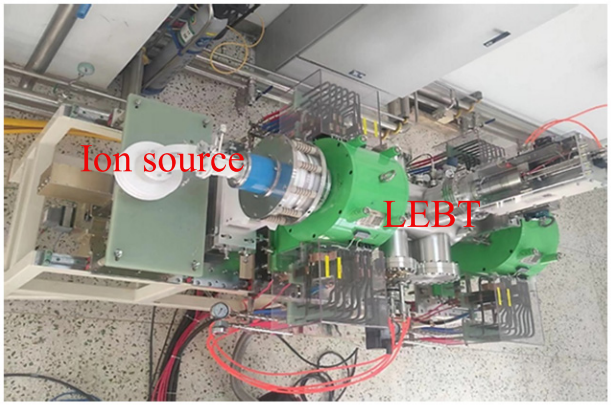

Fig. 3 (color online) The compact ion source and LEBT for PREF.