Summary of Ion Source Group Work in 2018

Ion sources have fundamental impacts to the operation status of existing facilities and research progress of those under construction.

In 2018, totally 6825.5 h beam time has been made by the ion sources for HIRFL operation, contributed by superconducting ECR ion source SECRAL/SECRAL-II with 2231 h and room temperature ECR ion source LECR3 with 4594.5 h respectively. Totally 19 beams of different ions or energies have been delivered to the downstream accelerators for diverse experiments covering the research fields of nuclear physics, material irradiation, medical application and so on. Highlights of the on-line ion source operation are the successful production of stable $^7\text{Li}^{3+}$ and $^{181}\text{Ta}^{31+}$ ion beams for HIRFL, and the on-line operation of SECRAL-II by replacing the former injector ion source SECRAL (Fig. 1).

Fig. 1 (color online) SECRAL-II in place for routine operation by replacing SECRAL.

To meet the needs of ADS linac commissioning, various ion beams have been delivered with two different ion sources, i.e. a 2.45 GHz ion source LIPS-1 and a 14.5 GHz ECR ion source LAPECR1 (Fig. 2). LIPS-1 is used to produce intense proton beams, typically of 10–20 emA/35 keV in either DC or pulsed modes. LAPECR1 is a multiple charge state ECR ion source capable of producing $>5\text{ mA H}^+$, $>5.0\text{ mA 4He}^+$, $\sim2.0\text{ mA 4He}^{2+/3}\text{He}^{2+/3}$ and so on. More than 600 h beam time has been made with LAPECR1 source in 2018 for ADS commissioning and experiments.

Before SECRAL-II was removed to injector ion source basement to replace SECRAL, we continued the high power exploration at 28 GHz. Obviously, high power operation can increase the output highly charged ion beam intensities which has already been reported in the Annual Report of 2017. However, there are many challenges to ion source technologies, and the typical one is the strong plasma power sink to the plasma chamber inner wall, which will ultimately lead to a burnt hole on the wall under high microwave heating when power density is high than 1 kW/l. However, at a moderate power level, the ion source can work stably for a long time. With a recently developed inductive heating oven (Fig. 3), SECRAL-II source was capable of producing very high intensity Ni beam. 360 eμA of Ni$^{17+}$ had been extracted successfully with 0.8 kW of oven power and 2.5 kW of microwave power.

LAPECR3 ion sources for Wuwei cancer treatment machine HIMM have been intensively operated all over the year for machine reliability check and treatment test. The typical delivered ion beam intensity of C$^{5+}$ is around 70 eμA. However, even at such a moderate beam intensity, frequent HV breakdowns and ion source failure has been
observed. The most frequent ion source failure is the microwave generator breakdown as a result of ion source high voltage sparks. \( \text{C}_2\text{H}_2 \) is very efficient in \( \text{C}^{5+} \) production but is very contaminative to the ion source plasma chamber and electrodes. With refined ion source extraction structure and improved microwave generator protection, the ion source can serve in routine operation without extra service for more than 30 days typically. At the meantime, a new LAPECR3 ion source (Fig. 4) aiming to produce more than 400 \( \text{eA} \text{C}^{4+} \) is also under development. Beam commissioning will be completed in early 2019.

The research activities on laser ion source are mainly focusing on short pulse intense ion beam production, typically highly charged metallic ion beams and hydrogen ion beam. There is a big challenge in \( \text{H} \) ion beam production with laser ion source. Two different technical solutions have been tried in the lab, \( i.e. \) cryogenic hydrogen target (Fig. 5), and titanium hydride \( \text{TiH}_2 \), and the experimental results showed that both of the methods worked, and reasonable \( \text{H} \) beam were produced. About 300 \( \text{eA} \text{H}^{+} \) has been made with cryogenic target (solid hydrogen), and several \( \text{eA} \text{H}^{+} \) has been detected with a \( \text{TiH}_2 \) target. Either of the afore mentioned technical solutions to proton beam with laser ion source works, but the production efficiency needs to be augmented by at least one order.

New machine development has also got obvious progress. 18 GHz LECR5 ion source for the National Fundamental Project SESRI has been mostly completed, except the power supplies. Thus, this project is in a very favorable condition to meet the annual goals in 2019. The 4\textsuperscript{th} generation 45 GHz FECR ion source development is moving on but very slowly as there is no much existing references and experience for the very challengeable \( \text{Nb}_3\text{Sn} \) coldmass. However, we are very happy to make a fundamental step forward by successfully building the first prototyping \( \text{Nb}_3\text{Sn} \) sextupole coil. It was wound with single wire and after all the procedures such as coil winding, heat treatment and potting, a coil very close to 1/2 size prototype design has been available (Fig. 6). Test at 4.2 K LHe bathing with a mirror structure test tooling indicates that the coils can stably work at designed current of 80% the critical current.

Year 2019 will be a very crucial year for the group and the projects we are in charge. Several major progresses should be made to meet the corresponding project goals, such as the success of the 1/2 prototype FECR, LECR5 ion source commissioning, SECRAL upgrade to SECRAL-I and so on.