Development of RIKEN 28 GHz SC-ECRIS for the production of intense metal ion beam†

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At RIKEN, we planned to synthesize new elements with atomic number (Z) higher than 118, after the experiments for synthesizing the super-heavy element ($Z = 113$).[1] For this purpose, the production of intense and stable highly charged metallic ion beams, such as $Ti^{12+,13+}$, $V^{12+,13+}$, and Cr^{13+} ions, are required. In particular, there is a strong demand for an intense beam of V^{13+} ions to synthesize the new element with $Z = 119$. Therefore, we conducted test experiments to produce these beams and studied the effect of magnetic field distribution to maximize the beam intensity of these heavy ions for several years.

It is well-known that the "scaling law"[2,3] and the "high B mode" operation[4–6] provide some important guidelines to optimize the magnetic mirror ratio of ion sources for the production of various charge states of heavy ions. As a first step to improve the ion source performance for the production of these metallic ion beams, we conducted a systematic study to optimize the magnetic field distribution using the RIKEN 28 GHz SC-ECRIS[7,8] and the liquid He-free SC-ECRIS[9] on the basis of these laws. In the systematic studies, it was concluded that the optimum magnetic mirror ratio ($B_{\rm ext}/B_{\rm min}$) is 2.2–2.7 for the production of V^{13+} ion beam. If we choose $B_{\rm min} \sim 0.6$ T, which is the optimum value for the 28 GHz microwave operation to maximize the beam intensity, the optimum $B_{\rm ext}$ is predicted to be 1.3–1.6 T. Therefore, we chose $B_{\rm ext}$ of 1.4 T for the production of V^{13+} ion beam.

We used a high-temperature oven[10] for the production of the V vapor. For long-term operation of the high-temperature oven, we fabricated a new crucible, whose volume is almost two times larger than that of the old one.[11] To obtain sufficient temperature for evaporating the materials, detailed simulation for optimizing the crucible structure was carefully performed and sufficiently high temperature was obtained to produce the vapor. The detailed results are presented in Ref. 10).

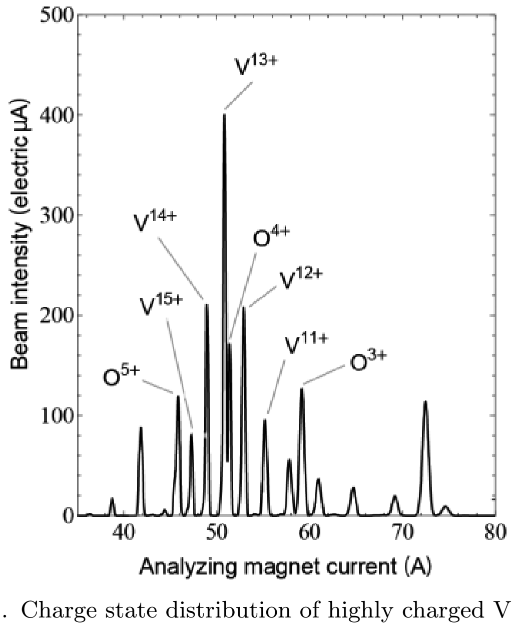

Fig. 1. Charge state distribution of highly charged V ions.

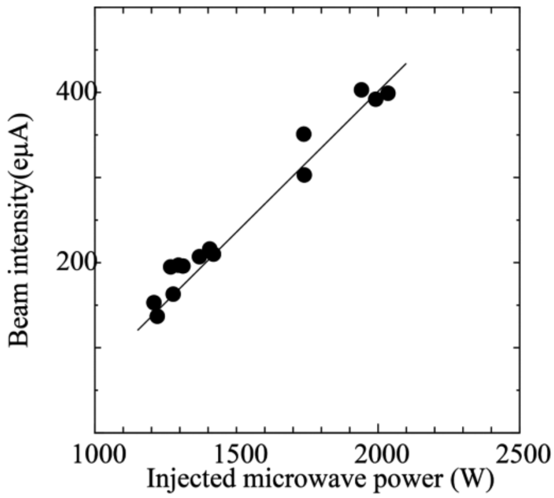

Fig. 2. Beam intensity of V^{13+} ions as a function of microwave power.

Figure 1 shows the typical charge state distribution of a highly charged V ion beam at the injected microwave power of ∼2 kW. The extraction voltage was 12.6 kV. The ion source was tuned to produce a V^{13+} ion beam. The beam intensity increased linearly with increase in the injected microwave power, as shown in Fig. 2, and obtained ∼400 electric μA of V^{13+} ion beam with ∼2 kW. For long term operation (longer than one month), we successfully produced ∼120 electric μA of V^{13+} ion beam without break.

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References

1) K. Morita, Proceedings of the 14th International Symposium on Nuclei in the Cosmos (NIC2016), JPS Conf. Proc. 14, 010004 (2017).
2) R. Geller *et al.*, Proc. 8th Int. Conference on ECR ion sources and their applications, NSCL report MSUCP-47 (MSU, Dec. 1987), p. 1.
3) R. Geller, *Electron Cyclotron Resonance Ion Sources and ECR Plasmas*, Institute of Physics, (CRC Press, Bristol, 1996).
4) T. Antaya, S. Gammino, Rev. Sci. Instrum. **65**, 1723 (1994).
5) S. Gammino *et al.*, Rev. Sci. Instrum. **67**, 4109 (1996).
6) D. Hitz *et al.*, Rev. Sci. Instrum. **73**, 509 (2002).
7) Y. Higurashi *et al.*, Rev. Sci. Instrum. **85**, 02A953 (2014).
8) G. Alton, D. N. Smithe, Rev. Sci. Instrum. **65**, 775 (1994).
9) T. Kurita *et al.*, Nucl. Instrum. Methods Phys. Res. B **192**, 429 (2002).
10) J. Ohnishi *et al.*, Proceedings of ECRIS 2018.
11) J. Ohnishi *et al.*, Rev. Sci. Instrum. **87**, 02A709 (2016).