# High-intensity vanadium-beam production to search for a new super-heavy element with $Z = 119$[†]

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In March 2020, we successfully accelerated the first beam ($^{40}\mathrm{Ar}^{13+}$) using several superconducting quarter-wavelength resonators (SC-QWRs)[2)] installed in RIKEN heavy-ion linear accelerator (RILAC)[1)] to achieve enough energy to synthesize new super-heavy elements (SHEs) with an atomic number greater than 118. To overcome the extremely small production cross section of SHE with $Z = 119$, it was necessary to provide a highly charged vanadium (V)-ion beam such as $^{51}\mathrm{V}^{13+}$ with very high intensity. Thus, we constructed a superconducting electron cyclotron resonance ion source (SC-ECRIS) for RILAC, which was named RIKEN 28-GHz SC-ECEIS "KURENAI" (R28G-K).[3)] R28G-K has essentially the same structure[4)] as another SC-ECRIS that is the only source of heavy ions including uranium for RIBF, which is renamed RIKEN 28-GHz SC-ECEIS "SUI" (R28G-S).[5,6)] When operating the SC-QWR, the particulate matter sputtered from the beam pipe irradiated by the beam is thought to significantly reduce the gap voltage by increasing the surface resistance of the cavity, thus we must suppress the beam loss as much as possible. For this purpose, we installed "slit triplet" in the low energy beam transport to limit the transverse emittance.[3)] This indicates that only a portion of the beam extracted from R28G-K is available despite the demand for an unprecedented beam intensity. Therefore, we systematically studied the effects of the amount of the V vapor and power of the microwaves, which heat up the plasma in the ion source, on the beam intensity, and the optimal parameters that would allow long-term experiments with the highest possible beam intensity.

The upper figure in Fig. 1 shows the two high temperature ovens (HTOs)[7)] installed in the ion source. The HTO was developed as an evaporator for high melting point materials such as vanadium. The V-vapor amount was equivalent to the sum of the consumption rates of the metallic V sample in each HTO crucible. The capacity of each crucible was approximately 2.2 gram of the granular metallic V. The $^{51}\mathrm{V}^{13+}$-beam intensity extracted from R28G-S was obtained as a contour plot in the lower figure in Fig. 1 as a function of the consumption rate of the V metal and the total power of the 18- and 28-GHz microwaves. As a consequence of the contour plot, it was deduced that a 400-electric $\mu$A $\mathrm{V}^{13+}$-beam can be produced at ∼6-mg/h consumption and 2.5-kW microwaves. Because the total capacity of the two HTO crucibles is 4.4 gram, we can provide the high intense V beam for one month without interruption. Furthermore, at 24-mg/h consumption and 2.9-kW microwaves, we also obtained the V-ion beam with an intensity of 600 electric $\mu$A that is suitable for essential development, for example, target development.

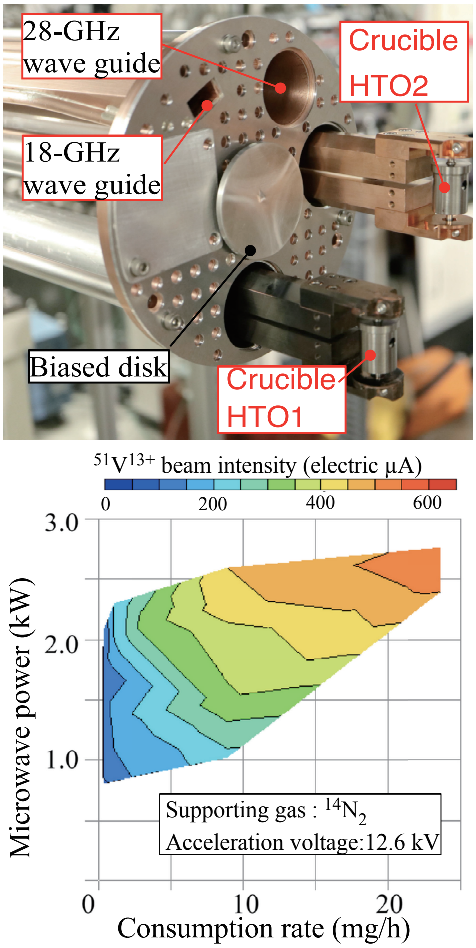

Fig. 1. Two HTO mounted on the injection flange of the plasma chamber of R28G-K (upper), and obtained contour plot of the $^{51}\mathrm{V}^{13+}$ beam intensity as a function of the consumption rate and the microwave power (lower).

References
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[†] Condensed from the article in the Proc. of 24th Int. Workshop on ECR Ion Sources (ECRIS'20), East Lansing, USA, September 2020, in press

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