CBECR ion source performance report: development of ^{64}Zn, ^{78}Kr and ^{197}Au ion beams

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The 14.5 GHz Charge Breeding ECR (CBECR) ion source demonstrates outstanding capability in producing high charge state ions due to its permanent magnet closed hexapole design for radial plasma confinement despite its low magnetic field at its injection end. As a consequence it has been pulled into service when the 6.4 GHz ECR1 and ECR4 have been comprised.

$^{78}Kr^{27+}$ for Radiation Effects Facility

We successfully produced high charge state ^{78}Kr for acceleration to 40 MeV/A for the Radiation Effects Facility. This application required the challenging charge state of 27+. Given that ^{78}Kr represents only 0.4% of natural krypton, we utilized enriched gas (50% ^{78}Kr with the remainder as natural Kr gas, primarily consisting of ^{84}Kr at 57% and ^{86}Kr at 17%). Figure 1 displays the charge distribution of the emitted current when operating with this enriched krypton gas. The maximum current intensity of extracted beam achieved was 190 pA without the hole collimator.

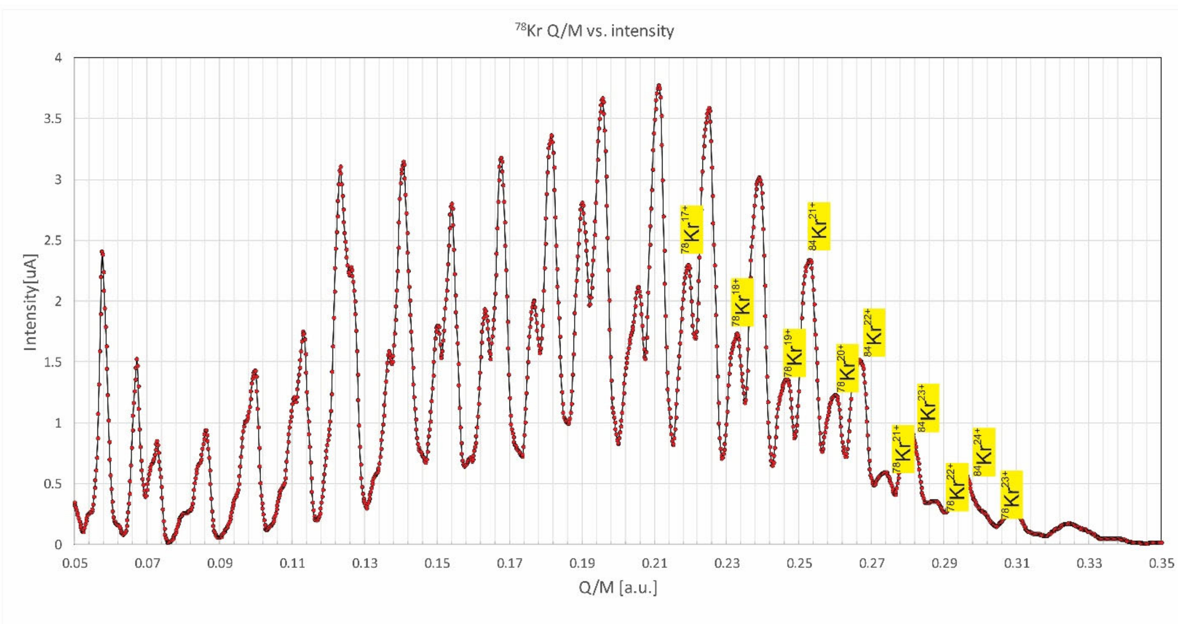

Fig. 1. Intensity vs. charge over mass ratio graph. Various charge states peak of ^{78}Kr and ^{84}Kr are labeled.

$^{64}Zn^{25+}$ at 47 MeV/A

During this reporting period, we fulfilled another high-energy beam request for $^{64}Zn^{25+}$ at 47 MeV/A. Since the CBECR lacks a radial port for conventional sputtering fixtures, we engineered a custom electrically isolated support for the Zn sample, positioning it axially approximately 1 cm from the entrance of the plasma chamber (Figure 2).

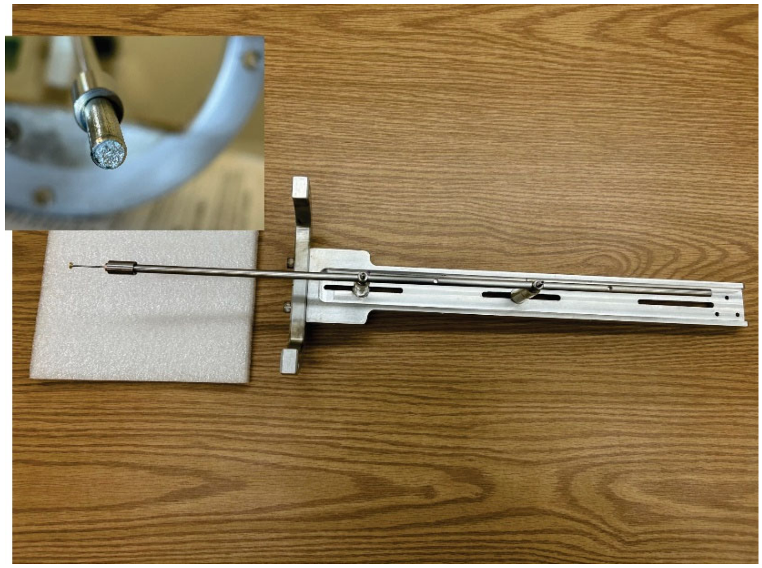

Fig. 2. Axial sputtering fixture for Zn sample (insert) and Au sample.

By applying a -800 V potential relative to the plasma chamber potential (11 kV), we successfully initiated sputtering. The resulting charge distribution appears in Figure 3. While the targeted charge state 25+ (charge to mass ratio, Q/M=0.3906) is not clearly distinguished due to overlap with the $^{16}O^{6+}$ charge state, we achieved beam extraction of 250 pA using the K500 cyclotron's separation capabilities. After approximately 10 days of operation, carbon coating formed on the Zn sample insulator supports, rendering the sputtering voltage application ineffective.

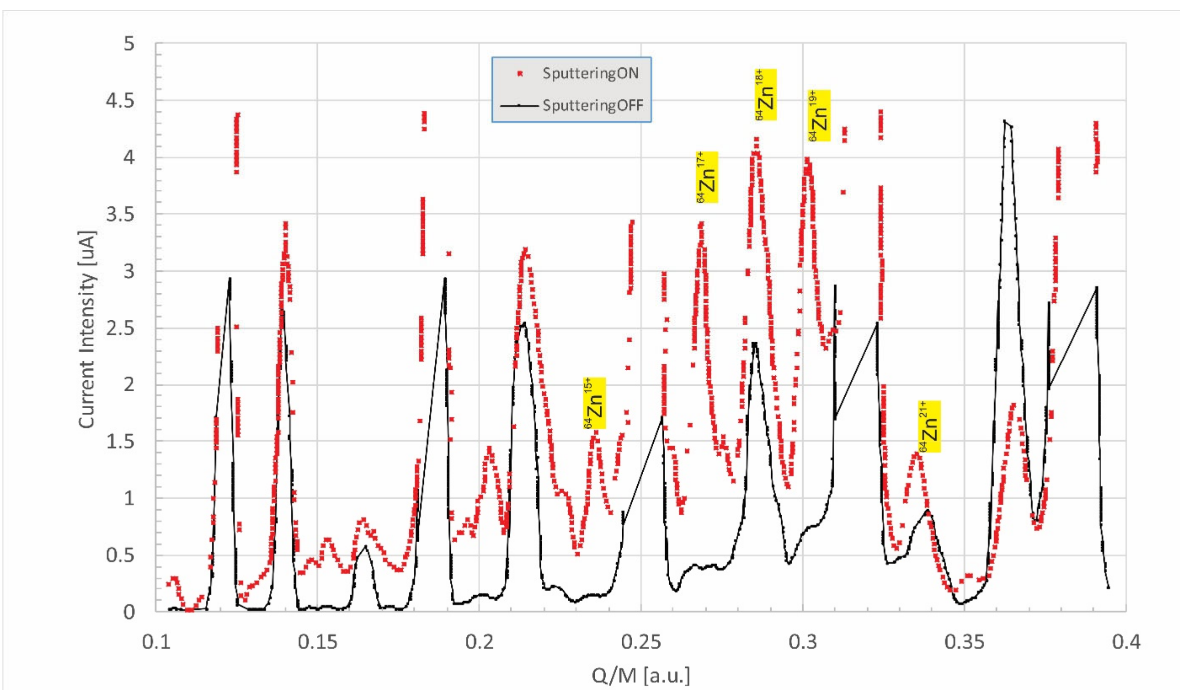

Fig. 3. Intensity vs. charge over mass ratio graph. Various charge states peak of ^{64}Zn (red) are labeled. With black is represented the normal current output when the sputtering voltage was turned off.

$^{197}Au^{36+}$ Development

Building on our success with axial sputtering of Zn, we further developed a $^{197}Au^{36+}$ beam. We modified the fixture by adding a protective glass tube to shield the sample support, significantly improving beam longevity and stability. Additionally, we positioned the Au sample 0.5 cm deeper than in the Zn configuration. This setup yielded impressive results: 7 nA without the hole collimator and 4 nA with the hole collimator for $^{197}Au^{36+}$. Figure 4 presents the current intensity function of the ratio of the charge to the mass.

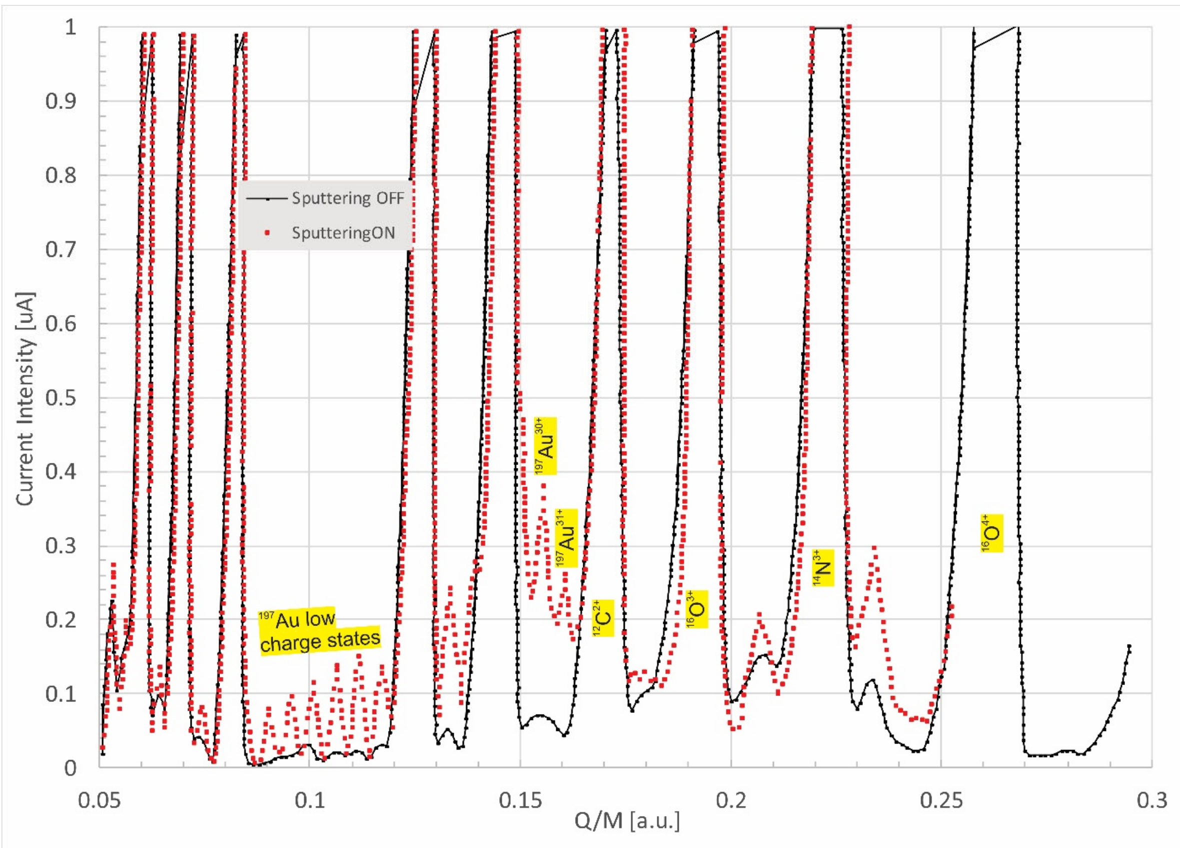

Fig. 4. Intensity vs. charge over mass ratio graph. Various charge states peak of ^{197}Au (red) are labeled. With black is represented the normal current output when the sputtering voltage was turned off.

In conclusion, The CBECR consistently demonstrates its effectiveness as an ion source capable of producing the higher charge states required for specialized beam applications. These results validate its value for demanding experimental requirements.