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SELECTIVE ENHANCEMENT OF HIGHLY CHARGED IONS EXTRACTED FROM THE SCECR ION SOURCE

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ABSTRACT

We demonstrate an important feature of the NSCL SCECR ECR ion source–namely it can be tuned to produce narrow charge state distributions with a high percentage of the ions in a single charge state. We show an oxygen spectrum with about 50% of the oxygen particle current extracted as O^{6+}, and an argon spectrum with about 20% of the argon particle current extracted as Ar^{11+}. This kind of tuning may have a major impact on the design and cost of second generation RIB facilities, when compared to multiple accelerator stages with intermediate stripping.

1. Introduction

The role considered for the ECR ion sources (ECRIS) in radioactive ion beam (RIB) projects is generally that of a singly charged ionizer. Then a modest single stage source is designed and one attempts to optimize the 1+ ionization efficiency. While several of the well known characteristics of ECR sources can be exploited by this approach, high energy radioactive beams would require multiple accelerator stages with intermediate stripping. State-of-the-art ECRIS for highly charged ions now being developed can also produce very intense intermediate charge ions. These sources have better confinement, higher densities and thus much higher ionization rates than the singly charged ECRIS ionizers. In some cases, they can be tuned to a very sharp charge state distribution where the intensity of one or a few highly charged ions have been significantly enhanced. One such ECRIS with this capability is the superconducting SCECR at NSCL. It is this mode, when properly utilized, that may have the most effect on the design and performance of second generation RIB facilities, by eliminating the need for intermediate stripping stages, as we will now attempt to demonstrate by considering a novel tuning of the SCECR.

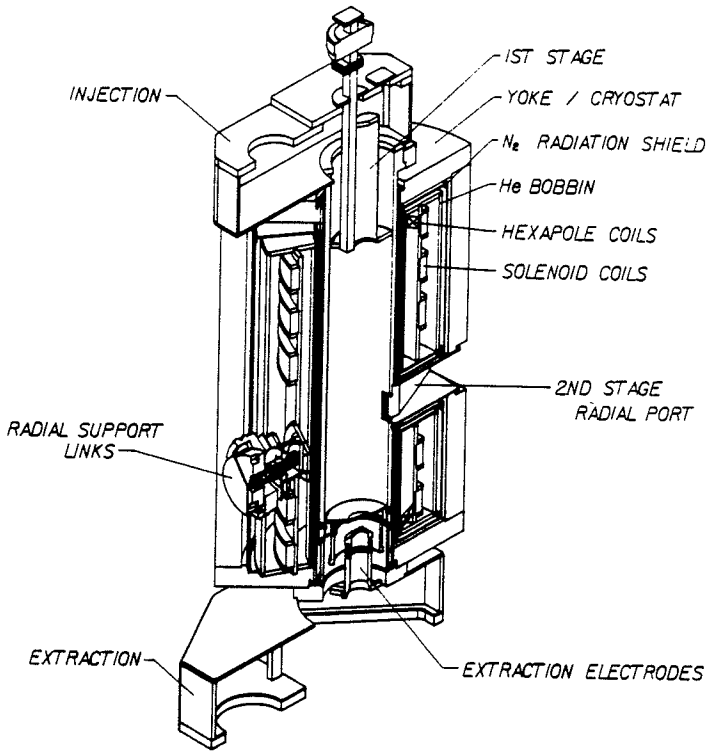

Fig. 1: The SCECR at NSCL, shown here in schematic form, is an ECR source based on a full superconducting coil set. This coil set permits variable frequency operation, or wide range magnetic field tuning at a given frequency.

2. Enhanced Oxygen and Argon Charge State Distributions

The NSCL SCECR source is shown in Figure 1. The SCECR is a large volume ECRIS with variable field and frequency capabilities.[1] For these tests, the source is operating at 6.4 GHz, but with substantially higher axial and radial magnetic mirror ratios than other sources having a similar operating frequency. In this high magnetic confinement mode, neither wall coatings nor electron guns are required to enhance the basic performance, and gas mixing has only limited effectiveness. In this mode, very high absolute extracted currents have been measured, e.g. O^{6+} at 0.65 emA. Also in this mode, very high absolute charges have been measured, e.g. Kr^{28+} and Xe^{38+}, at about 1eμA each.

An intermediate tune of the SCECR between these extremes yields very high fractions of particular highly charged ions. It is this mode of operation that may be of interest to proposed second generation RIB facilities. Figure 2 shows such a tune of the SCECR to maximize O^{6+} ion production. For this tune, the plasma composition is a mixture of approximately $(1/3)O_2$ and (2/3)He, by gas feed. The low charge state oxygen ions are almost completely suppressed, and the O^{6+} charge state is the most abundant electrically. Figure 3 shows a similar tune for intermediate charge state argon ions. The peak charge state is Ar^{10+} and the argon charge state distribution is

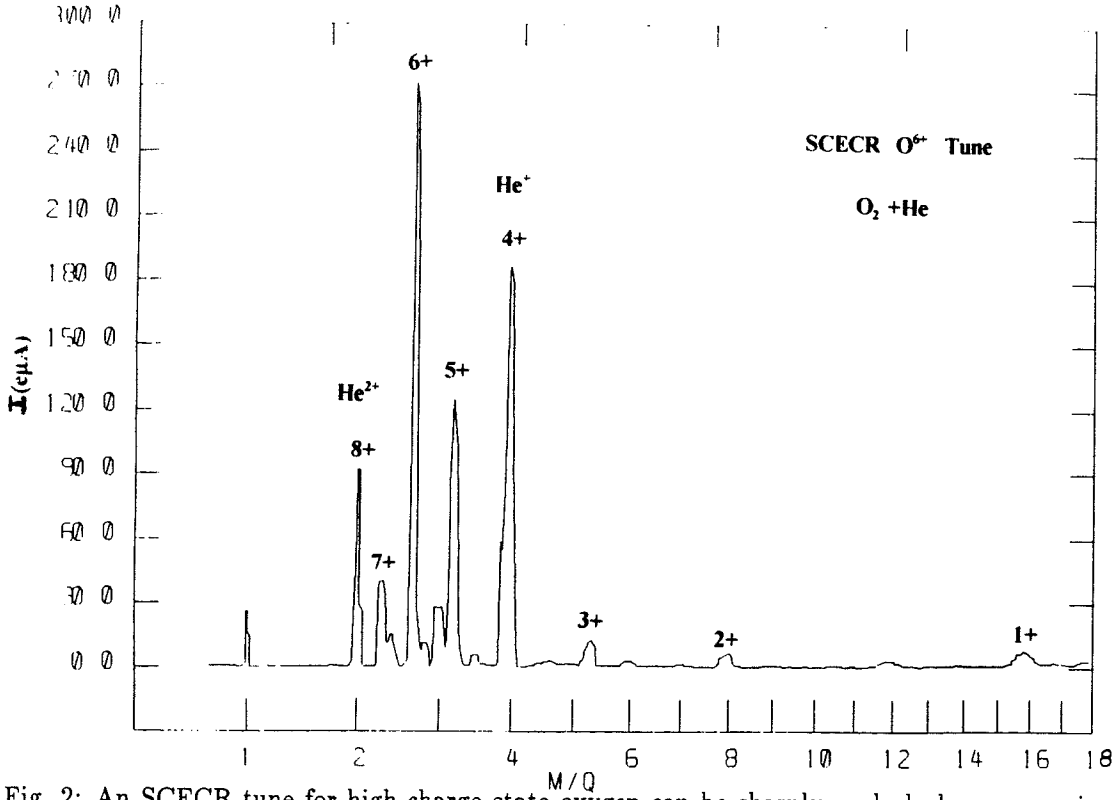

Fig. 2: An SCECR tune for high charge state oxygen can be sharply peaked– here approximately 40% of the extracted *particle current* is in the O $^{6+}$ charge state.

somewhat wider than that shown in Fig. 2 for oxygen. This broadening is purely an atomic effect and unavoidable.[2]

Generally, current distributions such as those shown in Figs. 2 and 3 distort the actual abudances of ions extracted from ECRIS. In Figure 4, we plot the respective oxygen and argon particle distributions for these tunes. For oxygen, O^{6+} is still seen to be the peak charge state, with about 50% of the oxygen particle current. For argon, Ar^{10+} is still the most abundant charge state, and about 60% of the total particle current is in the charge states Ar^{9+} through Ar^{11+}. If the total ionization efficiency of the SCECR is high, then these peak percentages of total particle current would compare very favorably with existing singly charged ionizers.

3. Summary and Conclusions

We have demonstrated that it is possible to obtain very sharply peaked extracted current distributions from the SCECR, having a high fraction of the total particle flux in one or a few highly charged states. We note that these are very preliminary results, and are likely to improve with further work. To gain a complete picture of this mode and its importance, a broader range of operating parameters and species must be explored. However, given the design of the SCECR, we can make some preliminary comments on some of these characteristics. First, we expect similar results

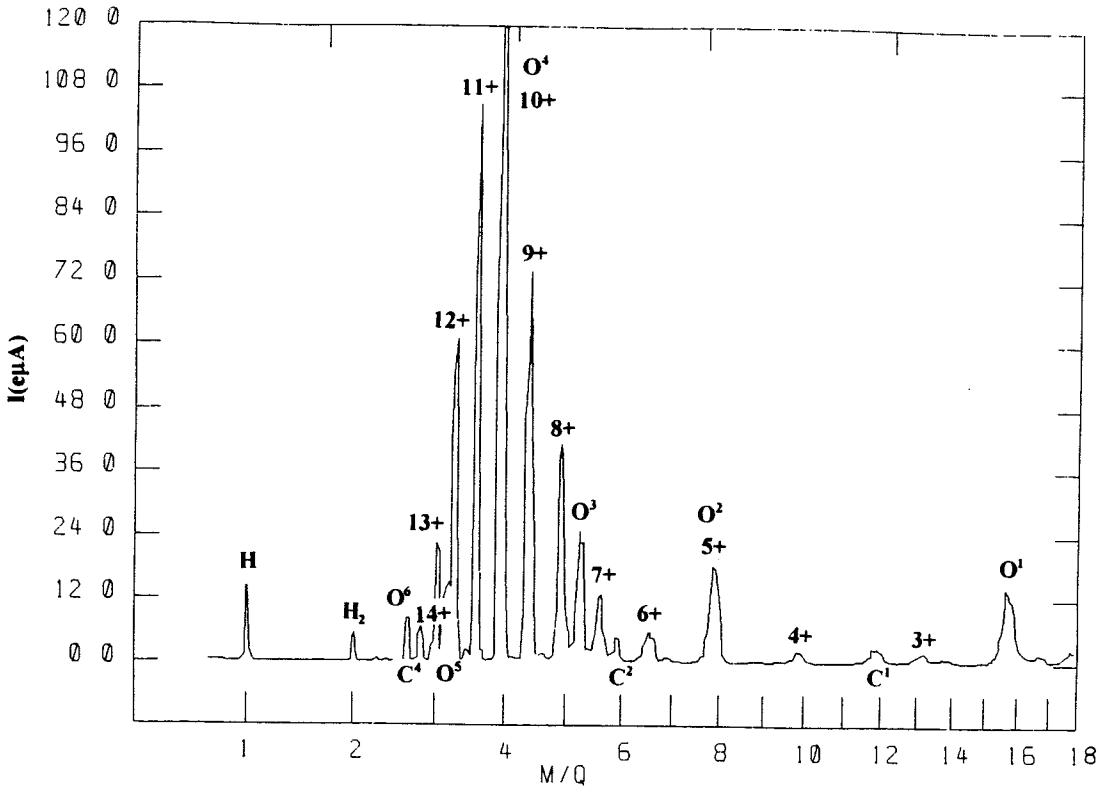

Fig. 3: For high charge argon, more charge states have similar ionization rates , so the charge state distribution is broader than for oxygen. Still, about 10% of the particle current can be extracted as Ar^{11+} ions.

for metallic species, as we have found no previously difference in operating performance between metallic and gaseous feed species in a similar ECRIS, the RTECR at NSCL.[3] Second, the total ionization efficiency is not presently known for the SCECR, but expected to be high from the low observed material consumption rate. (The ionization efficiency will soon be measured, probably during an upcoming experiment at NSCL to determine the natural abundance of ^{81}Kr.) If the ionization efficiency is indeed high, then this high charge state performance would approach that of most singly charged ionizer concepts.

While the scope of the present work is limited, it is sufficiently promising to suggest an import alternate concept for using ECRIS as RIB ionizers, namely to use an SCECR-class high charge state ECRIS to produce an initial intermediate charge ion beam which contains a large fraction of the total available particle current.

4. References

[1] T.A. Antaya, Les Edition de Physique 50 (1988) 707.

[2] T.A. Antaya, AIP Conf. Proc. 274 (1992) 653.

[3] T.A. Antaya and D. Cole, Proc. 13th Int. Conf. on Cyclotrons and Their Applications, Vancouver, (1992) 348.

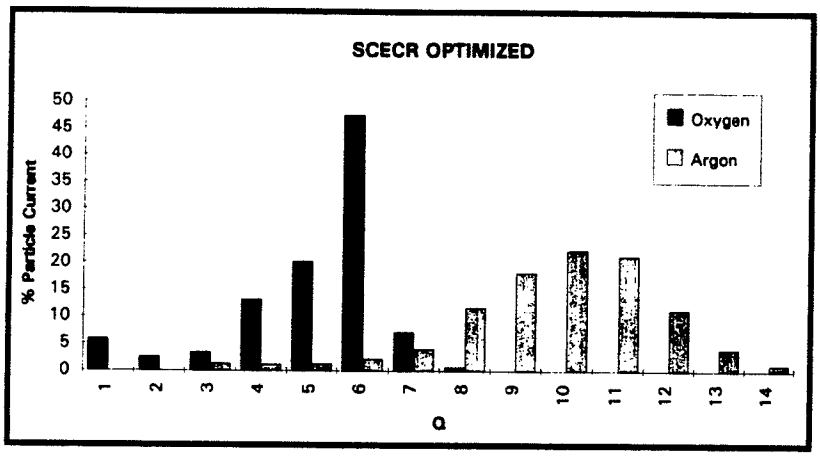

Fig. 4: The oxygen and argon particle distributions from Figures 2 and 3 are plotted here, as a percentage of the total particle current of that species.