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# DUAL ARC PENNING ION SOURCE GAS FLOW EXPERIMENTS†

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## Summary

Support gas, when added directly to an arc or admitted to an auxiliary chamber of a two-arc chamber ion source, increases the beam intensity for multi-charged ions such as $^{16}O^{5+}$. To clarify the mechanism of this intensity increase, gas flow rates from the auxiliary chamber to the main chamber have been measured by using the ORIC cyclotron as a mass spectrometer. The results show that only about three percent of the gas admitted to the auxiliary chamber reaches the main chamber. One can then infer that the improved operation probably results from the stabilizing effect of heating the common cathodes with the auxiliary arc and/or the more favorable distribution of the support gas to the part of the main arc close to the cathodes.

## Introduction

Previous experiments have shown that the addition of an easily ionized heavy gas (krypton or xenon) to the arc chamber increases the output of multi-charged lighter ions, for example, nitrogen and oxygen.[1,2]

In a refinement of this technique, an auxiliary arc chamber, for support gas, was added to the ORIC ion source, thereby providing a means of maintaining sufficient ion bombardment of the cathodes without adversely affecting the gas pressure in the main arc chamber (Figures 1, 2).[3] Use of the auxiliary arc chamber resulted in a high beam intensity and faster stabilization of the arc.

To gain a better understanding of the processes involved, a method has been developed to study the migration of gas from the auxiliary chamber to the main chamber.

## Experimental Method

The use of an accelerator as a mass spectrometer has gained wide acceptance.[4] In particular, the narrow phase stability limits after many turns of acceleration in an isochronous cyclotron allows the complete separation of most masses. Analogue beams, i.e., beams whose charge to mass ratio (m/q) are nearly equal, and harmonic beams $(h_1m_1/q_1) = (h_2m_2/q_2)$, where h is the rf harmonic number, are exceptions to successful separation. Tuning from one charge to mass ratio to another usually requires the adjustment of many cyclotron parameters, thereby leading to uncertainties in intensity measurements due to accelerator optimization and source fluctuation. However, after appropriate computations,it was determined that charge to mass ratios of $^{16}O^{5+}$ and $^{14}N^{4+}$ could successfully be accelerated to 64 cm in ORIC, with only one parameter change; i.e., the main magnet current.

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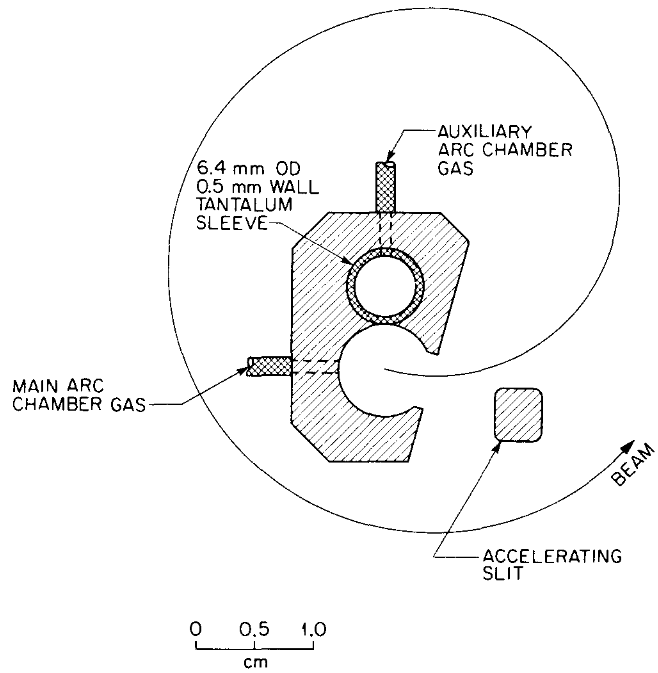


Fig. 1. Median plane cross section of the dual arc chamber source. The arcs in the two chambers share a single cathode at each end.

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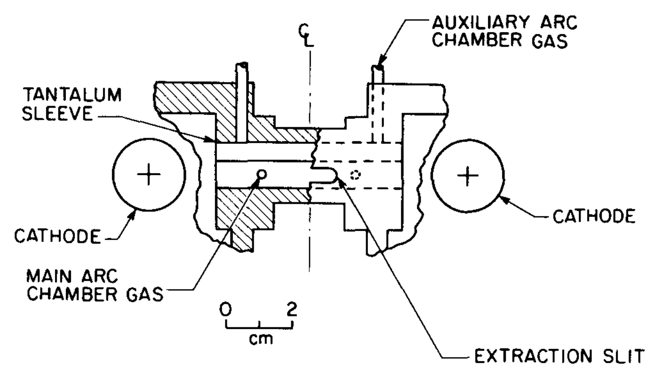


Fig. 2. Front view of the dual arc chamber source with a section removed to show the gas entry port to the main arc chamber and the cathode position in relation to the main and auxiliary arc chambers.

Figure 3 shows the phase history curve obtained using the ORIC measured magnetic field with the radio frequency set to 7.94 MHz. Adjusting only the main magnet current from 3403 A to 4393 A successfully allows the oxygen and nitrogen beams to be accelerated to 64 cm. This adjustment can be made rapidly, in less than one minute, so as to reduce the errors associated with ion source fluctuations.

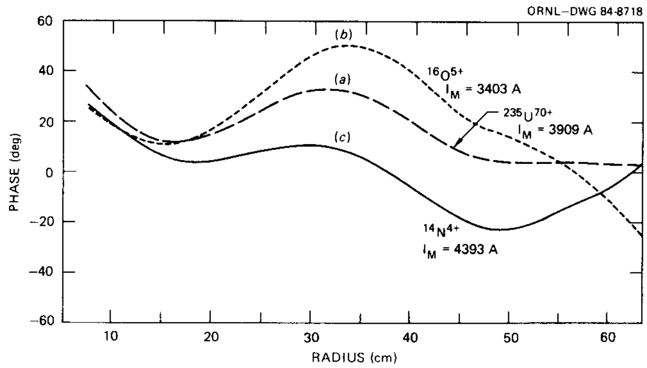


Fig. 3. Calculated phase relation between the rf and the beam for $^{16}O^{5+}$, $^{14}N^{4+}$, and the reference calculation for $^{235}U^{70+}$. Only the main magnet coil current was changed from the reference calculation to obtain the oxygen and nitrogen beams. Each beam makes about 145 turns to the radius at which measurements were made.

The following ion source experiments were conducted with ORIC. Two different gases were fed into the main and auxiliary arc chambers. For different arc conditions, the intensities of both charge states were then measured. The gases were then switched between the arc chambers and the experiment repeated.

## Ion Source Intensity Measurements

Two separate ion source measurements were performed. The first measurements were performed with neon and krypton gases. Figure 4 shows the intensity obtained for $^{20}Ne^{3+}$ as the neon gas flow is varied with fixed arc current. Curve (a) is with neon fed only to the main chamber. In this case, a maximum intensity of 9 μA was detected. Curve (b) is the maximum intensity of $^{20}Ne^{3+}$ that was detected when neon gas was fed into the auxiliary chamber. This intensity occurred for a krypton gas flow of 0.27 cc/min in the main chamber. A factor of 37 was observed between the maximum neon currents detected in the two cases. In this first experiment, the ORIC cyclotron was tuned only for the $^{20}Ne^{3+}$ beam.

In the second experiment (Figures 5 and 6), oxygen and nitrogen gases were used simultaneously and the ORIC cyclotron tuned back and forth between the $^{14}N^{4+}$ and $^{16}O^{5+}$ as previously described. Figures 5 and 6, are the data obtained for oxygen and nitrogen. With nitrogen in the main chamber at a fixed gas flow of 1.7 cc/min (a level correct for maximum beam current), the $^{14}N^{4+}$ beam intensity was 50 to 60 μA at 64 cm radius as the oxygen gas flow in the auxiliary chamber was varied (Figure 5). With the nitrogen gas moved to the auxiliary chamber and oxygen in the main chamber the $^{14}N^{4+}$ intensity reached a maximum value of only 1.7 μA as the flow rate was changed (Figure 6). Thus the intensity of the $^{14}N^{4+}$ beam was reduced by a factor of 30 to 35 when the gas entry point was moved to the auxiliary chamber.

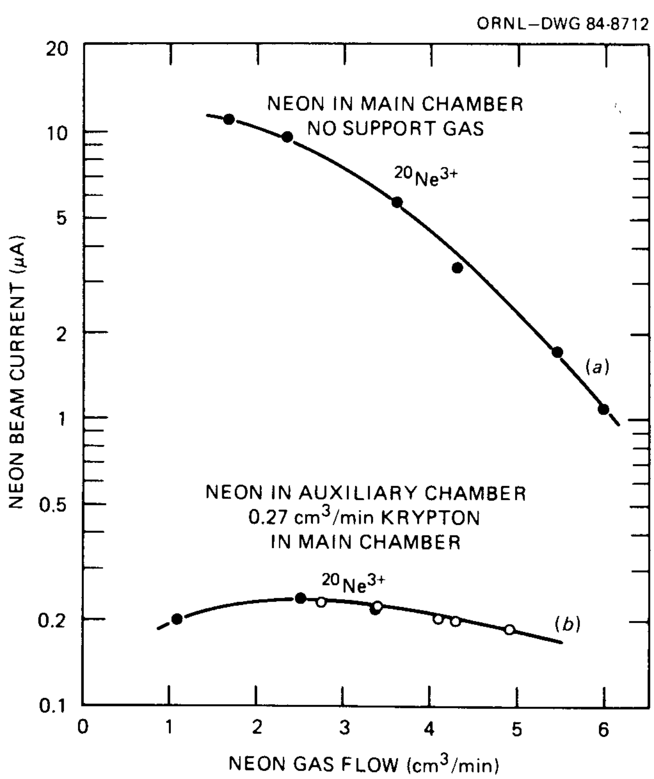


Fig. 4. Curve (a) is the intensity of $^{20}Ne^{3+}$ where neon is admitted to the main chamber with no support gas. Curve (b) is the $^{20}N^{3+}$ intensity with krypton support gas in the main chamber and neon in the auxiliary chamber.

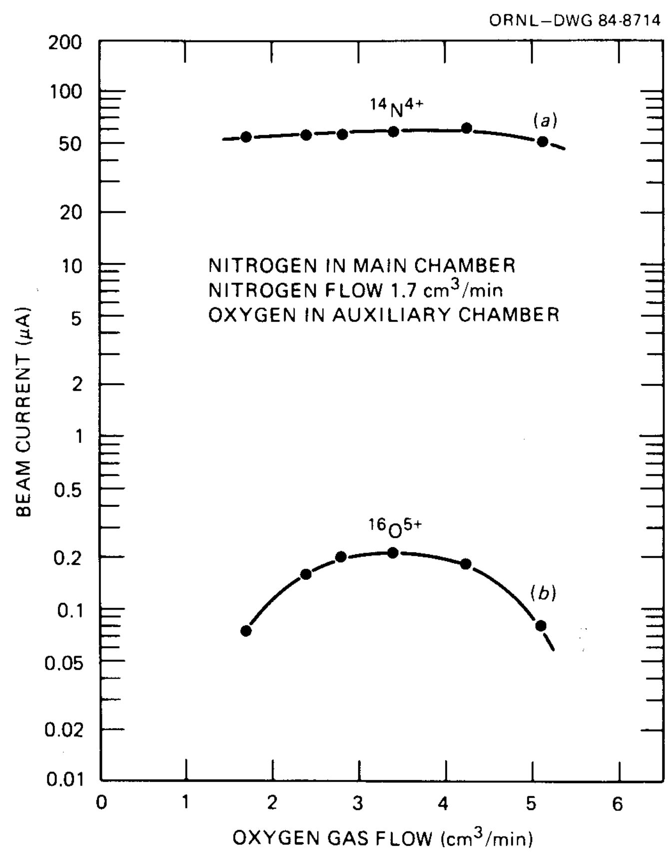


Fig. 5. Curve (a) is the intensity of $^{14}N^{4+}$ beam with nitrogen gas in the main chamber at a fixed flow. The flow of oxygen in the auxiliary chamber was varied. Curve 5(a) should be compared with 6(a) where the nitrogen was admitted to the auxiliary chamber. Curve 5(b) is the $^{16}O^{5+}$ intensity and should be compared with 6(b).

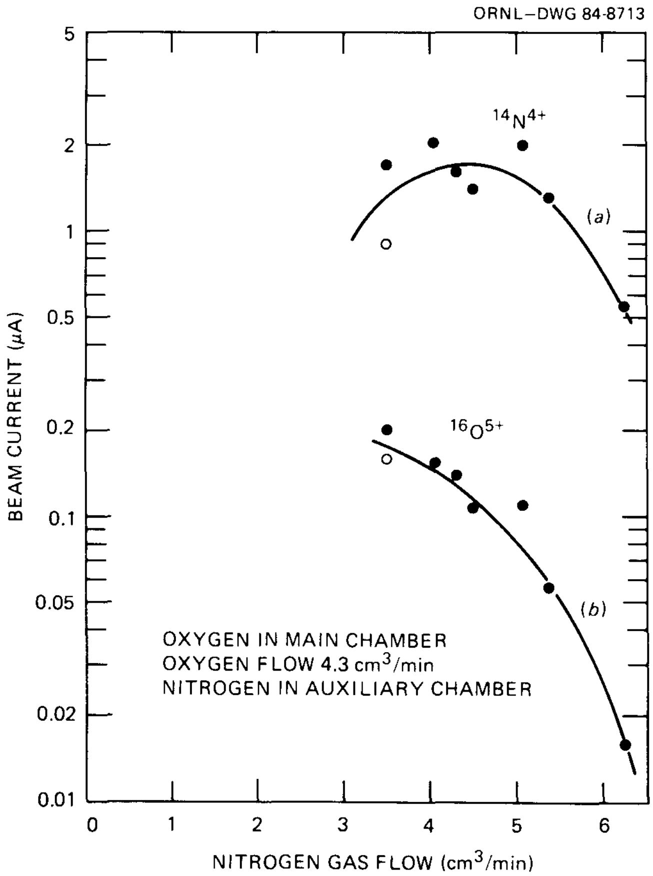


Fig. 6. Curve 6(a) is the intensity of $^{14}N^{4+}$ beam with nitrogen admitted to the auxiliary chamber. Curve 6(b) is the $^{16}O^{5+}$ beam intensity with oxygen admitted to the main chamber.

In comparing the oxygen data for similar conditions (Figures 5 and 6), practically no difference in intensity is observed. We believe that this occurred because the oxygen gas flow required for support of the main chamber arc was too high for optimum production of $^{16}O^{5+}$. Normally an oxygen arc without xenon or krypton support gas must start at fairly high flow rates and correspondingly low output. Over a period of 30 minutes to an hour the gas flow can be reduced and the beam current will rise substantially. In this case we had no suitable support gas and the oxygen flow rate remained high during the experiment.

## Conclusions

When either nitrogen or neon are admitted to the auxiliary chamber, only small currents of ions of those gases are accelerated from the main chamber. These results tend to support the hypothesis that gas supplied to the auxiliary chamber does not significantly contaminate the main arc but stabilizes it and increases beam intensity by either a favorable distribution of support gas at the cathodes or by heating of the cathodes by the auxiliary arc.

## References

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