Title
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HEAVY ION SOURCE DEVELOPMENT AT THE BEVATRON

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Abstract

The Bevatron 20 MeV duoplasmatron source is currently being modified with the goal of producing 1 mA of $^{20}Neon^{3+}$. Initial tests at 420 KeV show a total beam of 20 mA of which 400 μA is $^{20}Neon^{3+}$. The quantity of beam in various charge states is determined with a pulse field magnetic spectrometer.

Titanium sublimation and cryogenic pumping of the PIG source in the High Voltage Terminal and its resultant effects on the acceleration of carbon and nitrogen will be discussed.

Introduction

Duoplasmatron Development at the Bevatron is under way in response to a need to produce low emittance high intensity neon beams for the 750 keV EVE SuperHilac injector. The source used as a model for the above work is the 20 MeV duoplasmatron that was designed in 1961 as a 100 mA proton source.[1] Figure 1. The parameters that were optimized for greatest $^{20}Neon^{3+}$ production were the exit anode to Z electrode gap, the Z electrode diameter and canal length. A more comprehensive treatment of duoplasmatron configuration vs heavy ion charge state output is given in a Unilac report.[2]

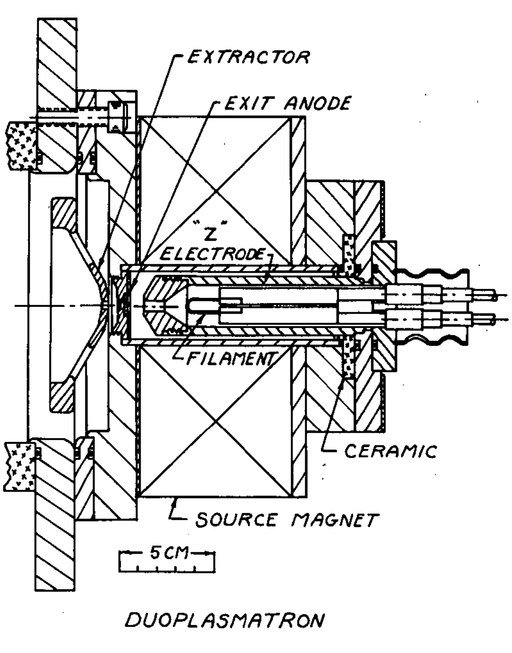

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Figure 1 Duoplasmatron

All initial tests were performed at 420 keV using a pulsed field spectrometer to determine the quantity of various charge states in the beam. Figure 2 shows a sketch of the spectrometer. The entrance collimator is .015 in. wide by .75 in. long and the drift length is 11 in. to the faraday cup. The faraday cup has a .020 in. wide aperture and can be moved to give a suitable offset. The magnet, located between the collimator and the faraday cup, is energized during the beam pulse by a pulsed 600 volt power supply. Figure 3 shows both the magnet field ramp and the faraday cup current displayed on the same time frame indicating particles of various charge states with the higher charge states showing at the left of the frame.

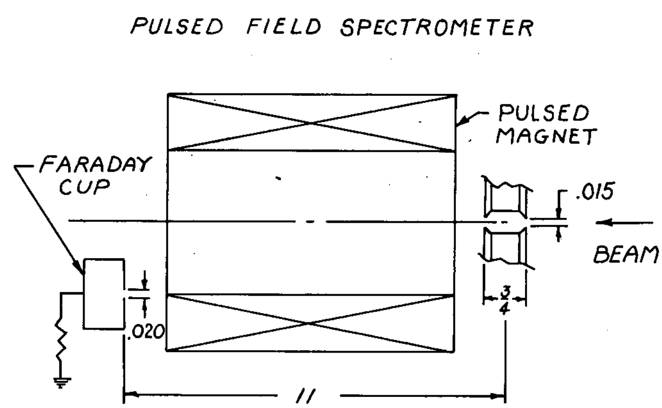

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Figure 2 Pulsed Field Spectrometer

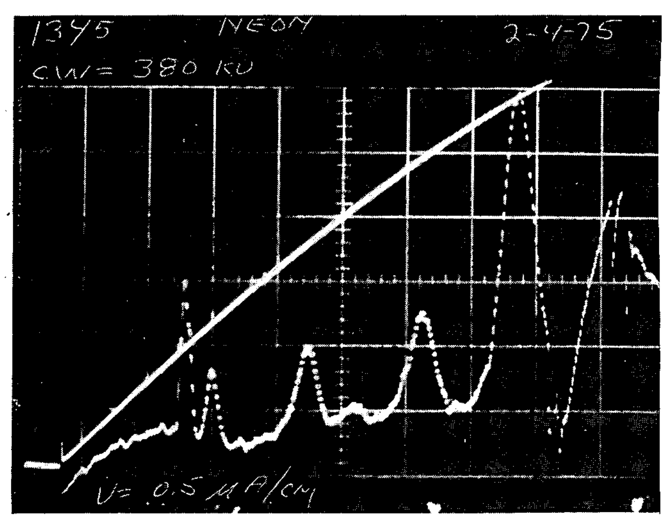

Figure 3 Spectrograph of neon beam showing pulsed field ramp and peaks of helium, nitrogen, and neon with $^{20}Ne^{2+}$ on the far right.

The spectrometer was initially calibrated on hydrogen and helium to verify the location of the various ions and then the source was tuned for $^{20}Neon^{3+}$. For any given physical geometry, the most critical parameter was inlet gas pressure, which was about 5 microns. A dual arc pulser is used to give independent control over cathode and Z electrode current of about 8 to 12 amperes. A 0.030 inch diameter source exit aperture was used to produce a total beam of 20 mA of which 2% was $^{20}Neon^{3+}$.

The source was then fitted to the spare source magnet from the EVE SuperHilac injector. Using an einzel lens and 35 kV extraction, approximately 20% of the beam was transmitted from the source through 107 degrees to a large faraday cup. The source emittance was measured to be 7.9π cm-mrad at 30 keV. Work is continuing toward developing a more efficient transport system.

Pig Source Improvement - Source Vacuum

An important area in the development of better heavy ion source performance lies in establishing adequate vacuum in the source chamber, and accelerating tube. A typical gas flow for nitrogen operation of 0.5 cc/min STP gives a Q of 6.3×10^{-3} Torr -1/sec. and with a conductance from source to the pumping manifold of 40 1/sec., a pressure of 1.6×10^{-4} Torr is obtained which is at a level where charge exchange losses for high charge state ions can be quite severe. Thus a Titanium pump and liquid nitrogen trap was designed for the source terminal. Figure 4

The main manifold at the ground end of the accelerating column is pumped by a 650 1/sec turbo pump, an 800 1/sec Hg diffusion pump, and a 400 1/sec vac-ion pump. The terminal end of the accelerating tube has a 400 1/sec vac-ion pump and the total of all pumps give a net speed at the downstream end of the source box of only 125 1/sec due in part to the low conductance of the long, small diameter accelerating tube.

It was thus necessary to open one end of the source box and provide as large an opening as possible so as not to be conductance limited. The limiting aperature restriction from source chamber to pump was made 3 1/2 x 5 inches thus permitting an additional 1750 1/sec at the source opening for nitrogen.

Operation

The initial tests of the Titanium pump were made with CO_2 gas, and during this time the system pressure was monitored at the CO_2 gas inlet, the source chamber and the accelerating tube vacuum manifold. Power was applied to the Ti-Ball pump in increasing increments until the source pressure reached a minimum valley at 2×10^{-6} Torr where the system indicated a conductance limited condition. During this time the gas valve was closed. Figure 5 CO_2 gas was then let into the system until the inlet pressure reached 200 microns, which is a reasonable level for running $^{12}C^{4+}$ ions. More power was applied to the Ti-Ball pump and once again the conductance limit was reached at a pressure now of 5.5×10^{-6} Torr. The titanium pump was then turned off and the source pressure stabilized within minutes to 6.2×10^{-4}, a factor of 100 higher in pressure.

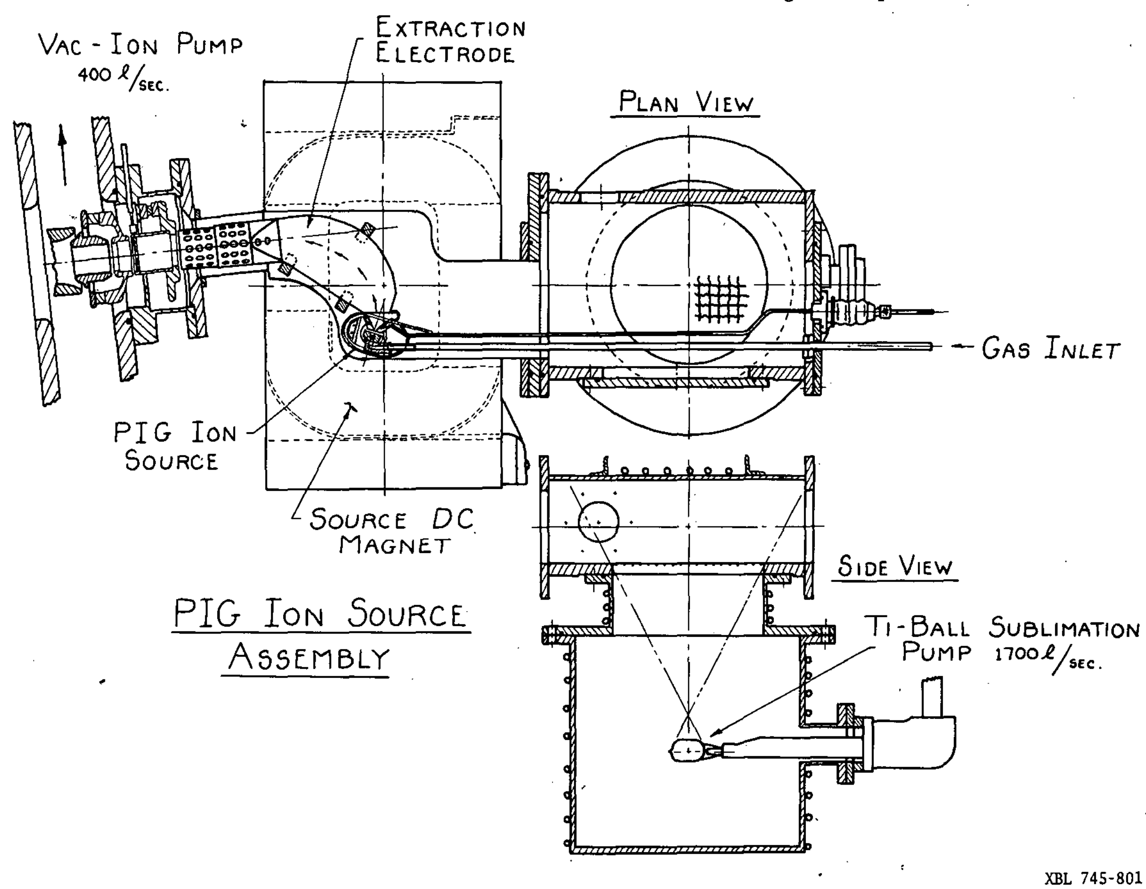

Figure 4 PIG Ion Source and Titanium Sublimation Pump.

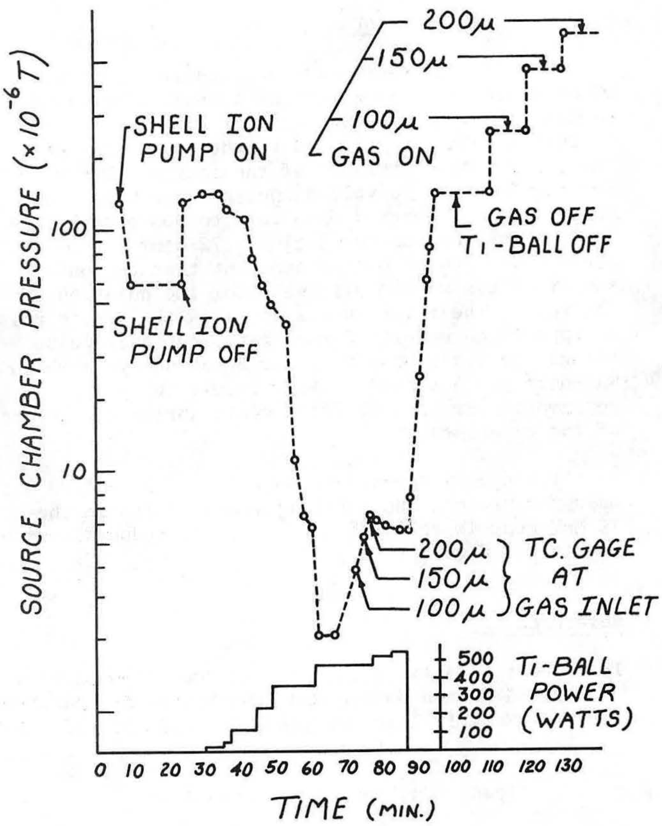

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Figure 5. Source chamber pressure vs time and titanium pump power.

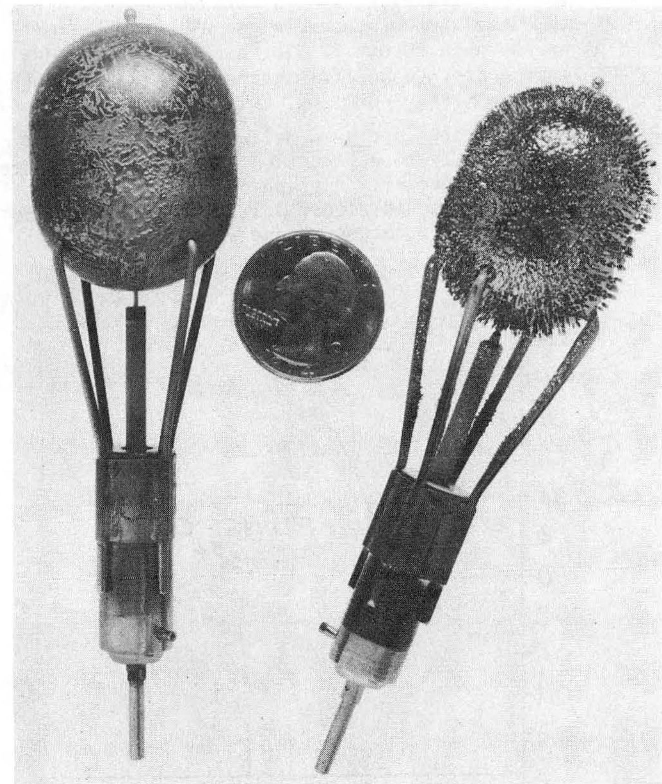

Figure 6. Comparison of two Ti-Ball units. Left unit is coated with titanium carbide and has failed.

The titanium sublimation pumping system has been in operation on the 20 MeV heavy ion source for several months. The rated speed for CO_2 is 1600 l/sec at a sublimation rate of 0.12 grams/hour giving a lifetime of about 270 hours for a 35 gram titanium ball. The best pumping occurs if the sublimation tank is cleaned and lightly sandblasted when the surface coating becomes too thick.

Contamination of Ti-Ball Pump

Pumping contamination has been experienced during operation with nitrogen or CO_2 gas, and is exhibited in the following manner. A gradual pressure rise is noted after a period of a few hours and increased pump power fails to recover the pump. Examination of the Ti-Ball elements shows that in all cases the surface is covered with a dull coating of titanium carbide that is extremely temperature and abrasive resistant. Figure 6 shows a picture of two Ti-Ball elements. The element on the left is contaminated and is covered with a dull layer of ti-carbide while the picture on the right displays a unit that was functioning well when removed and has approximately 90% of its titanium evaporated. An observation on this topic comes from Curtiss-Wright Corporation who have developed a plasma spray for the working surfaces of their rotary engines that shows extreme wear resistance. (4) The plasma is Ferro TiC which is a titanium carbide base embedded in a matrix of high chrome alloy steel. It has been found that the best way to avoid contamination of the pump is to keep the Ti-Ball hot enough to constantly evaporate new surface material.

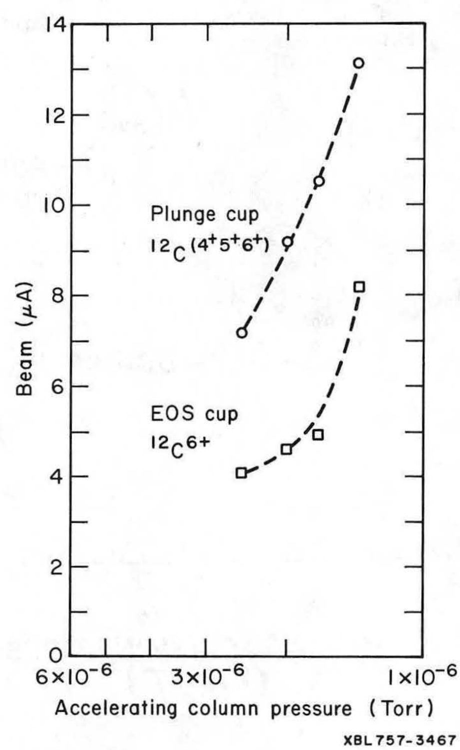

Figure 7. The effect of increased pumping speed on the amount of $^{12}C^{6+}$ injected into the Bevatron.

The added pumping speed increased the $^{12}C^{6+}$ beam injected into the Bevatron from 4 μA to a total of 8 μA as shown in Figure 7. The alpha beam showed a 50% increase to 100 μA of injected beam and although the titanium system pumps O_2, CO_2 and CO most favorably and does not pump helium. This increase was due primarily to a reduction in the base pressure of the source chamber. A graph of the performance of oxygen is shown in Figure 8 indicating a behavior similar to that of carbon as one would expect.

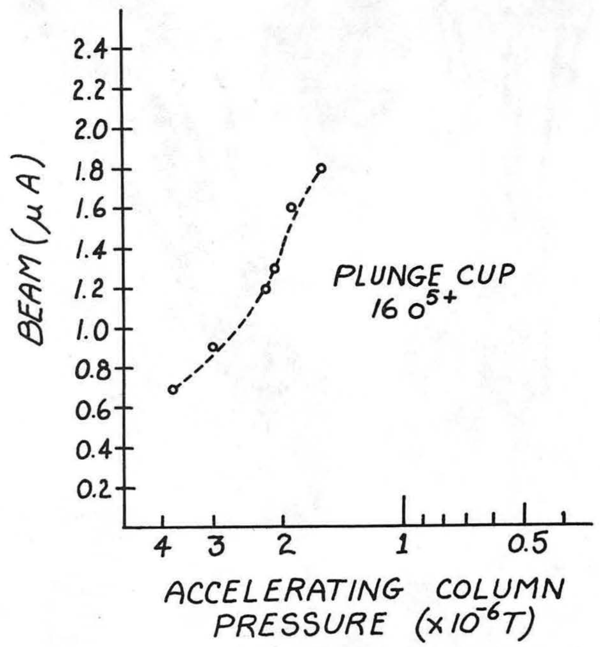

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Figure 8. $^{16}O^{5+}$ at 5 MeV/nucleon vs accelerating column pressure.

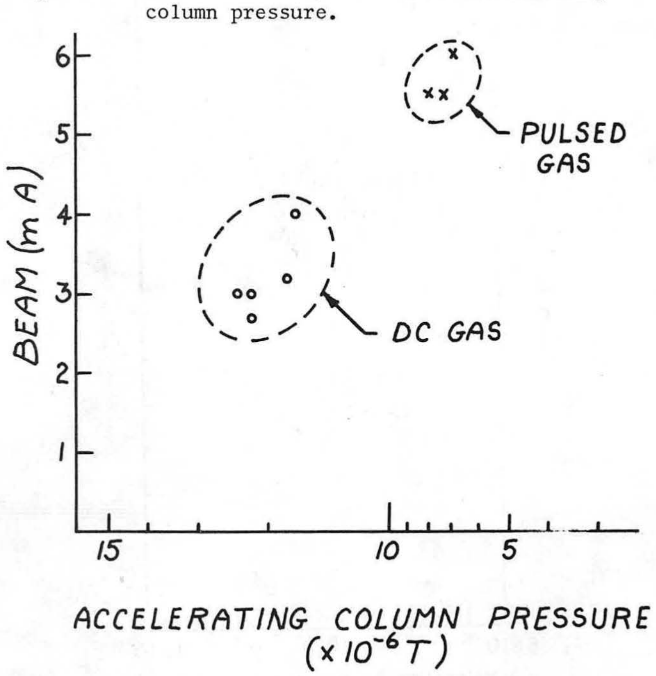

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Figure 9. 20 MeV protons vs accelerating column pressure.

Pulsed Valve Operation

The PIG ion source is operated at a pulse rate of 1 pps with a pulse length of 1 msec. The gas is supplied through a pulsed Skinner air solenoid valve to reduce both the gas load to the pumps and lower the average base pressure of the source. The valve is operated by a 30 volt dc pulse whose time and duration can be varied from zero to 900 msec. This feature was very useful during a 72 hour $^{15}N^{5+}$ experiment when it became apparent that the only supply of gas was insufficient for the duration of the run. The solution was to allow the arc to pulse at 1 pps which was its normal rate, but only pulse the gas to the source once per Bevatron cycle which was once per 6 seconds. As a result the gas consumption dropped to 0.15 cc/min during the balance of the experiment.

The source operates regularly in the pulsed gas mode for protons and a net increase of 75% in the 20 MeV beam is achieved due mostly to reduced source emittance. Figure 9

References

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4. Curtiss-Wright, "September 1974 POP-SC".

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