IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

A PENNING ION SOURCE IN A 7-MV VAN DE GRAAFF

P. Arndt, W. Jenter and H.-E. Mahnke
Hahn-Meitner-Institut für Kernforschung Berlin GmbH
Bereich Kern- und Strahlenphysik
1 Berlin, Germany

Summary

A Penning type ion source with axial extraction has been installed in the 7-MV Van de Graaff for the production of heavy ions. The source test in the accelerator and beam parameter measurements (currents with emittance and energy spread) proved the source to be adequate for the accelerator combination VICKSI.

Introduction

Within the accelerator project VICKSI[1] at the Hahn-Meitner-Institute in Berlin the existing 7-MV Van de Graaff (type CN from HVEC) is being changed into a heavy-ion accelerator to serve as the injector machine into a split-pole cyclotron. It is planned to produce beams of all kinds of ion species within the mass range from 1 to 40. In order to use the combined machine to its full capacity mostly doubly charged ions will be accelerated in the Van de Graaff with anticipated average currents of up to 20 μA.

The results on a Penning-type ion source with axial extraction[2] seemed to meet our proposed figures. However before designing a new Van de Graaff-terminal for the axial PIG-source it was necessary to see whether the source can fulfill the specific conditions dictated by space and power limitations as well as by the access time to the terminal of the single stage machine. Therefore in a first installation of the source no elaborate adaption was made but the normally used RF-ion source on the pulsed CN-terminal was simply replaced by the axial PIG-source with its own power supplies.

In the following we report on results and on the experience obtained during the 4-months period in which the Van de Graaff was run under typical experimental conditions with the axial PIG-source. Parallel to the machine test studies of essential beam parameters such as emittance and energy distribution were performed on a test-bench set-up before completing the design of the new Van de Graaff terminal for VICKSI.

Ion source and terminal arrangement

The axial PIG-source

The PIG-source with axial extraction was originally designed by Baumann, Heinicke and Bethge[2] who also did careful studies of the discharge behaviour[3]. The cold cathode discharge mode in which the source is run is characterized by a high discharge voltage, low discharge current and a pressure of about 10^{-3} torr. The charge-state distribution of the extracted beam indicated that single impact ionization is the dominant ionization process in the discharge.

For our purposes we had to change the construction of the source by improving the vacuum tightness against an external gas pressure of about 16 kgf/cm^2 and by reducing the power for the magnetic field produced by a solenoid around the anode cylinder. The dimensions of

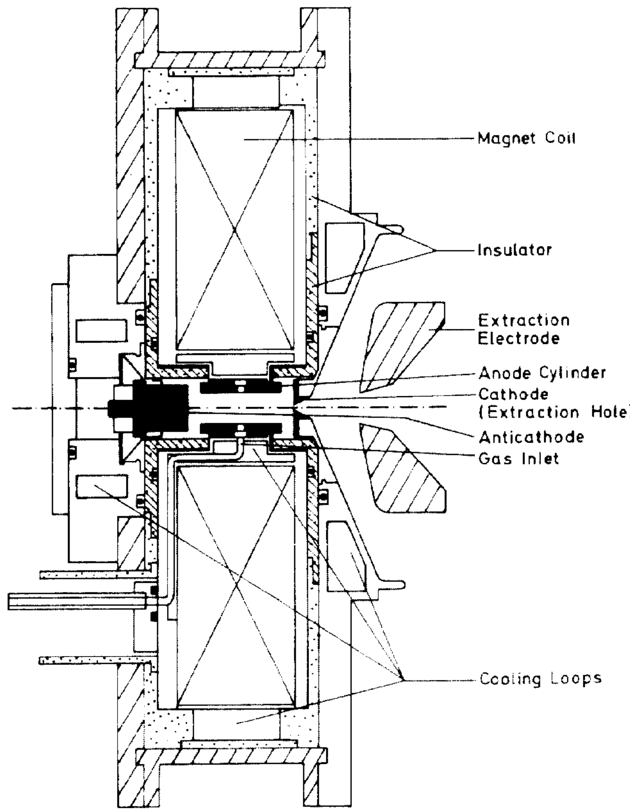

Fig. 1 Sectional view of the principle parts of the axial PIG-source.

the discharge chamber and the magnetic field configuration were kept as in the original design[2]. The principle parts of the source are shown in a sectional view in Fig. 1. The cathode-flanges are insulated from the coil with the anode cylinder by ceramic* inside the vacuum and by Vespel** outside. Cooling loops are built in around the anode cylinder, in both cathode-flanges and around the coil. In the Van de Graaff a small compressor circulates tank gas through the loops which is sufficient for cooling the source.

Typical operating data of the source with the gases used in our experiments were

arc voltage U_a = 1...4 kV

arc current I_a = 1..20 mA

magnetic field B = 0.5..1.1 kG

gas flow F = 3..15 st.cm^3/h

(for H_2 and He higher gas flows were sometimes used).

Summing up the power needed for running the source we get 280 W at maximum plus 80 W for the cooling compressor.

All power supplies for the source were conventional, unregulated power supplies. For optimizing the beam current the magnetic field (by the current through the coil), the arc voltage and, within certain limits given by the accelerator vacuum, the gas flow could be adjusted. The parameters were controlled by the measured beam current out of the accelerator and by meter reading by means of a closed-circuit television system.

Terminal arrangement

The beam formation and transport into the accelerator tube is done as in the original pulsed-CN-terminal:

> Extraction with a potential of up to 30 kV, einzel lens, 30°-magnet (mass-energy-product around 0.3 MeV).

The beam is focused by the einzel lens (object-distance 110 mm, image-distance 500 mm) onto a 3-mm diameter aperture followed by a tube focus (gap lens) to match the tube optics, and then accelerated in the HVEC-tube. Analyzed beams were measured behind a 90°-analyzing magnet.

Performance in the accelerator test

For the test in the accelerator three identical sources were prepared for quick source changing. Over the 4-months running period an average lifetime of the source of 180 hours was reached. When a source was replaced the ceramic insulators were cleaned and a new anticathode was mounted. The source was then run on the test bench for about an hour for a short test. During one "period" very often several gases were run which had no obvious effect on the performance of the source, esp. on its lifetime.

Due to the large magnification of the einzel lens in the terminal only a small fraction of the ion beam out of the source is accelerated.

Gas	I[μA] 1^+	2^+	3^+	4^+	5^+
H_2	2				
He	10	0.12			
N_2	1	0.07			
CO		C^{2+}:0.05			
Ne	> 1	1	0.04	$5 \cdot 10^{-3}$	
Ar	> 1	0.5	0.03	0.01	$0.5 \cdot 10^{-3}$

Tab. 1 Electrical currents of different analyzed ion beams out of the CN-Van de Graaff with the axial PIG-source.

In Tab. 1 the observed ion beam currents after acceleration up to between 3 and 7 MV and analyzing by a 90°-magnet are given.

Optimal parameters of different ion beams

Parallel to the accelerator test optimal beam parameters such as currents with associated emittances of different charge state separated beams were measured on a test bench set-up (the added adjective "optimal" also stands for long term stability). The separated beams were produced by 20-kV extraction, followed by a 64-mm diameter einzel lens and a crossed-field analyser (Wien-filter) of 130-mm length with a magnetic field strength of 2.1 kG produced by a permanent magnet. This arrangement together with the diagnostic elements (slit grid with 20 $0.3 \times 60\text{-mm}^2$ slits, and a slit of $0.3 \times 70\,\text{mm}^2$ mounted on a movable Faraday cup) is schematically shown in the insert of Fig. 2. An example of a slit grid spectrum and the corresponding emittance area is given in Fig. 2 for an Ar^{2+}-beam. The results for different ion beams are summarized in Tab. 2.

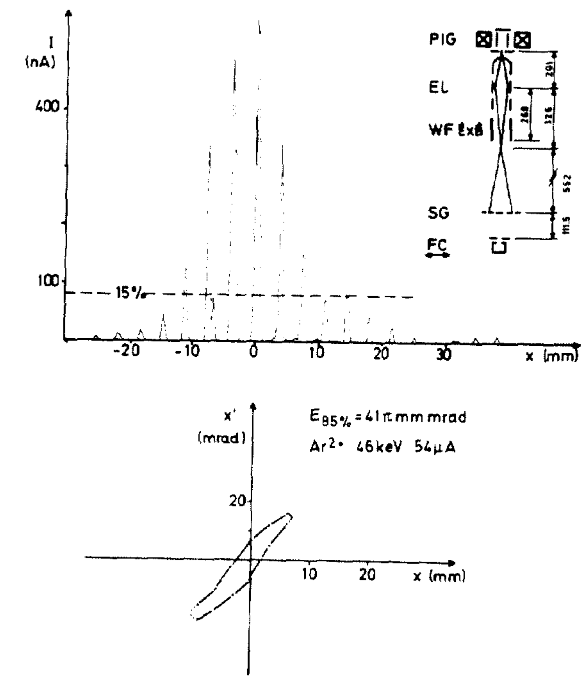

Fig. 2 Slit grid spectrum and emittance contour for about 85 % of an Ar^{2+}-beam of 46 keV.

Gas	I [μA] Molecule	1^+	2^+	3^+	$E_{80\%}$ [π · mm mrad] Molecule	1^+	2^+	3^+
H_2	370	40	-	-	30	65	-	-
^3He	-	225	1.2	-	-	70	85	-
N_2	870	120	6		100	65	80	
Ne	-	480	50		-	110	60	
Ar	-	600	54	5	-	60	35	40

Tab. 2 Electrical currents and emittances (of about 80 % of the respective beams) of different ion beams.

All emittances were measured in the direction parallel to the deflection of the Wien-filter. In a measurement along the vertical direction no measurable difference could be found. From the accuracy in the determination of the divergence which was mainly given by the width of the slits in the grid only an upper limit of the energy spread of less than 400 V could be deduced.

A better estimate was obtained from a bunching test experiment. Fig. 3 shows the observed time structure of a bunched Ar^+-beam of 24 keV at two different applied buncher voltages (amplitude) together with the sketched arrangement. The buncher frequency was 9 MHz; the corresponding bunching parameters are given together with the recorded and calculated curves. The measured half width of the pulses of 10 ns indicates that the energy spread must be less than 80 V, which is in agreement with a note given by Baumann and Bethge[4].

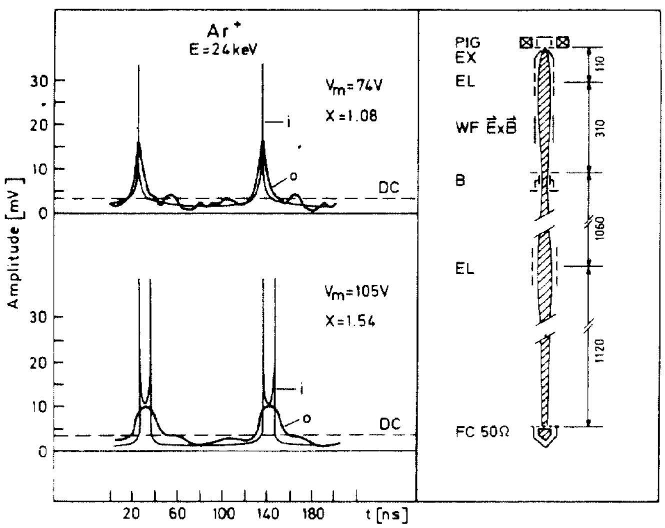

Fig. 3 Observed (o) and ideal (i) time structure of a bunched Ar^+-beam of 24 keV.

Conclusion

In the Van de Graaff test installation the axial PIG-ion source has proved to be a suitable source for use in single stage machines. Its lifetime is long enough to yield an adequate ratio of running to shut down time. The measured beam parameters as intensity, emittance and energy spread proved that with this source the anticipated currents with VICKSI can be reached and that this source may also be advantegeous for other purposes.

We would like to express our gratitude to Drs. H. Baumann, K. Bethge and E. Heinicke and to the II. Physikalisches Institut, Universität Heidelberg for generously letting a prototype of the ion source. We also thank Dr. H. Homeyer for his skillful help in getting the ion source project going and all VICKSI collaborators for their advices. Finally we want to thank Dr.D. Hilscher, D. Renner, D. Erdmann and all members of the terminal and Van de Graaff-crew and the technical department, without whose help the source test in the accelerator would not have been successful.

This work was supported by the Bundesminister für Forschung und Technologie.

References

* Frialit, Aluminum oxide, Friedrichsfeld GmbH.

** Polyimid, Dupont

1 VICKSI-proposal, HMI-report B-118 (1972)

2 H. Baumann, E. Heinicke, and K. Bethge, IEEE Trans. Nucl. Sci. NS-19 (1972) 88.

3 H. Baumann, E. Heinicke, and K. Bethge in Proceedings of the II. Intern. Conf. on Ion Sources, SGAE, Vienna (1972) 577.

4 H. Baumann and K. Bethge, Nucl. Instr. and Meth. 122 (1974) 517.