AN IMPROVED ION SOURCE EXTRACTION SYSTEM OF A 3 MV VAN DE GRAAFF ACCELERATOR

A VERMEER and A J VEENENBOS

Fysisch Laboratorium, Rijksuniversiteit, P O Box 80 000, Utrecht, The Netherlands

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The proton beam current available from our KN 3000 Van de Graaff accelerator has been more than doubled by the installation of a newly designed focussing electrode

1. Introduction

The HVEC KN 3000 Van de Graaff generator in Utrecht provided stable proton beam currents of up to about $90\ \mu\text{A}$. Higher beam-current settings caused the beam to jump to another "mode", in which the beam could not be adequately focussed. Fig 1 gives an illustration of this phenomenon measured with a beam profile monitor, placed at the position of the entry slits of the analysing magnet. A well focussed proton beam is observed for beam currents up to $90\ \mu\text{A}$ (lower beam). A small change in the settings of the control knobs leads to a badly focussed beam of $120\ \mu\text{A}$ (upper beam), that can hardly be manipulated by the ion-source controls, such as the gas- and magnet controls. The ion source had to be restarted from zero current to get back the well-focussed mode. During these measurements the generator was provided with a HVEC-C-SO-173 ion source, with a pyrex bottle and a stainless steel lined aluminum canal (length = 12 mm, $\varnothing = 2.1\ \text{mm}$). According to the specifications the source can deliver proton beams of more than 1 mA.

Fig 1 Profiles of the proton beam measured with a beam-profile monitor. Lower beam: a well-focussed proton beam of $90\ \mu\text{A}$. Upper beam: a badly focussed proton beam of $120\ \mu\text{A}$. The distance between the two markers is 38 mm.

Since high beam currents are essential for several nuclear structure experiments, the limitations of the beam current were investigated. Because the observed phenomena strongly suggested shortcomings in the functioning of the ion source and extraction system, this part of the accelerator was investigated in more detail.

2. The ion source system

The operation of the ion source and the extraction system was studied at the accelerator with rolled-off tank. The beam current of the ion source can then be measured by using the accelerator tube as a Faraday cup by electrically connecting all the electrodes. With this set-up it was found that at higher beam-current settings, the measured beam current was only a small fraction of the current on the focussing electrode. This caused a heavy loading of the focus power supply and impeded the functioning of the focussing electrode. Lowering the internal resistance of the focus power supply from $5\ \text{M}\Omega$ to $100\ \text{k}\Omega$ and increasing the rectifiers from 5 to 20 mA gave only a small improvement. The mentioned phenomena clearly show that at higher beam-current settings a gas discharge appeared between the exit of the source and the focussing electrode. This caused a blowing-up of the beam and partly a short-circuiting of the focussing electrode.

The vacuum at the focussing electrode, which is rather critical, is obtained by pumping via the accelerator tube. The conductance of the accelerating tube is rather low, for hydrogen between 30 and $40\ \text{l/s}$, depending on the pressure. At the source end of the tube the focussing electrode is mounted on a metal plate. The pressure at the extraction system of the ion source is obtained by pumping through the canal (length = 87 mm, $\varnothing = 14\ \text{mm}$) in the focussing electrode (see fig 2, lower half). This

Fig 2 The extraction system of the ion source. The lower half gives the set-up with the HVEC focussing electrode, the upper half the new configuration as described in the text.

causes a strong reduction of the pumping speed around the focussing electrode.

The discharge between the source and the focussing electrode is stimulated by the following two effects: backstreaming fast electrons produce hard X-rays which are only partly absorbed by the shield of HEVIMET material around the focussing electrode (see fig 2), the outer part of the ion beam sometimes hits the inside of the long canal of the focussing electrode, as can be shown in a geometrical consideration¹⁾. On the basis of these observations a new focussing electrode was designed, which will be described in the next section.

3. The new focussing electrode

In fig 3 the new focussing electrode is shown. The canal is 20 mm shorter than that of the old electrode, this prevents the ion beam from hitting the wall. The diameter of the extraction hole is increased from $\varnothing = 6$ mm to $\varnothing = 10$ mm. At the end piece of the focussing electrode four big slots ($\varnothing = 24$ mm) are milled to make full use of the available pumping speed at the extraction system.

The vacuum in the accelerator was previously produced by a Pfeiffer turbomolecular pump system with a pumping speed of 260 l/s, which has a low compression ratio for hydrogen²⁾. An Edwards Diffstak pump has now been installed, which has a pumping speed of 1300 l/s for hydrogen. Due to its smaller dimensions it could be installed closer to the exit of the accelerator.

Sometimes, a change was observed in the column current during adjustments of the beam. This happens when a part of the beam hits the tube electrodes. This disturbing effect could be avoided by electrically connecting two tube electrodes to the focussing electrode, which makes the transition from the focussing electrode to the first tube electrode more gradual. At the same time the resistor of the first electrode was changed from 400 M Ω to 200 M Ω (see fig 2).

4. Results

With the improvements mentioned above the accelerator provides proton beams of more than 200 μ A on target in the energy range from 1 to

Fig 3 The new focussing electrode

3 MeV. The horizontal and vertical exit slits of the analysing magnet were 2 mm. In the whole energy range the beam could be adequately adjusted with all ion source parameters. Optimization of the ion source beam was facilitated by making the current through the source magnet adjustable, in the original design it had a fixed value.

It is expected that, due to better operation conditions, the lifetime of the ion sources will increase considerably. Statistics are, of course, not yet available, but the lifetime of the first source operating in

the new set-up was more than twice the average lifetime obtained previously.

The high beam currents have been essential in recent experiments on resonant absorption of high-energy gamma rays³⁾.

References

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