MICROGAN ECR ION SOURCE IN A VAN DE GRAAFF ACCELERATOR TERMINAL

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Abstract

The Van de Graaff accelerator at IRMM works since many years providing proton, deuteron and helium beams for nuclear data measurements. The original ion source was of RF type with quartz bottle. This kind of source, as well known, needs regular maintenance for which the accelerator tank must be completely opened. The heavy usage at high currents of the IRMM accelerator necessitated an opening about once every month. Recently, the full permanent magnet Microgan ECR ion source from PANTECHNIK was installed into a new terminal platform together with a solid state amplifier of 50 W, a dedicated dosing system for 4 gases (with respective gas bottles H2, D2, He and Ar), and a set of dedicated power supplies and electronic devices for the remote tuning of the source. The new system shows a very stable behaviour of the produced beam allowing running the Van de Graaf without maintenance for several months.

INTRODUCTION

The high intensity quasi mono-energetic neutron source at IRMM is driven by a vertical 7 MV Van de Graaff accelerator (VDG) producing either continuous or pulsed ion beams [1]. The accelerator is operated 24 hours a day and seven days a week. The maintenance cycle with the original RF source was about once a month. In order to improve availability of the machine as well as the operation of the ion source, it was decided to replace the RF source with an ECR ion source and also update the high voltage platform.

The Microgan ECR ion source [2] working at 10 GHz is now providing single-charged or multi-charged ions like proton, deuteron, helium and argon.

We will recall the principle of this ion source adapted to the existing beam line before describing the Van de Graaff accelerator high voltage platform constraints and technical solution adopted. The command and control hardware/software will be discussed. Finally, beam results in term of tuning, intensity and stability will be presented.

Microgan Ion source

The Microgan is an ECR ion source, for which the magnetic circuit is entirely made with permanent magnets both for the radial and longitudinal fields, so the total electrical power is extremely low. The minimum B structure (Fig. 1) is made to work with a 10 GHz RF wave. This source can work with RF power up to 200 W (if water cooled) depending on the element and charge state needed.

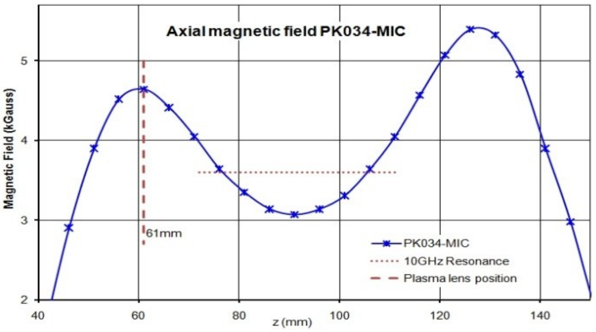


Figure 1: Microgan axial magnetic field

In this application, the requirement of 60 µA intensity for all beams (see table 1), led us to work with 50 W of maximum RF power if the plasma chamber is not cooled.

Table 1: Microgan intensities & VDG requirements

Usual guaranteed intensities (in µAe)							VDG
Ions/Q	1	2	3	4	5	8	1
H	7000						60
D							60
He	5000						60
O	4000	400	170				
P	2000	1200	700	200	20		
Ar	2000	1290	600	220		20	

Nevertheless, the ion source produces too high intensity with respect to the Van de Graaff limitations and the emittance of such an ECR ion source. Simulations with QuickfieldTM software and beam transport calculations combined with measurements done on a dedicated test bench at the Pantechnik's factory, that reproduced the first part of the accelerator, rendered the final set-up as shown in Fig. 2.

The plasma electrode aperture has been reduced to 3 mm in diameter. A simple gap extracting puller is followed by an Einzel lens to adapt the beam at the entrance of the present 30° analysing magnet. The plasma electrode aperture has been reduced to 3 mm in diameter. A simple gap extracting puller is followed by an Einzel lens to adapt the beam at the entrance of the present 30° analysing magnet.

This magnet is useful to clean the beam from contamination, especially to remove the molecular beams. We optimized the mechanical size of each element in order to maximize the analysed beam characteristics (size and intensity) in the buncher that is used for the pulsing system.

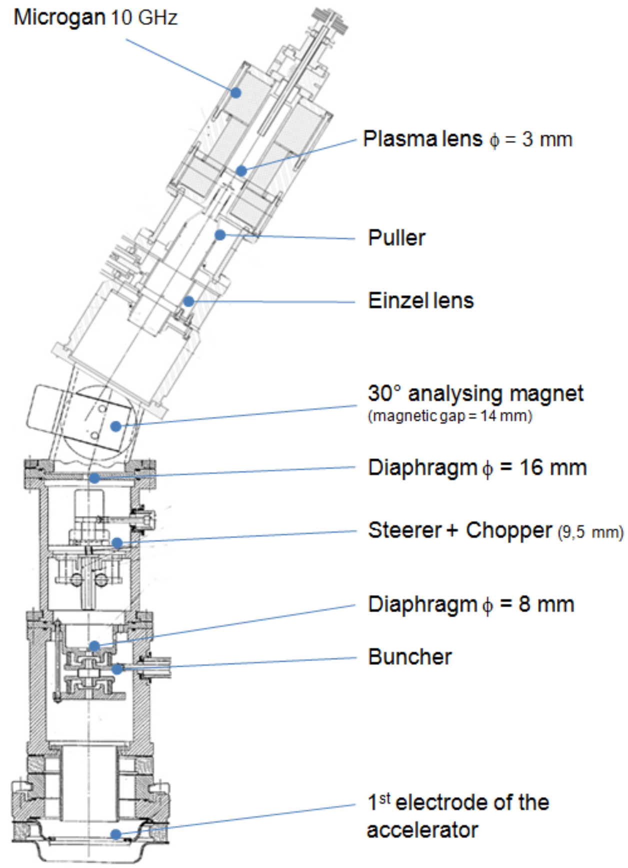


Figure 2: Overview of the VDG beam line before the high energy acceleration

VDG PLATFORM AND CONSTRAINTS

The Van de Graaff accelerator terminal is filled with up to 15 bars of a mixture of dry N2 (80 %) and CO2 (20 %) with a minor adding of SF6. This condition led us to test all critical parts that have to work under this pressure condition. A 15 bars test tank was built and used to test all mechanical components as well as electronic devices while powered (see Fig.3.a). Thus, the solid state 10GHz RF amplifier was tested together with the coaxial to wave guide designed feed-through. This component has to work at high pressure and in the same time has to be sealed with a leak rate under vacuum side better than 10-9 mb.l.s-1. The RF signal is generated with a DRO followed by a remote DC control attenuator allowing the RF power control.

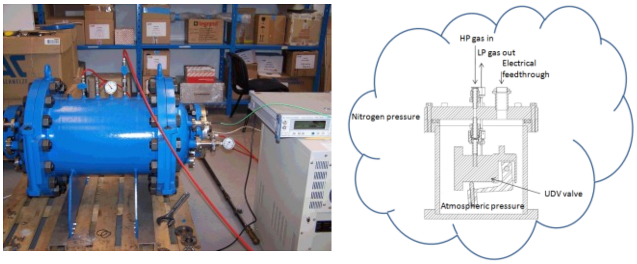
Mechanical constraints were taken into account also for the gas system which is fully high pressure proof. The dosing valves (Pfeiffer UDV type, see Fig.3.b) are under atmospheric pressure in a dedicated closed container allowing a reliable behaviour. Four gas circuits are connected to the two dosing valve in the way that gas mixing of argon and helium allows producing multi-charged ions of argon (see Fig.3.c). Gas changing from proton to deuteron or helium and argon is remote controlled. About 3 hours are needed to change ion. The life time of a full gas bottle is several months of usage.

Special efforts were made to minimize the size of all equipment on the high voltage platform as the space is limited. On the other hand, the lack of any cooling liquid on the high voltage platform required the use of some pressure proof fans to cool down ECR components.

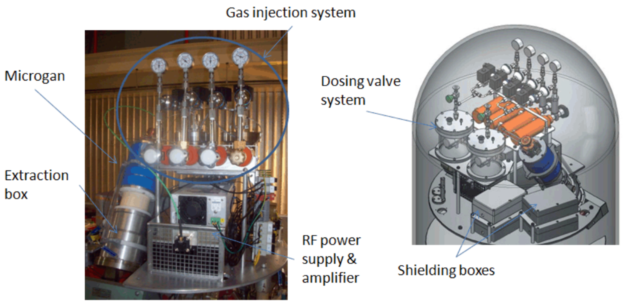
The most important electrical constraint is the low total power available on the high voltage platform (about 1500 W at 400 Hz AC current). A part of it (50 W maximum) is used by the RF amplifier and the rest is used for the electronic devices and power supplies.

Since the Van de Graaff is operated at high voltage up to 7 MV, all electrical components need a hard protection against electrical sparks and discharges. This protection is achieved by placing the components in dedicated shielded boxes where all cables (power and signals) are plugged on special CEM protected feed-through.

The last constraint is given by the charge the belt of the Van de Graaff is able to provide which corresponds to about 200 µA of ion beam current. That's why the full current of the source has been reduced with a small plasma lens aperture (3 mm) and a low RF power (few watts). The analysing magnet allows the selection of the ion beam of interest together with a stable behaviour of the column with almost 60 µA for each kind of ions.



3.a) Pressure test tank 3.b) Dosing valve system



3.c) high voltage platform view

Figure 3

SIMULATIONS, TRANSPORT, TEST BENCH

Simulations of the electric field of the extraction system have been carried out with the QuickField^{TM} software (see Fig. 4). The puller with a 10mm aperture is facing the plasma electrode with a 25mm gap. It's immediately followed by an Einzel lens. This system can operate with a 15 to 30 kV extraction potential, while the Einzel lens potential is about 2/3 of the extraction. Beam calculation have been carried out with TRANSPORT[1] software (Fig. 5) and predicted a high efficiency of the beam focussing at the entrance of the bending magnet (100 %) and ensuring more than 40 % of the full collimated beam in the the buncher system.

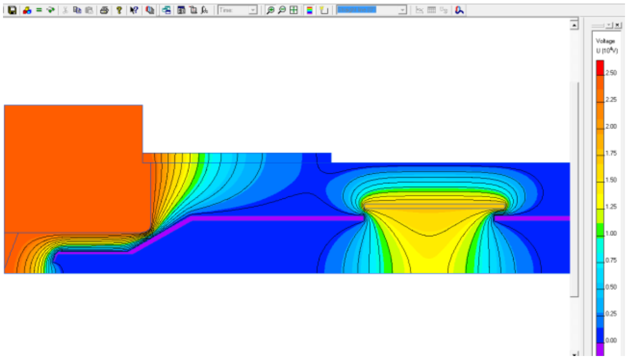


Figure 4: Extraction and focussing electric field simulation

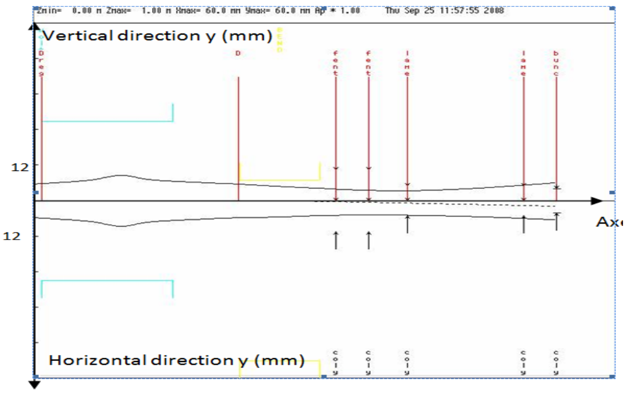


Figure 5: Vertical and horizontal D+ beam envelope

Those results were verified on the dedicated test bench built at Pantechnik's factory. The maximum beam size measured was 12 mm in diameter at the entrance of the magnet. The diaphragm at the entrance of the buncher with an 8mm aperture clearly reduces by about 60 % the beam intensity.

This bench was also used to find out the best parameters in terms of transport together with the more stable beam parameters for the tuning of the ion source (gas, RF, extraction mechanical adjustments).

COMMAND & CONTROL

The hardware consists of 3 CNA control modules (from Group3 company) to control all signals (D/A) for the gas system as well as the RF amplifier and generator ones (Fig. 6). They are all connected together in series with optic fibers. The main tank of the Van de Graaf is equipped with a single optic feed-through and the last fiber is going to the command and control room. A dedicated computer running a Labview^{TM} software controls the ion source and the extraction system.

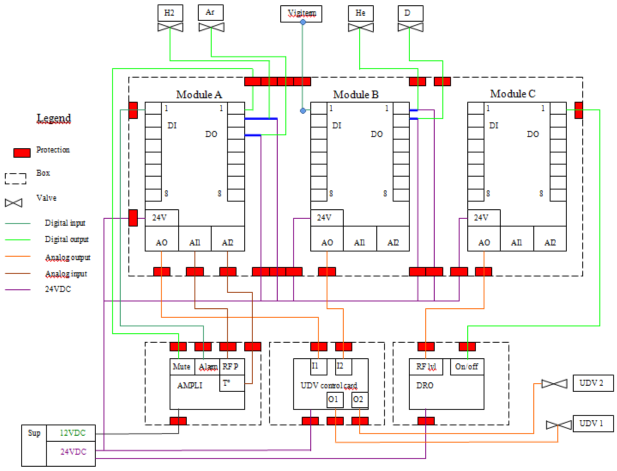


Figure 6: C&C hardware principle

RESULTS

On site acceptance tests have been successfully carried out in May 2010. The easy tuning of the system was demonstrated as well as the high reliability. The required intensities were measured at 3 MeV acceleration voltage on the accelerator column. Table 2 below shows the different parameters and intensities obtained at the bottom of the column, i.e. vertical position of the Faraday Cup. One should note that each beam has been identified with the mass spectrometer after the 3 MeV acceleration.

Table 2: Beam currents and parameter

Ion	P col	Uext	I ext	P RF	Gaz	U einzel	I CF25
Type	10^{-6} torr	turns	mA	W	Type	kV	µA
H^+	1.13	33	1.2	14.8	H_2	27.75	65
D^+	1.21	26	1.5	14.9	D_2	20.72	75
D_2^+	1.21	26	1.5	14.9	D_2	20.72	>100
He^+	0.92	26	<1	10.3	He	20.31	62

The H^+ beam at 60 µA was maintained without any operator neither regulation loop during 48 hours (see Fig. 7) to demonstrate the stability of the system. “Night and day effect” (temperature variation) was observed and induced +/-5 % change on the beam intensity for which the requirement was +/-20 %.

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[1] TRANSPORT PSI software

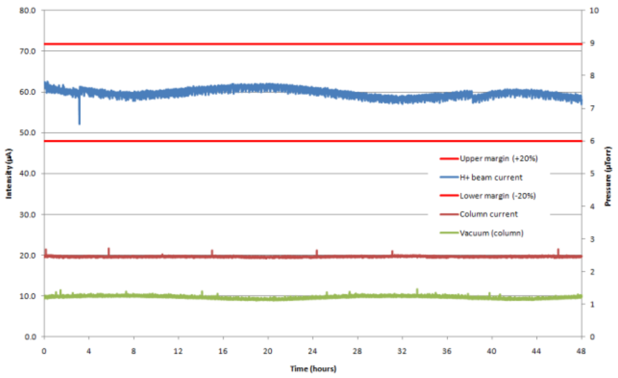

Figure 7: Beam stability recording

CONCLUSION

A new high voltage terminal in the Van de Graaf accelerator at the IRMM laboratory including a MicroganECR ion source was installed and commissioned in May 2010. It was demonstrated that the new system fulfilled the difficult constraints of such accelerator with high pressure conditions and an electrostatic sparking environment. H+, D+ and He+ beams were measured with the required intensities. The H+ beam stability was demonstrated through 48 hours operation without any intervention.

The system is supposed to have a high reliability and will allow to reduce the number of periodical maintenance of the machine.

Further tests are now needed to verify the ability of the system to work in the pulsed mode using the present chopper-buncher system.

[1] http://irmm.jrc.ec.europa.eu/html/about_IRMM/laboratories/The_Van_de_Graaff_laboratory.htm
[2] C. Bieth et al., RSI, 71, 899 (2000)