COMMISSIONING OF THE RFQ1 INJECTOR*

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Abstract

The RFQ1 accelerator is being developed at Chalk River to test the limits of cw RFQ technology. A 50 kV injector has been built and is now being commissioned as the first phase of the program. This paper describes some of the innovative features of the RFQ1 injector and reports on initial operating experience.

Introduction

The RFQ1 cw accelerator[1] is a radiofrequency quadrupole designed to accelerate 75 mA of protons to 600 keV. The development of RFQ1 at Chalk River was undertaken to verify design and construction techniques for future applications of cw RFQ's. The RFQ1 injector[2] must supply a well matched beam to the RFQ with the proton beam current smoothly variable from zero to 90 mA while the injection voltage remains fixed at 50 kV. A suitable injector has been built and is being commissioned. The ion source, the beam transport system and the ancillary equipment that comprise the injector are described below along with some preliminary test results.

Ion Source

Two suitable ion sources are readily available. The CRNL duoplasmatron[3] (see Fig. 1), originally developed for the Fast Intense Neutron Source (FINS), generates ion beams with high atomic fractions at relatively low beam currents. On the other hand, the CRNL duoPIGatron[4], shown in Fig. 2, produces high total beam currents with relatively low proton fractions. By tailoring the extraction geometries,

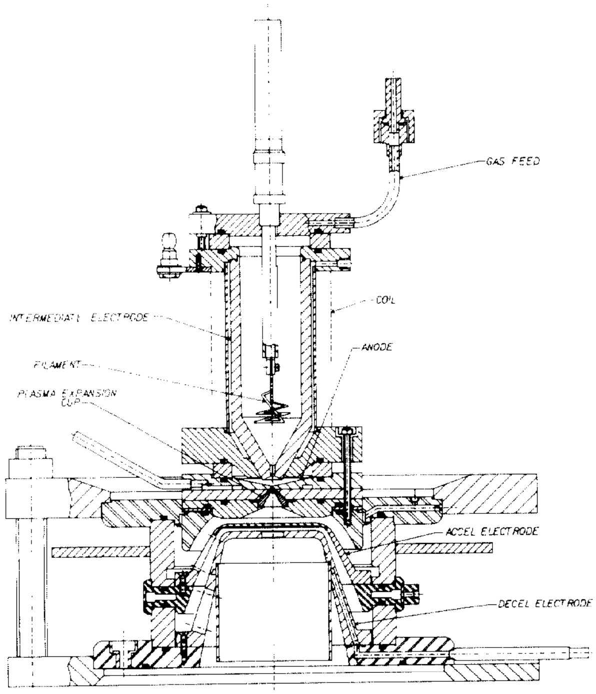

Fig. 1 The CRNL duoplasmatron ion source.

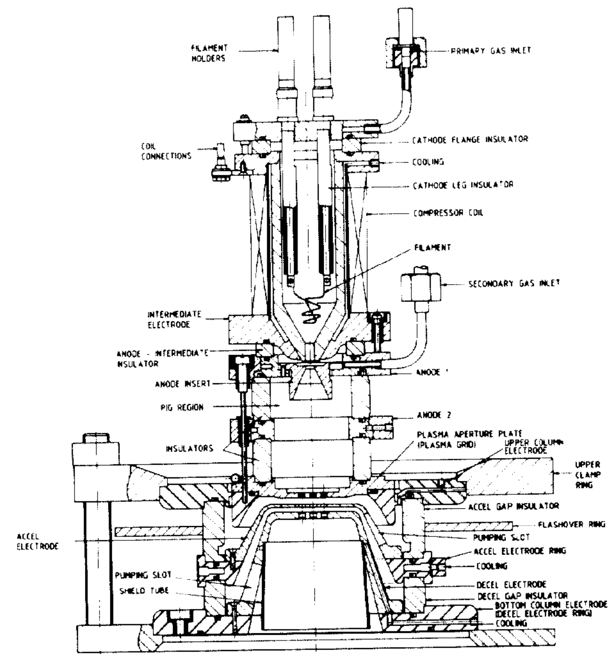

Fig. 2 The CRNL duoPIGatron ion source.

different phase-space distributions can be obtained from the two sources while maintaining essentially the same emittance. Specifically, the duoplasmatron is equipped with a single 1.0 cm diameter extraction aperture whereas the duoPIGatron has three extraction apertures 0.5 cm in diameter arranged in an equilateral triangle with 0.76 cm centre-to-centre. The normalized rms emittance of the beam from either source is expected to be less than 0.04 π cm-mradians.

The proton current is adjusted by operating the plasma generator with various mixtures of hydrogen and an inert gas. The flow of hydrogen is chosen to give the desired proton current while the flow of the inert gas is regulated to keep the extraction column matched at 50 kV leaving the emittance virtually unchanged.

Beam Transport

The beam transport system performs two equally important functions. Firstly, unwanted species such as H_2^+, H_3^+ and inert gas ions are separated from the protons. Secondly, the slightly divergent beam from the ion source is matched to a 0.9 cm diameter waist at the entrance to the RFQ with minimal emittance growth. Both objectives are achieved with a relatively simple three element system. The divergence of the beam from the ion source is reduced by a 15 cm long solenoid with a 7 cm diameter bore and a maximum induction of 0.25 T. The various species are then separated and the proton beam is focused equally in both planes by a 60° bending magnet with entrance and exit pole face rotations of 22.1°. The magnetic induction is only 82 mT corresponding to a nominal bending radius of 40 cm which provides complete sepa-

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ration of the protons from the unwanted species after a short drift. A 16 cm pole gap accommodates the vacuum chamber walls as well as water cooled liners. The divergence of the beam will be adjusted yet again by a 13 cm long solenoid with a 6 cm diameter bore and a maximum induction of 0.45 T that will eventually be mounted 15 cm from the entrance to the RFQ.

The magnet vacuum chamber is equipped with a ± 5° gimbal for aligning the ion source, numerous diagnostic ports, a plunging swirl-tube beam dump at the exit port and separate beam dumps for undeflected beams and molecular ions. The residual gas pressure is adjusted to achieve a compromise between multiple scattering and space-charge compensation. The entire assembly is shown in Fig. 3.

Ancillary Equipment

A novel system supplies filament, coil and arc power to the ion source. Each power supply has been split into two separate chassis. One houses the rectification circuitry and is situated in the high voltage dome. The other contains the control circuitry and is located in the control and instrumentation cabinets at ground potential. An optically coupled telemetry system[5] provides electrically isolated feedback. A separate high-voltage isolation transformer transfers power from each control unit to the corresponding rectification unit. This arrangement makes the power supplies less susceptible to malfunctions caused by arcdowns and also facilitates computerized data acquisition and control. The optically coupled telemetry system also accommodates the remote control of the gas flows to the ion source via mass flow controllers.

Three diffusion pumps, each with a pumping speed of 8000 L/s for hydrogen, evacuate the magnet chamber. Flap valves (see Fig. 3) are used to reduce the pumping speed, increasing the residual gas pressure to the desired value. The vacuum system is operated via a programmable controller (PC) by a vacuum process controller (VPC). The VPC monitors the vacuum with ionization and convectron gauges, displays the pressure digitally and supplies process control signals to the PC and vacuum status signals to the computerized control system. The PC ensures that the vacuum system is started up and shut down in the correct sequence. In addition, in the event of an excursion the PC closes the vacuum chamber entrance and exit ports and shuts down the vacuum system so that damage to components is minimized.

A 19 L/s recirculating deionized water cooling system operating at 860 kPa supplies the 3 L/s of coolant required by each swirl tube beam dump and, in addition, cools the emittance measuring unit that will initially be fitted to the exit port of the injector and later to the exit port of the RFQ. The heat exchanger maintains coolant temperature at less than 40°C. The deionizer which insures a minimum water resistivity of 10 MΩ-cm operates on a parallel circuit even when the main circuit is shut down. The beam dump cooling circuits are fitted with computer-controlled solenoid-actuated pneumatic valves. These circuits are also equipped with flow, temperature and pressure transducers all of which are monitored by the computerized control system.

The computerized data acquisition and control system is described in a companion paper[6].

Status

All electrical, vacuum and cooling systems have been fully commissioned. An overview of the completed injector is shown in Fig. 4.

A pressure of 3×10^{-6} Pa (2×10^{-8} Torr) has been achieved in the magnet chamber with the source valved off. Even with a source gas load of 16 sccm, a 5×10^{-4} Pa (4×10^{-6} Torr) vacuum can be maintained. The diffusion pumps are not equipped with isolation valves. Nonetheless, injector operation has not been impaired by backstreaming of oil even when the pumps are not started simultaneously.

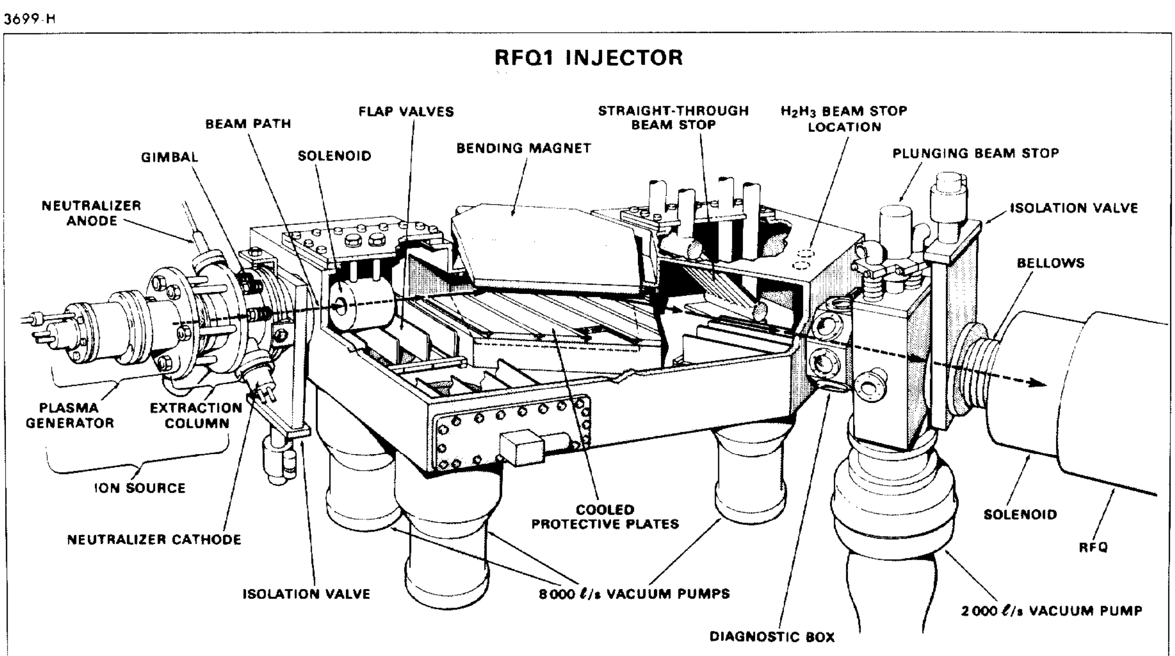

Fig. 3 Artists impression of the RFQ1 injector.

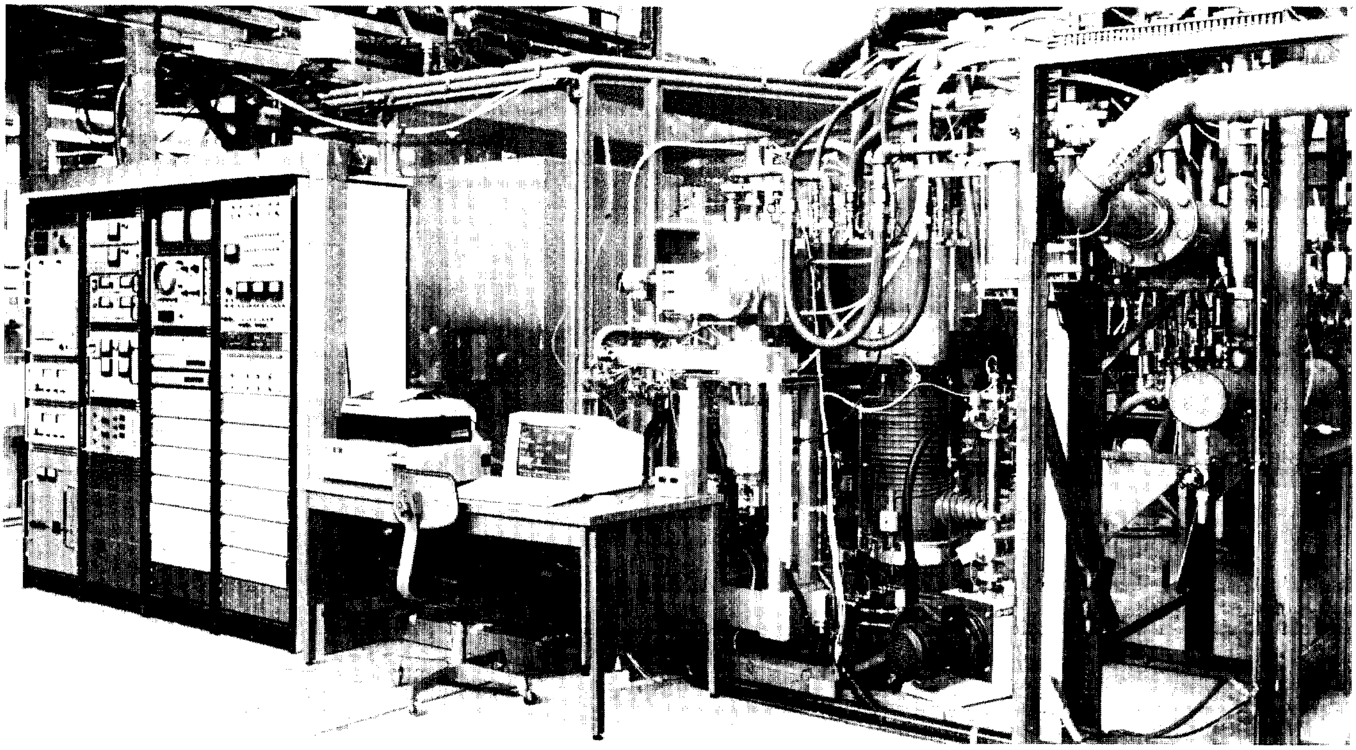

Fig. 4 Photograph of the RFQ1 injector.

Splitting the ion source power supplies has proven to be an effective method of confining voltage breakdown damage to the rectification circuitry, thus minimizing down time. The mass flow controllers were unsuitable for ion source applications as delivered. To minimize settling time, the manufacturer had introduced an overshoot of up to 100%. The overshoot was reduced to less than 2% with a settling time of less than 1 s by using a ramped high impedance source to generate the control signal.

A beam has been extracted from the duoPIGatron ion source and transported through the first solenoid and the bending magnet to the plunging beam dump. The proton fraction at an extraction voltage of 32 kV with a total beam current of 110 mA was 37%. The proton current from the ion source has been varied from 1.2 mA to 40 mA at a fixed extraction voltage of 32 kV while maintaining an approximate match by mixing argon with the hydrogen feed gas. The ion source has been conditioned to 50 kV and operated with a total current of 210 mA. The proton fraction has yet to be measured at 50 kV but is expected to be approximately 47%.

Emittance measurements will be made and a beam will be injected into the RFQ by the end of 1987.

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