Title
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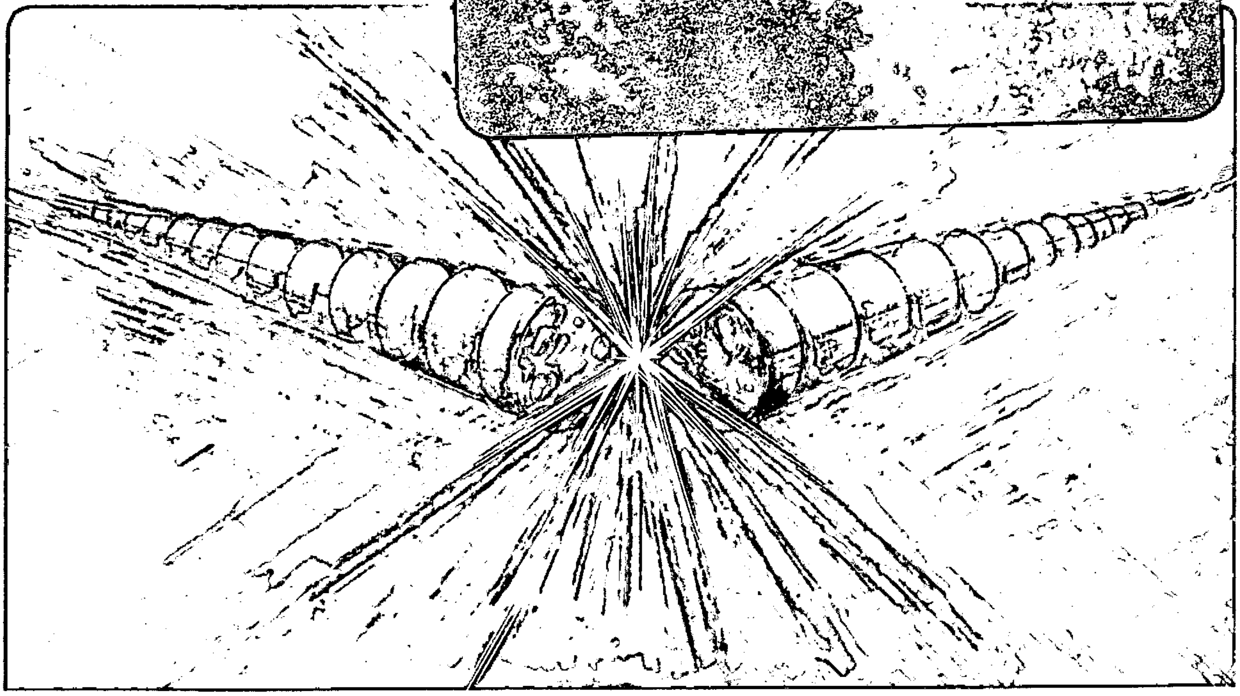

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DISCLAIMER

IMPROVED BEVATRON LOCAL INJECTOR ION SOURCE PERFORMANCE*

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Abstract

Performance tests of the improved Bevatron Local Injector PIG Ion Source using particles of Si 4+, Ne 3+, and He 2+ are described. Initial measurements of the 8.4 keV/nucleon Si 4+ beam show an intensity of 100 particle microamperes with a normalized emittance of .06 π cm-mrad. A low energy beam transport line provides mass analysis, diagnostics, and matching into a 200 MHz RFQ linac. The RFQ accelerates the beam from 8.4 to 200 keV/nucleon. The injector is unusual in the sense that all ion source power supplies, the A.C. distribution network, vacuum control equipment, and computer control system are contained in a four bay rack mounted on insulators which is located on a floor immediately above the ion source. The rack, transmission line, and the ion source housing are raised by a D.C. power supply to 80 kilovolts above earth ground. All power supplies, which are referenced to rack ground, are modular in construction and easily removable for maintenance. A.C. power is delivered to the rack via a 21 kVA, 3-phase transformer.

Introduction

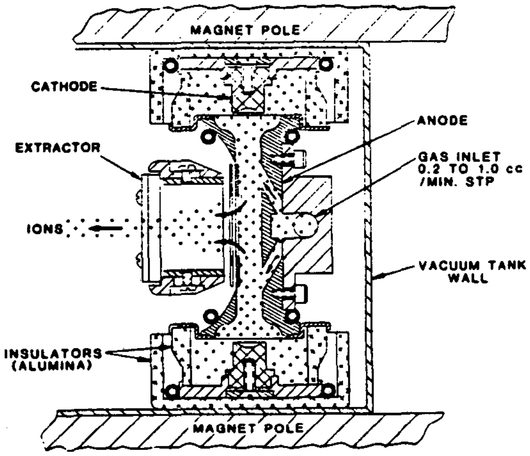
The installation of the improved local injector began in August 1983 shortly after the successful completion of the RFQ linac acceptance tests. The PIG ion source was first used at the Bevatron in 1971. Since that time, numerous improvements have been made to improve its performance. In the present upgrade, the principal challenges have been the development of a silicon sputter electrode, the adaptation of the source to a new 80 kV platform, and the recommissioning under computer control. In general, the source must be capable of producing all ions from mass one to 40 with a typical pulse width of one msec and a duty factor of 0.2%. The final injector configuration will employ both a PIG and a Duoplasmatron ion sources. Only the PIG ion source is operational at this time.

Source Description

The main body of the ion source measures 8.9 cm high and 2 alumina insulators are used to electrically insulate the cathodes from the vacuum tank surfaces. The titanium cathodes are 0.8 cm in diameter and are held in place by machine screws permitting easy replacement during service periods. Particular attention was given toward tailoring the anode exit aperture geometry for optimum beam brightness. The current configuration consists of two parallel tantalum plates spaced 0.5 mm apart having an exit aperture of 1.5 mm wide by 15.9 mm high. (Fig. 1)

The extractor electrode is supported by an alumina insulator and has the feature of being remotely adjustable in minute increments across the exit aperture which is very useful when optimizing the ion current. Gas is supplied to the source by a pulsed piezoelectric valve that is positioned next to the source anode in the vacuum chamber permitting a very rapid response to changes in gas timing and pulse width. A typical time width and delay relative to the arc pulse for helium ions would be 6 msec and 10 msec respectively, and will change depending upon the gas being used.

The sputter source used for the production of silicon ions is identical to the gaseous source with the addition of a sputter electrode fitted in the anode directly opposite from the extraction aperture. The material used for the sputter electrode is single crystal silicon bonded to a copper support by high conductivity epoxy.



PIG ION SOURCE

Fig. 1

Source Terminal

The design of the 8.4 kev/nucleon input energy of the RFQ is such that the required source terminal voltage for silicon 4+ ions is 59 kV. In view of the modest terminal voltage, several liberties were taken in the design of the source room and the hot rack containing the source and it associated equipment. The hot rack is insulated by four epoxy fibre glass legs and the source components are cooled with low conductivity water that is carried by nylon reinforced PVC water hose. The ion source is pumped by a 1500 l/sec turbo pump and is equipped with an emergency power source for the oil circulating pump in the event of a power failure. The 60 kV (3 insulator) column incorporates an einzel lens and provides a means of carrying the extraction potential to the source. Some adjacent charge state discrimination is provided by a vertical collimator slit that is located near the source focus. The source and accelerator column are shown in Fig. 2.

Transport System

An overall sketch of the source and beam transport system is shown in Fig 3. Beam profile monitors in stations 1, 2, and 3 give an excellent view of the beam profile in both the horizontal and vertical planes, and the faraday cups in the three stations give a measure of transport efficiency. Two

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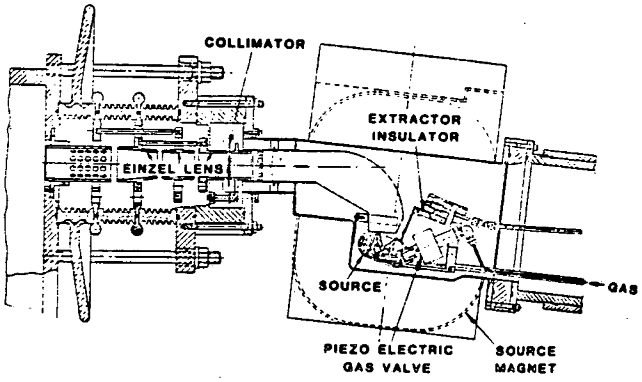
quadrupole doublets, a 70 degree bending magnet, and a quadrupole 4-plet are used to transport the ion beam and tailor it to the requirements of the RFQ input. The 70 degree magnet provides mass analysis and the 2 steering magnets give adequate beam correction if needed. The emittance device in station #3 has a multiple slit paddle in the reference location and a scanning single slit in the downstream location. By using the station #3 cup and the RFQ exit cup during the emittance measurement, both the injected and transmitted emittance may be measured.



ION SOURCE AND ACCELERATOR COLUMN

Fig. 2

Ion Source Power and Control System

Old System

Prior to the construction and development of the Radio Frequency Quadrupole (RFQ) pre-accelerator the Penning Ion Gauge (PIG) and Duoplasmatron ion sources were alternately squeezed into a very small 3m by 3m Cockcroft Walton (C.W.) terminal house. Operation and maintenance of the ion source and the concomitant power supply system was cumbersome and very time consuming. The subsequent replacement of the C.W. generator by the RFQ pre-accelerator has allowed for the complete physical and electrical reconstruction of the ion source power supply system. The following paragraphs will discuss the salient features of the new design.

New System Requirements and Specifications

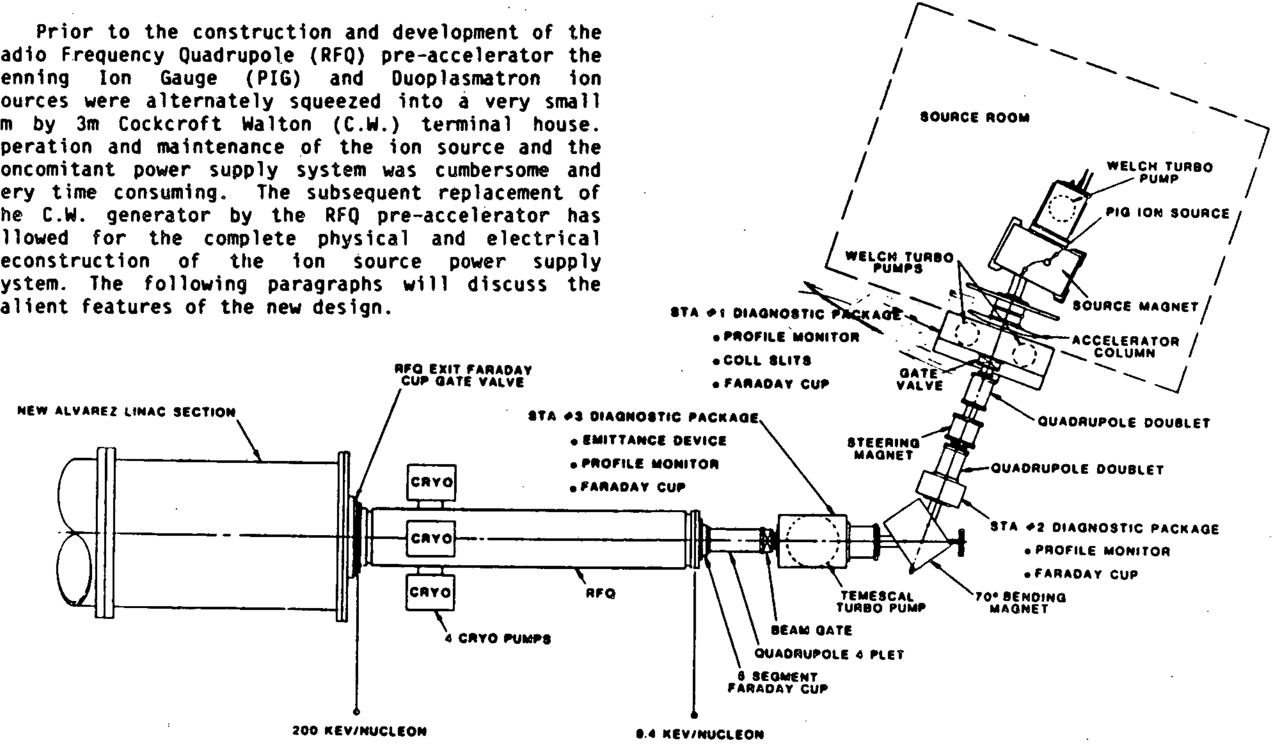
As a major source of ions for the biomedical therapy program, each system had to be very reliable, easily maintained, readily accessible, and above all completely safe for operating personnel to use.

The general specifications [1] for the ion source power supplies are well within realizable limits of current technology. All supplies, three of which are pulsed, are voltage or current regulated from 0.1% to 1.0% of their peak operating values. The primary design requirement was the construction of a stable, corona free, distributed high voltage frame work which would contain these supplies and be consistent with the proposed system requirements.

Computer Control

All monitor and control signals for the ion source and power supply system are manipulated by an on-board computer system using standard Multibuss [2] controller boards. The chassis contains a 16 bit 8086 based processor board, several standard parallel I/O cards, and an in-house serial link card to communicate with the central control computer at the Bevatron.

All internal signals to and from the on-board computer are opto-isolated and electromagnetically shielded from the adjacent power supplies. All external digital and analog signals to and from the power supply rack are transmitted via a multi-channel wide bandwidth fiber optic system.



LOW ENERGY BEAM TRANSPORT SYSTEM

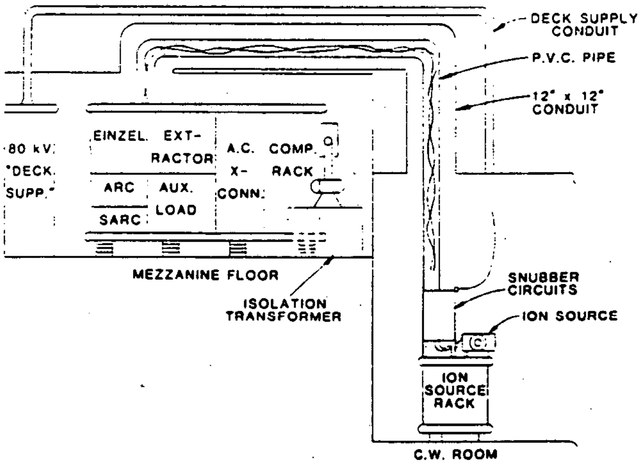
XBL 855-2399

Fig. 3

Physical Configuration

For reasons of economy and readily available space the ion source power system is mounted in a separate room on the "mezzanine" floor above the old C.W. room (see Fig. 4). Centered in the room and mounted on eight 30.5 cm insulators is a four bay equipment rack which contains the arc chamber supplies, electrostatic focusing supplies, source magnet supply, computer control equipment, A.C. power distribution, and cross connect wiring. Power and control cables which interconnect the ion source to power supplies exit through the top of the rack, cross 30.5 cm of air space and enter two 10.2 cm P.V.C. pipes centered inside a 30.5 cm square conduit.

This forms a high voltage transmission system which terminates at the ion source support rack and contains the source magnet, ion source, and local vacuum pumping equipment. All high voltage cables connected to the ion source are terminated by resistive snubber circuits. The entire distributed system of the ion source support rack, transmission lines, and power system rack can be raised to 80 kV D.C.



ION SOURCE POWER SUPPLY SYSTEM

(FRONT VIEW OF POWER AND ION SOURCE RACKS)

XBL 854-7275

Fig. 4

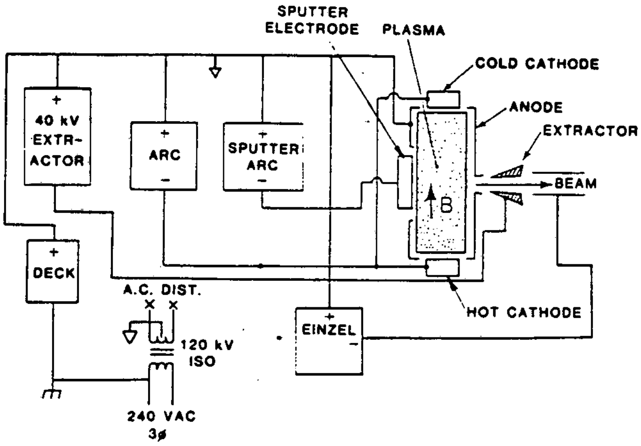
Ground Configuration

Of key importance is the choice of the electrical ground configuration for the ion source. In the configuration used here, the extractor electrode is floating and pulsed negative with respect to ion source ground, as shown in Fig. 5. This requires some careful attention to the extractor electrode design and necessitates the construction of a negative extractor supply. In this configuration, all the supplies are grounded to the supporting rack framework. Construction is modular and lends itself very nicely to easy removal and maintenance of individual supplies.

Alternatively, to avoid high voltage breakdown, the extractor electrode could be grounded to the source magnet. This would require that the arc chamber and it's associated supplies float above the extractor ground potential by 40 kV or more. These floating supplies must also be physically isolated from any metallic grounds, including the supporting rack framework, which is common to the source magnet assembly. Though this technique has been used in the past the present ion source design parameters have allowed us to implement the simpler floating extractor electrode scheme.

A.C. Power Distribution System

Due to the low pre-acceleration voltage required for the RFQ all A.C. power to the racks is provided by a 120 kV, 10 kVA, 3 phase oil filled isolation transformer designed and built by a commercial company.



PIG ION SOURCE POWER SUPPLY SCHEMATIC

XBL 854-7277

Fig. 5

Conclusion

The principal ions used in the commissioning of the Bevatron local injector ion source where those of helium, neon, and silicon and the intensity and normalized emittance data are shown in Table 1. The ease with which the ion source and beam line can be tuned from one ion to another is due in large part to the conservative design and the computer control of the ion source and beam line components allowing set point operation plus smooth control of any four variables simultaneously. Rapid particle beam optimizing is thus assured and up to ten different sets of particle tunes can be stored and recalled.

Table 1

Ion	Intensity Particle uAmp Station #3	Emittance Normalized (π-cm-mrad)	
		H	V
He 2+	600	0.06	0.05
Ne 3+	350	0.06	0.06
Si 4+	100	0.06	0.06

References

[1] Edward L. Alpen et. al, "The Heavy Ion Medical Accelerator (Final Design Summary)", PIG Ion Source Power Supply Specifications, Table 4-2, June "84", LBL PUB 5122, p 27.

[2] Trademark of Intel Inc.

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