A BRIGHTER H^- SOURCE FOR THE INTENSE PULSED NEUTRON SOURCE ACCELERATOR SYSTEM*

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Summary

Further increases in the beam intensity of the Intense Pulsed Neutron Source (IPNS) at Argonne National Labortory required the replacement of the H^- source with a higher current source. A magnetron ion source of Fermi National Accelerator Laboratory (FNAL) design was adapted with a grooved cathode to provide a stable 40-50 mA of beam operating at 30 Hz for up to a 90 μs pulse duration. Problems of space charge blowup due to the lack of neutralization of the H^- beam were solved by injecting additional gas into the 20 keV transport system. The source has recently been installed in the machine and the available input to the accelerator has more than doubled.

Introduction

The previous H^- ion source used double charge exchange of a low energy proton beam to produce H^- ions.[1] This source was highly reliable but was limited to 15 to 20 mA at 20 keV. In order to reach future goals in the accelerator, an ion source which produced at least 40 mA was required. Earlier Argonne studies of a Penning H^- ion source[2] were somewhat discouraging due to unreliability and high hydrogen gas flow requirements. A magnetron ion source developed at FNAL[3] has worked reliably for several years and Brookhaven National Laboratory (BNL) has also recently switched to H^- injection and is using a FNAL adapted source.[4]

Preliminary testing of the magnetron source indicated less development would be required for our application due to its better reliability and gas flow requirements. With the standard magnetron, sufficient beam current could be obtained but was limited to less than 30 μs in pulse duration for the required 30 Hz repetition rate. With the high arc current required (120-150 A) cathode overheating would result.

By incorporating a focusing groove in the source cathode as discovered by BNL,[5] the required arc current for source operation decreased to 40 A. Operating at a 30 Hz rate with a 70 μs pulse width now produces a nominal cathode temperature of ~370°C. The grooved cathode produces a more stable arc with less low frequency noise. Also, with the lower arc currents required, less hydrogen flow is necessary to maintain the discharge. A cross section of the magnetron with a groove in the cathode is shown in Fig. 1.

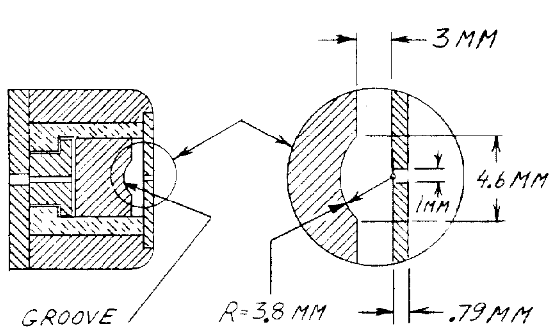

Fig. 1. Magnetron source with grooved cathode.

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General Description

The general layout of the source as installed in the 750 kV terminal is shown in Fig. 2. The extractor electrode and magnet poles are at terminal ground potential and the source itself, including the pulsed arc supply, pulsed gas supply, and cesium supply are pulsed to a negative 20 kV potential. The H^- beam is extracted and bent horizontally 90° by a magnetic dipole. The pole pieces are identical to FNAL's with a gradient index equal to 1. The beam is then focused by a set of three dc quadrupole magnets and injected into the column. A vacuum valve used to isolate the column from the source immediately follows the quadrupoles. This valve also has an insulated beam stop for local beam monitoring.

Hydrogen System

The hydrogen gas is injected into the discharge volume of the source by a modified Veeco PV-10 piezoelectric valve.[3] Adjustment of the source pressure is accomplished by varying the width of the 100 V pulse driving the valve. The microprocessor control system is capable of automatically controlling this width to regulate the source pressure to a preset valve. The nominal source pressure operating at 30 Hz is 4×10^{-5} Torr.

Cesium System

An external cesium boiler is used to provide the cesium vapor to the discharge volume. The normal operating temperature of the boiler has been ~150°C. The boiler isolation valve and the cesium transfer line are kept near 300°C to prevent condensation of the cesium vapor.

Arc Pulser

The pulsed arc supply is a 1 Ω, 90 μs, SCR switched, pulse forming network. The network is capable of being charged to 600 V with a regulated dc power supply. The arc current amplitude, start time, and width are remotely adjustable.

Extraction Pulser

The extraction pulse is provided by a regulated 20 kV supply stiffened with a 1 μF capacitor. This voltage is switched with an Eimac 4PR250C pulse modulator tube. Pulse timing and amplitude are controlled remotely.

Beam Neutralization

It was discovered on the test stand that by simulating the column vacuum system pumping on the 20 keV beam line, the beam would blow up quite rapidly due to the lack of space charge neutralization. By adding from .1 to .5 atmospheric cm^3/min of hydrogen gas into the beam line following the quadrupole triplet (Fig. 2), one could observe the effect of neutralization moving earlier in time along the length of the pulse. To facilitate higher pressures in the beam line for neutralization purposes and to limit the gas flow into the column, the 2.54 cm aperture originally in the exit of the source box was removed and a 4.9 cm diameter tube, 20 cm long, was installed following the vacuum isolation valve (Fig. 2).

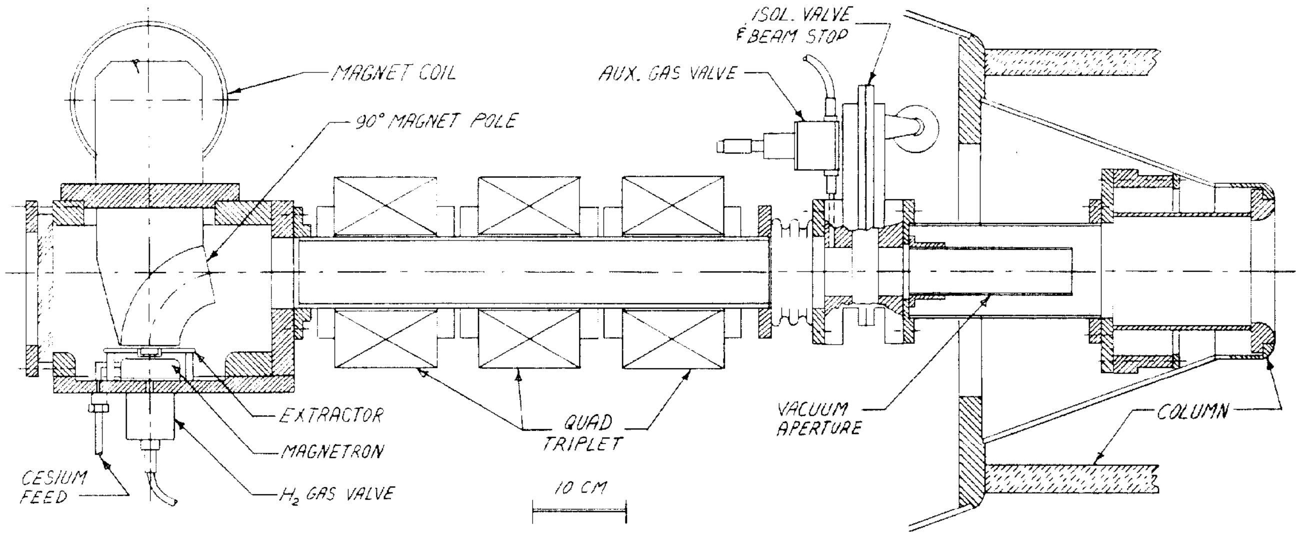

Fig. 2. Top view of H^- source in the 750 kV terminal.

Operating on the accelerator, we are presently injecting ~.2 atmospheric cm^3/min of dry nitrogen gas into the beam line. This provides good neutralization after about 30 μs of beam time. Since the full width of the beam is not needed for the accelerator, the leading edge of the beam is removed by the 750 kV beam chopper.[6] The chopper is also used as a safety backup enabling the source extractor to pulse continuously when beam in the accelerator is inhibited.

Vacuum System

The vacuum system in the terminal consists of a Welch 1500 l/s turbomolecular pump mounted on the bottom of the source box. The turbomolecular pump is backed by a 15 ft^3/min Welch roughing pump. The previous source actually required twice the hydrogen gas flow as the magnetron, but was pumped in the terminal with two 30,000 l/s bulk titanium sublimation pumps. This required the column vacuum system to pump very little hydrogen.

The previous column vacuum system consisted of two Ultek 1200 l/s ion pumps, one 1000 l/s cryopump, and one 1500 l/s turbomolecular pump used mostly on pump downs. To ease the burden on the ion pumps due to the increased gas flow through the column, two additional 1000 l/s cryopumps were added. During normal operation when the source box pressure is 4×10^{-5} Torr, the column vacuum box pressure is 1.6×10^{-6} Torr.

Ion Optics

Calculated vertical and horizontal profiles of the 20 keV transport line assuming substantial beam neutralization were produced by SYNCH (Fig. 3).

The following emittance values were obtained on the test stand for a 40 mA, 20 keV beam using a slit scanner immediately following the quadrupoles:

Horizontal $(\varepsilon_x \beta\gamma)$ 90% - .09 π cm-mrad
Vertical $(\varepsilon_y \beta\gamma)$ 90% - .14 π cm-mrad

Controls

The control system was designed to serve a fully operational source and provides controls and readouts for all pertinent parameters, both from a remote location and locally at the source. The data handling is based on the CAMAC protocol, but as with any source where millivolts and kilovolts are processed, a great deal of interfacing is also needed. All data processing and display is provided by a Kinetic Systems 3880 CAMAC-based microprocessor.

The major control system elements are a color video display and a special purpose keyboard, a CAMAC crate housing the microprocessor and primary interfacing modules, and the special purpose interfacing modules. Three general types of interfacing are employed: 1) direct connections for local ground systems, such as, vacuum and magnet supplies, 2) motor controls for a few special situations, and 3) fiber optic links for most other parameters. About twenty 6 ft fiber optic links are used to communicate between the pulsed 20 kV extractor potential, for example, the hydrogen gas and arc pulsed supplies, and also to return analog information by FM. Of course, fiber optic links are also used for sending timing and control information to and from building ground potential.

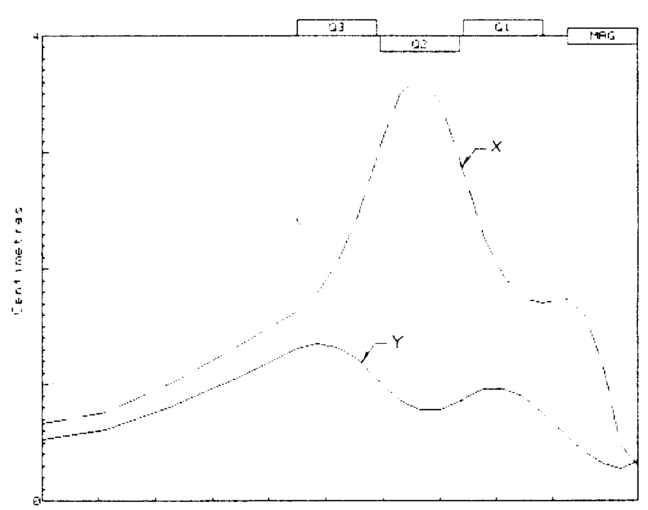

Fig. 3. Calculated beam profile through 20 keV transport line.

Operator Interface

The operator display and control method is designed to provide all information in easy to understand form and allows multiparameter tuning to be easily accomplished. The TV format provides for 16 binary status parameters (name displayed if abnormal, blank if normal), about 30 dependent and independent variables, each with title, numeric value and units, and an operator communication area. All variables are shown with a two-digit identification code and are subdivided into subsystems, such as, "vacuum" and "extractor" system.

A parameter is selected for control by entering its two-digit code and then selecting a color at the special keyboard. The parameter and its value are then displayed with one of four background colors (red, blue, green or yellow) corresponding to the four colored sets of up/down buttons used for control. In this way, any four related (or unrelated) parameters can be controlled without having to reselect them while the color clue relationship allows rapid identification of the proper control.

The microprocessor also scales the data so that readouts are in proper engineering units and provides for blinking parameter values that exceed operator entered limits.

The remote console has identical display and keyboard attributes, so that only one control methodology need be learned. The ground based microprocessor has nearly identical software, the only difference being the bit serial CAMAC highway communication protocol necessary to link it to the source potential CAMAC crate.

Operation

Typical source parameters for normal operation are listed in Table I. In the recent first two week run on the accelerator, peak 50 MeV beams of 16 mA were obtained. This compares to the 6 mA normally obtained from the previous source. Of course, in an accelerator operating 24 hours a day, the utmost concern is reliability. During the same two week period, the source and its related equipment were charged with 1.3 hours of downtime out of a scheduled 360 hours.

Table I.

Repetition rate	30 Hz
Arc width	70 μs
Arc current	30-40 A
Arc voltage	140-150 V
Cathode temperature	370°C
Source body temperature	160°C
Cesium boiler temperature	150°C
Cesium valve and feed line temperature	~280°C
Extraction voltage	20 kV
Extraction current	200 mA

Acknowledgments

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