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THE DESIGN OF AN 860 KEV PRE-ACCELERATOR FOR THE NEW SIN HIGH CURRENT INJECTOR CYCLOTRON

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Summary

The new injector for the SIN 590 MeV ring cyclotron will deliver a continuous 72 MeV proton beam of more than 1 mA. The pre-accelerator for this injector is of the Cockcroft-Walton type and will incorporate some unconventional features. A 40 keV 30 mA source is decoupled from the acceleration tube by a 4 m long beam transport system. The beam line consists of two 45° bends which filter out the parasitic H_2^+ and H_3^+ beams and is dispersionless for the remaining clean beam of protons. The acceleration tube is of a simple constant gradient type with a large aperture. Solenoids and quadrupoles are able to match the 40 keV beam to the acceptance of the tube for a wide range of intensities. A low power chopper and a 50 MHz buncher will be installed inside the dome. A 300 keV test stand with a 40 keV ion source, associated beam line and a 260 keV prototype accelerating tube is under construction.

Introduction

A new injector for the SIN 590 MeV isochronous ring cyclotron is under construction[1]. The injector consists of an 860 KeV d.c. pre-accelerator and a 0.86 to 72 MeV four-sector isochronous ring cyclotron. Figure 1 shows the layout of the SIN accelerator complex with the present installation (above) and new addition under construction (below). The 860 keV pre-accelerator consists of a 900 KV, 30 mA, d.c. Cockcroft-Walton generator, a high voltage dome housing an ion source and a 40 keV beam line, and an accelerating column. The pre-accelerator will deliver an 860 keV, 15 mA d.c. proton beam with a $\Delta E/E \leq 10^{-4}$ and a normalized emittance of less than π 0.5 mm mrad. With these requirements, and taking into account phase compression effects and flattop R.F. acceleration in both (72 and 590 MeV) ring accelerators, a proton beam intensity of more than 1 mA, at 590 MeV, can be achieved. The upgrading of the pre-accelerator to double the intensity of the high energy beam is envisaged for the near future. Because of the stringent requirements imposed upon the pre-accelerator, mainly as far as the beam intensity and quality are concerned, it was deemed necessary to build a 300 keV ion source-accelerating column test facility.

Design Considerations

The layout of the ion source-accelerating column test facility is shown in figure 2. A cusped field, single aperture, ion source with a four-electrode extraction configuration was designed and fabricated, following SIN specifications, at the Culham laboratories[2]. Figure 3 shows a simplified cutaway view of the ion source. The design is basically a scaled version of similar ion sources used by Culham for fusion research.

The chosen layout for the 40 keV beam line inside the high voltage dome offers some considerable advantages over the more conventional design of having the ion source attached directly to the acceleration tube:

- Only protons are accelerated. The parasitic H_2^+ and H_3^+ ion species normally present are dumped at a low energy level. The resulting clean beam will reduce sparking in the acceleration tube and lower the current load in the 820 kV power supply. In the 860 keV beam-

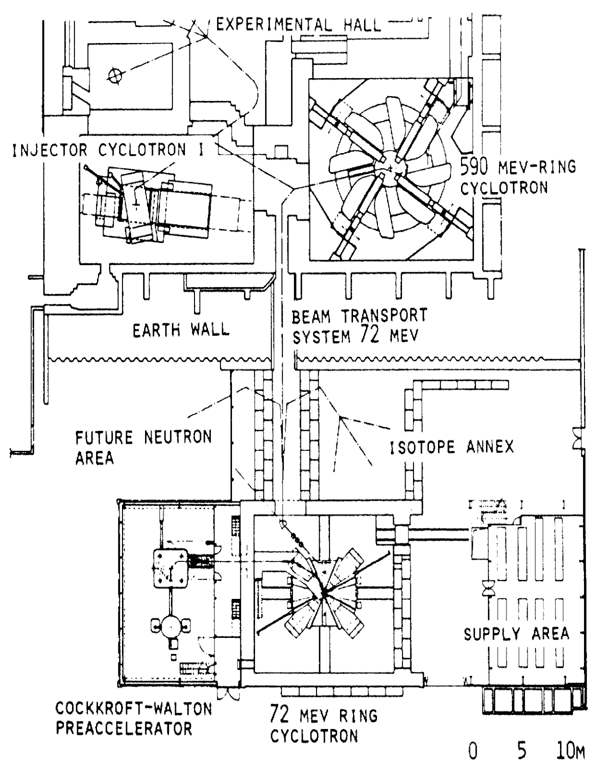

Figure 1 Plan view of the accelerator arrangement at SIN showing the present (above) and the new (below) installations. The main accelerator is an isochronous ring-cyclotron for protons of 590 MeV. Injection is done at 72 MeV. The injector cyclotron I can also be used as a multiparticle, variable energy cyclotron for low energy experiments. The injector cyclotron I and the 590 MeV-ring came into operation in 1974. The new injector is under construction. It is a combination of a isochronous fixed energy ring-cyclotron with a pre-accelerator of 860 keV. The ring consists of four sector magnets with two 50 MHz accelerating structures and two flattop-resonators operating at 150 MHz. A splitter will peel off part of the 72 MeV proton beam for the production of isotopes (mainly I^{123}) in the isotope annex.

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line there is no need to have immediately after the tube a bend to eliminate the H_2^+ and H_3^+ particles, giving more flexibility in the layout of this beam line.

- The possibility of having a vacuum valve between ion source and acceleration tube. The cathode of the source can be replaced without venting the column. The relatively large distance between source and column allows different vacuum conditions in these two regions. Control of the residual gas pressure will be an important tool for the neutralization of high current beams.
- The possibility of using, in spite of the high current beam, a constant gradient large aperture acceleration tube rather than a complex Pierce type column. The strong lens action at the tube entrance is used to guide the beam optimally through the tube (see figure 4).
- Possibility of measuring the ion source emittance before acceleration. Elimination of beam halos at low energy. The beam intensity can be varied either by means of collimators or by changing the energy of the extracted beam from the ion source ($I \sim V^{3/2}$).
- In addition to the continuous beam one can produce a large variety of pulsed beams using a variable duty cycle, variable frequency chopper. This chopper deflects the low energy beam towards a collimator in front of the buncher.

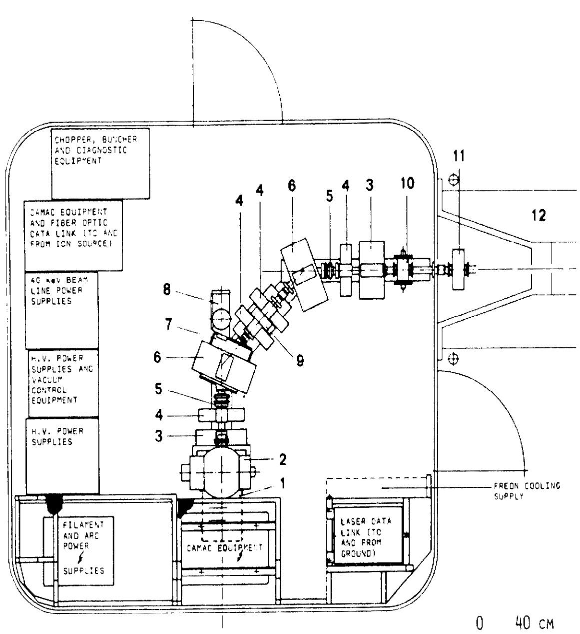

Figure 2 Dome layout showing the location of the ion source, the 40 keV beam line components and the auxiliary equipment. 1) ion source, 2) turbomolecular pump, 3) solenoids S1 and S2, 4) quadrupoles Q1 to Q4, 5) steering magnets, 6) 45° bending magnets M1 and M2, 7) magnet vacuum chamber with H_2^+ and H_3^+ beam stopper, 8) diagnostic chamber and beam dump, 9) diagnostic chamber, 10) chopper, 11) buncher, 12) accelerating column.

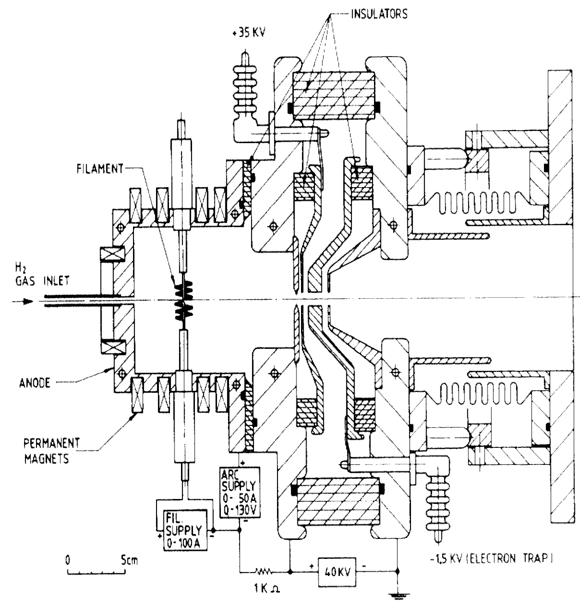

Figure 3 Schematic view of the ion source showing typical potentials applied to the extraction electrodes.

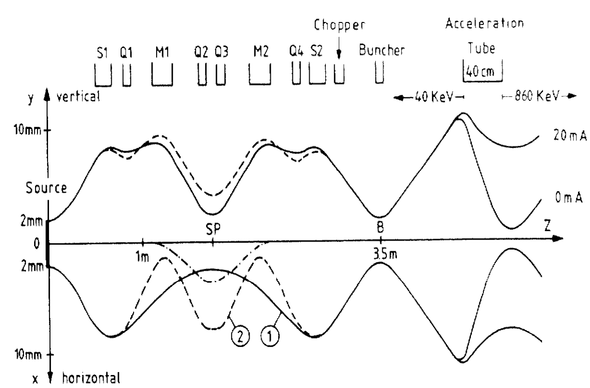

Figure 4 Beam envelopes of 40 keV proton beam between ion source and acceleration tube. M1 and M2 are 45° rectangular bending magnets with a field of 1.1 kGauss, S1 and S2 are solenoids with fields up to 2.5 kGauss and Q1 to Q4 are quadrupoles. All elements are excited symmetrically with respect to the symmetry point SP. M1, Q2, Q3 and M2 are responsible for the dispersionless 90° bend, while S1, Q1, Q4 and S2 are used to form a one to one image of the source at the buncher position B, 90 cm in front of the acceleration tube. The strong entrance lens of the tube is used to focus the beam to the exit of the tube. Two cases with beam currents of 0 and 20 mA are shown with the assumption that the beam is fully neutralized before entering the tube. The figure shows two different optical solutions 1 and 2 and the dispersion trajectory -·-·- for a momentum spread of 1 %. Parasitic H_2^+ and H_3^+ beams are eliminated after magnet M1. The chopper operates between 40 and 1000 Hz and is used as a beam pulser with duty cycles between 0 and 100 %. The 50 MHz buncher will be used mainly for investigating longitudinal space charge effects.

The optics of the 40 keV beam line is well suited for a wide variety of ion sources. In addition to the Culham source we plan to build a large aperture reflex arc source[3] and measure its optical properties on the test stand.

A 2000 l/s turbomolecular pump is located at the exit of the ion source for pumping hydrogen. The cooling of the ion source, beam line components and diagnostic equipment is provided by a closed Freon 113 circuit. The assembly of all the elements was done on a 3.90 x 3.90 m aluminium platform supported by five insulating legs. The 2.60 m high dome is powered by a 260 kV, 30 mA Cockcroft-Walton generator built by Haefely & Cie (Basel). Electrical power in the dome is supplied by a 450 kV-50 kVA insulation transformer. Cooling to the dome is provided by a second freon circuit of PVC tubes running inside of one of the supporting legs. Figures 5 and 6 show the test facility during installation. The high voltage dome was built to match exactly the needs for the final 860 keV pre-accelerator. The high voltage power supply can be upgraded to the full 900 kV-30 mA capacity by stacking extra elements. Two identical 450 kV insulation transformers will then be connected in series to power the dome components at this voltage. A 2.5 MHz driven fibre-optic link between ion source and platform, and a laser link between H.V. dome and ground potential are used for data acquisition and the transmission of control information.

Several types of accelerating tubes are under study. At the moment the LAMPF design of a constant gradient, SF_6 insulated column looks most attractive. The final design and construction of a prototype tube for the 300 keV test stand should take place during 1979.

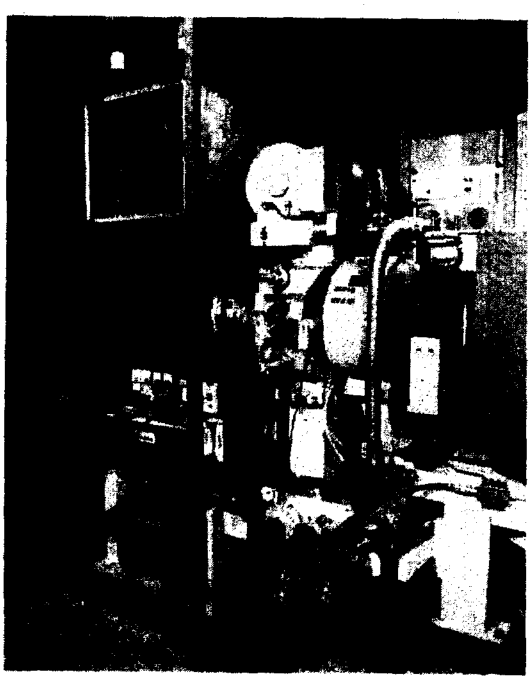

Figure 5 View towards the ion source. Hanging from insulators is an aluminium box housing a CAMAC crate and the gas flow control valve.

Figure 6 View of the ion source and 40 keV beam components during installation.

Experimental results on the test stand

The output of the ion source was measured at 20 and 40 keV. The unanalysed continuous current was 35 mA at 40 keV and scaled according to the $V^{3/2}$ law. The fraction of protons in the beam was more than 50 % and the normalized emittance was about π x .25 mm mrad. In a preliminary test at the beginning of March 1979 the optical properties of the beam line were verified in principle: Proton beams of 20 and 40 keV were bent by 2x45° eliminating the H_2^+ and H_3^+ ions. Sharp beam spots of less than 4 mm diameter were observed at positions SP and B (see solution 1 of fig. 4). The dispersionless characteristic of the 90° bend was observed as well.

Acknowledgments

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