THE NEW AGS H^- RFQ PREINJECTOR*

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Introduction

The AGS will soon be replacing the 750 keV Cockcroft-Walton (C-W) preinjector for the 200 MeV linac by an RFQ preaccelerator. The motivation for this is improved reliability, simpler maintenance, and the convenience of having the source at ground potential. In addition, the fact that there will now be a 35 keV transport section between the source and the RFQ allows us to install a fast chopper at low energy, which will be used for better longitudinal matching of the linac beam to the AGS acceptance ("painting") [1]. At the same time, the upgrade includes improving the instrumentation and controls for the entire low energy beam transport (LEBT) section of the linac. The layout of the new beamline is shown in Figure 1.

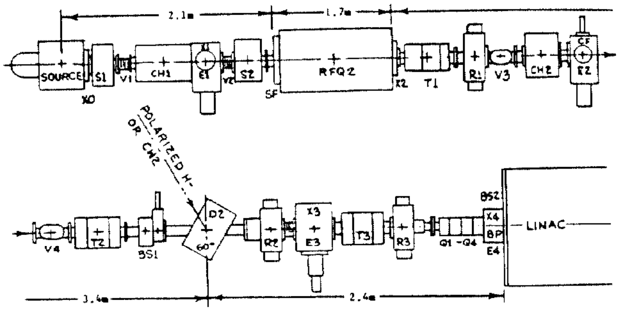

Fig. 1 Layout of the new RFQ preinjector beamline: BP –Beam phase probe; BS – Beam stop; CF – Coaxial Faraday cup; CH – Chopper; D2 – Bending magnet; E – Emittance analyzer; Q – Quadrupole; R – RF cavity; S – Solenoid lens; SF – Segmented Faraday cup; T – Quadrupole triplet; V – Vernier steering magnet; X – Beam current transformer.

The RFQ, accelerating the H^- beam from 35 keV to 753 keV, was designed and built at Lawrence Berkeley Laboratory. All components are designed to operate at 10 Hz repetition rate, 500 µS pulse width, although to date tests have been done at the present linac rep-rate of 5 Hz. In the following sections, the source, RFQ, 35 and 753 keV transport lines, beam choppers, and instrumentation will be described, and the performance given. The complete beamline is now operating in a test area, and will be installed in the preinjector area this summer.

H^- Source

The H^- source being used is a magnetron surface-plasma source, basically the same as is presently used with the C-W. The source was modified from its normal cathode focusing groove and slit aperture, to provide a better match to the acceptance of the RFQ, which is symmetrical in x and y. The modifications include a spherical dimple in the cathode to geometrically focus surface produced H^- ions into the 2 mm diameter anode aperture, and a 2 mm diameter extractor electrode aperture. Extraction is across a single 3 mm gap at 35 kV, and the voltage is pulsed at the source rep rate. While the H^- current measured 10 cm from the source can be in excess of 100 mA, the full current can not presently be transported to the entrance to the RFQ. Further optimization of the extractor geometry is planned.

A transverse magnetic field of approximately 700 Gauss is provided in the discharge region by SmCo magnets. The source, pulsed to – 35 kV, is mounted in a reentrant fashion in a vacuum box pumped by a 1500 l/s turbomolecular pump. There are provisions for a second turbopump to be mounted as a backup. The extractor electrode, at ground potential, mounts at the exit port of the box. Typical pressure in the source box during 5 Hz operation is 3×10^{-6} Torr.

35 keV Transport Line

The transport line from the source to the RFQ is 1.9 m long. It is pumped in the middle by a 1500 l/s turbopump. The matching of the beam from the source to the RFQ, while maintaining the beam symmetry, is accomplished by two 10 cm diameter, 25 cm long solenoid lenses, the first of which quickly captures the beam from the source and makes it parallel, and the second brings the beam to a waist just inside the RFQ entrance. These solenoids, which are scaled up in size from a CERN design [2], are pulsed, typically to 400-500 A (B=3.5 - 4.4 kG). The tune of the line is sensitive to the space charge of the beam, but the beam is typically space charge neutralized within ~ 50 µS by ionization of background gas. The line also contains two sets of steering magnets.

RFQ

The RFQ was designed and built by Lawrence Berkeley Laboratory, and arrived at BNL in September, 1987. It was designed to accept an input beam of 35 keV, and the designed output energy is 753 keV. The vane length is 1.62 m. The calculated transmission of a 50 mA beam having a normalized emittance of 0.10 π-cm-mrad is 97%, with an output emittance of 0.12 π-cm-mrad. At 100 mA the calculated transmission is 81%. The operating frequency of the RFQ is 201.25 MHz, matching the linac frequency. The cavity is pumped by two 1500 l/s cryopumps, and pumps down quickly to an ultimate pressure of about 2×10^{-7} Torr.

The cavity and vanes are fabricated from fully annealed, copper plated mild steel. The cavity is water cooled on the outside. RF power is fed through a single port at the longitudinal center, and the azimuthal field distribution is stabilized via three sets of vane coupling rings [3]. The final unloaded Q was measured to be 6942, and the required rf power is approximately 160 kW for a 50 mA beam. Operating at this power and the designed duty factor of 0.5%, a 260 kHz frequency shift was observed from a cold start. A single rotating tuner loop with automatic frequency tracking, having a range of 360 kHz, allows the RFQ to be kept on frequency during warmup. The maximum surface field in the RFQ is calculated to be approximately 1.5 Kilpatrick.

753 keV Transport Line

The design of the transport line from the RFQ to the 200 MeV linac was influenced by the fact that beams from both a second C-W and an RFQ for polarized H^- share the final 2.4 m of the transport line. The decision was therefore made to leave that section of line intact (although elements can be operated at different settings), and install the new RFQ in line with the linac but set back approximately 6 m from it. Figure 2 shows the beam envelope from the RFQ to the linac calculated for a 50 mA beam with the program TRACE 3-D [4]. Transverse matching is via magnetic quadrupoles, and the longitudinal bunch structure is maintained from the RFQ and matched to the linac via three rf buncher cavities. The bunch motion is handled by TRACE-3D in a linear (first order) fashion, while in our case the phase excursions are so large that the fields of

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the buncher cavities are very nonlinear (sinusoidal). Therefore, independent ray tracing calculations were made with essentially the same tune of the line as shown in figure 2, and which still included space charge, but had the proper cavity fields. These calculations show that about 75% of the beam out of the RFQ will fit into a conservative longitudinal linac acceptance of ±35 keV and ±30°.

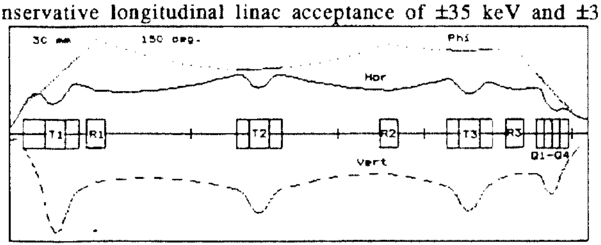

Fig. 2 Beam envelopes at 50 mA for the 753 keV section. The overall length is 5.8 meters.

Beam Choppers

A fast beam chopper has been installed in the 35 keV line to allow 2.5 MHz modulation of the beam for bunch-to-bucket injection into the AGS, which should significantly reduce capture losses. This chopper is a slow-wave electrostatic deflection device, with pulsed voltages of ±1 kV on opposing plates. A digital delay generator with 2x1024 RAM locations will allow one to vary the phase and width of each 2.5 MHz pulse. Rise and fall times on the order of 10 ns have been measured on the chopped beam pulses upon exiting the RFQ. Because the chopper affects the space charge neutralization of the beam, the tune of the 35 keV transport line changes, and even after retuning the solenoids there is so far typically a 25-40% loss in beam intensity out of the RFQ while chopping. More details of this chopper are given in another paper in these proceedings [1].

A second, fixed frequency sine wave chopper in the 753 keV line can be used in conjunction with the 35 keV chopper, to fill only single microbunches of the 200 MHz linac. This will be used by linac beam users for high resolution time-of-flight experiments. The chopper is driven by a high Q tank circuit at 10 MHz, thus requiring modest drive power to deflect the 753 keV beam. The repetition period of the microbunches can be varied from every 50 nS (35 keV chopper off), to once per linac pulse.

Instrumentation

Beam intensity is measured in 5 locations along the line (2 before and 3 after the RFQ) using toroidal current transformers. Resistors are distributed around the winding to damp coil resonances, allowing a 20 ns risetime into a termination. Through the amplifier, small signal risetimes of 70 ns can be observed. A five segment (bulls-eye and 4-quadrant) Faraday cup mounts directly on the front of the RFQ, for use in steering and focusing of the beam into the RFQ. The signals can be processed in several ways via a sum-difference-ratio circuit for real-time control, as well digitizing sampled information, or integrating, for average position information. A fast, coaxial Faraday cup [5], with approximately a 2 GHz bandwidth, is located downstream of the RFQ. This allows one to observe the shape of individual 200 MHz bunches, and is very useful in monitoring the bunching and fast chopping. The horizontal and vertical emittance can be measured at 4 places in the line. These units use the standard slit and multicollector technique [6], although we are trying a new construction method that gives a 1.33 mrad per channel resolution in a compact unit.

Performance

Figure 3 shows the beam current measured out of the source, in the middle of the 35 keV transport line, and out of the RFQ. By limiting the source output (discharge current) to that giving the optimum optics, one can get essentially 100% transmission through the RFQ at 40 mA. At higher source current, the output from the RFQ is typically 50 mA, with 85-90% transmission. Figure 4 shows x and y emittances measured in the 35 keV line when transmission through the RFQ is optimized. The normalized (90%) emittance in both planes is typically 0.11 π-cm-mrad. Figure 5 shows the emittances measured 23 cm from the RFQ exit (measured before the 753 keV line was installed). Here, $\varepsilon_n(90\%)=0.12$ π-cm-mrad in both planes, and the orientations are in very good agreement with the predicted RFQ output. The measurement of the bunched beam out of the RFQ on a single pulse basis can be done with the coaxial Faraday cup. Figure 6 shows two 200 MHz bunches, taken 27 cm from the exit of the RFQ. After correcting for the 350 ps risetime of the scope, the bunch widths are ±25° FWHM.

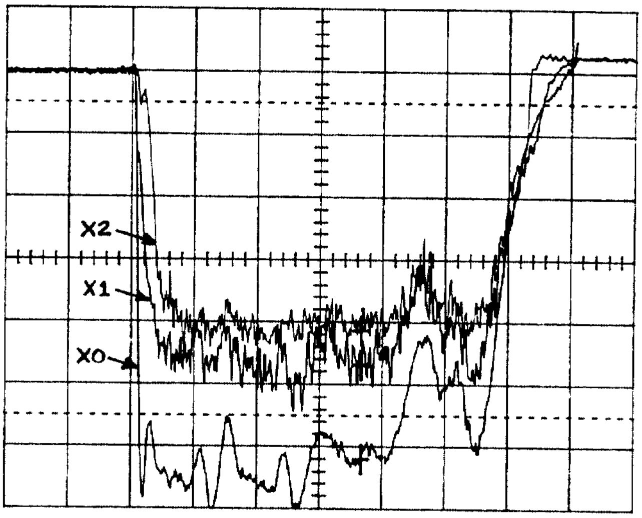

Fig. 3 X0 – beam out of the source; X1 – between the two solenoids; X2 – at the RFQ exit. Horizontal: 100 μs/div., Vertical: 10 mA/division.

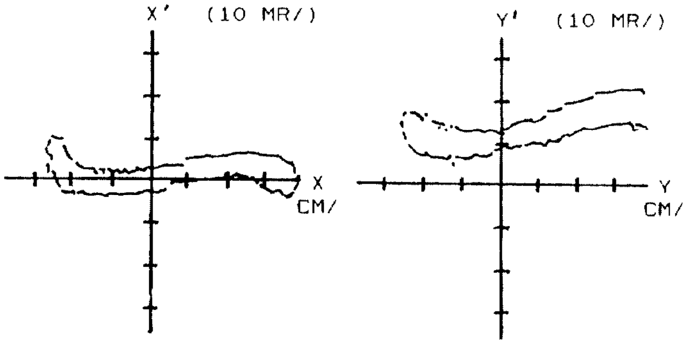

Fig. 4 Emittances measured in the 35 keV transport section. $\varepsilon_n(90\%)\approx0.11$ π-cm-mrad in both planes.

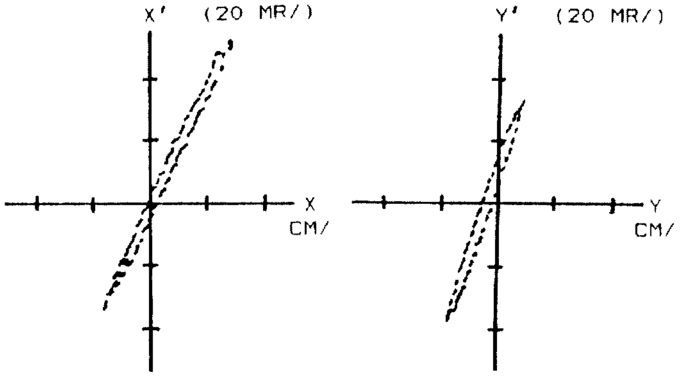

Fig. 5 Emittances measured 23 cm from the RFQ exit. $\varepsilon_n(90\%)\approx$ 0.12 π-cm-mrad in both planes.

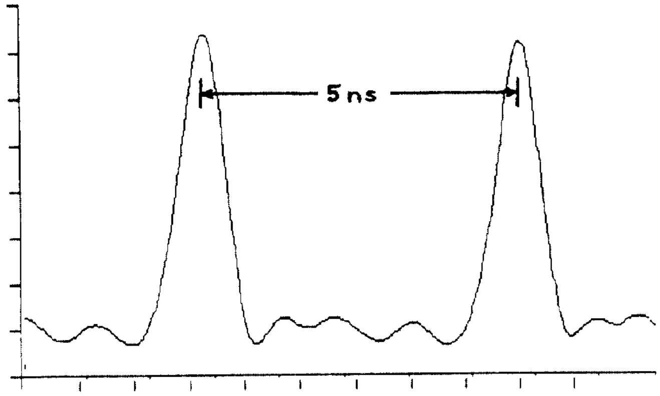

Fig. 6 200 MHz bunches measured on the coaxial Faraday cup. The bunch spacing is 5 ns, FWHM≅0.8 ns.

Following these measurements, the new portion of the 750 keV transport line was installed (the 3.4 m section to D2 in figure 1). To date, 40 mA of H^- has been measured after D2, with a 75% transmission from the RFQ exit. We are now preparing to do an energy analysis of the beam.

Schedule

The entire new preinjector line is now operating in the test area. Beam studies will continue through much of the summer. Immediately following the summer shutdown of the linac in June, the C-W and a portion of the LEBT line will be disassembled and a floor put in the C-W pit area. Installation of the new preinjector is expected to start in September, and the line will be commissioned while the AGS heavy ion program is running. The new preinjector should be fully operational by the end of 1988.

References

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