Beam Instrumentation For The SSC RFQ

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Abstract

A detailed description of the SSC RFQ beam instrumentation is presented. Most of the instrumentation is located in the RFQ end walls. The upstream end wall contains a segmented Faraday cup, a segmented aperture and a wire scanner. The down stream end wall contains a segmented aperture and wire scanner. Two current toroids are used to measure the transmission through the RFQ. The output of the RFQ is a low emittance, pulsed 2.5 Mev H^- beam with peak current of 25 mA and maximum pulse length of 35 μs. Typical beam data are shown with the emphasis being on instrumentation performance.

I. INTRODUCTION

The RFQ instrumentation consist of two current toroids, a segmented Faraday cup, two wire scanners and two segmented apertures. All of the instruments except the current toroids are actuated instruments and mounted in the end walls. Of the two current toroids one is up stream and one is down stream of the RFQ. The toroids have been electrically matched to allow for proper transmission measurements during commissioning. The wire scanners are placed up and down stream of the RFQ to measure the beam profile and position information. Also up stream is the segmented aperture and the segmented Faraday cup which will define a maximum beam size and measure the beam position and current respectively. Down stream is a segmented aperture which defines the beam size entering the Drift Tube Linac (DTL) matching section. Figure 1 shows the RFQ with the instrumentation mounted.

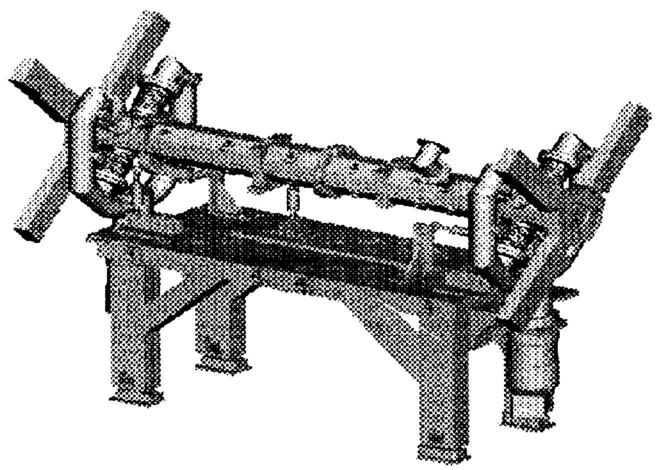

Figure 1. RFQ with end wall actuator mounted instrumentation.

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II. DESCRIPTION OF THE BEAM INSTRUMENTS

The entrance end wall contains the segmented aperture and Faraday cup which can be used as separate instruments or as a system with 1 mm spacing between them. The segmented sections of each instrument can be monitored independently. Beam positioning is accomplished by producing equal current on all four segments. By placing the aperture and Faraday cup in the beam line at the same time, beam size and position can be obtained. When the instruments are at the beam line center, the operator can steer the beam into the RFQ by monitoring the current on the individual wedges. Once the segments have equal current values, the Faraday cup can be removed to allow for beam transmission into the RFQ. A second aperture is used in the exit end wall of the RFQ to define the maximum beam size into the DTL matching section. The transmission through the RFQ is measured by two matched current toroids. A 195 mm OD toroid surrounds the ion source low energy beam transport and is mounted just upstream of the RFQ entrance end wall. A matched toroid is mounted in a temporary diagnostic chamber at the exit of the RFQ. When the two current toroid waveforms are superimposed, the ratio is the total current transmission through the RFQ as a function of time. The wire scanners located at both the entrance and exit end walls are designed to have three separate wires that are electrically isolated to cover X,Y, and 45°. The profile is measured by stepping the wire through the beam and recording the current on each wire. By plotting the position and the measured current at each step location, the profile can be determined[1-2].

The electronics to read out the sensing instrumentation consists of a preamplifier, an integrator, and a waveform digitizer which all reside in a VME crate. The Faraday cup and aperture electronics are designed to measure a voltage produced by the beam current flowing through the preamplifier's input impedance. A fixed gain stage to matches the full scale input to the waveform digitizer when a beam current of 25 mA is being measured. The wire scanner electronics measures the signal current through an active transimpedance-difference circuit. A VME programmable 2 gain selectable second stage is used to match the full scale input of the waveform digitizer based on the dynamic range requirements of the beam current. The current toroid preamplifier measures a voltage that is produced by the current toroid and has a fixed gain based on the selected transformer's sensitivity (V/A). The circuit also produces an integrated output which can be digitized with an ADC. Figure 2 shows a digitized waveform from the integrator card with the integrated signal superimposed. The waveform is 35 μs long and both were digitized at 200ns per point.

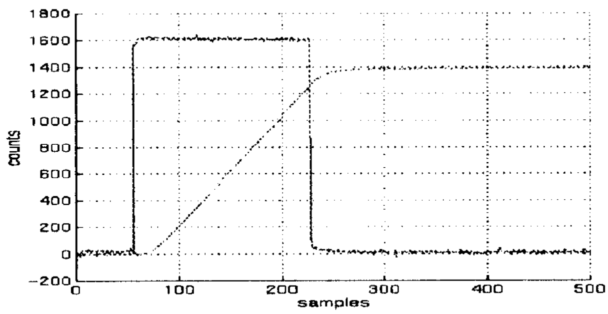

Figure 2. Digitized 35 μs pulse and integrated output.

The waveform digitizer has a analog bandwidth of 11 MHz and a sampling rate of 5 MHz. The VME board was designed by Mike Shea (FERMI LAB) and Alan Jones (FERMI LAB/ SSCL) and is now commercially available from OMNIBYTE CORP, VMIC, and JOERGER ENTERPRISES INC. The electronic specifications for each analog VME board are shown in table 1.

Table 1
RFQ instrumentation specifications

VME Board	Bandwidth	Input Channels	Input Range
Faraday Cup	DC - 10 MHz	4	5 - 50 mA
Wire Scanner	DC - 10 MHz	3	.25 mA - 5 mA
Current Toroid	DC - 10 MHz	4	0 - 100 mA
Digitizer	5MHz	4	±1 V

Figure 4 shows a single channel of the Faraday cup preamplifier card. The first stage is a buffered difference circuit. The second stage is a gain stage with a low pass filter of 3dB @ 10 MHz designed to produce a 4 volt output into 50 ohms with a 100 mA input current. Figure 3 shows a functional diagram of the Faraday cup circuit. The output is passed to the integrator card where both the waveform and integrated waveform are then digitized. A biasing circuit for control of secondary emission which occurs when the beam interacts with the intercepting material is connected to the input of the amplifier. Secondary emission from beam intercepting monitors can be difficult to understand at low energies. Problems with biasing of instrumentation at 35 keV were observed at the LEBT and have disappeared at 2.5 MeV. A more detailed discussion of these issues can be found in ref [3]. When the bias supply is connected, the circuit no longer has DC response.

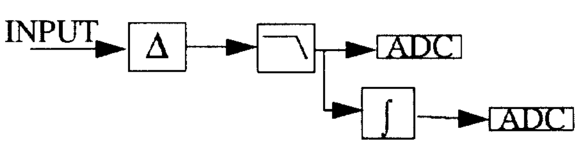

Figure 3. Faraday cup functional circuit.

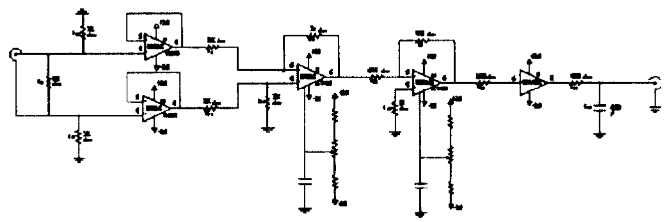

Figure 4. Circuit diagram for a Faraday cup channel.

The wire scanner and segmented aperture circuits have the functionality. The current toroid electronics has the preamplifier and integrator circuit on the same board. Figure 5 shows the down stream segmented aperture head without the actuator. The intercepting material is made of Graphite and is insulated from the copper housing by KAPTON film.

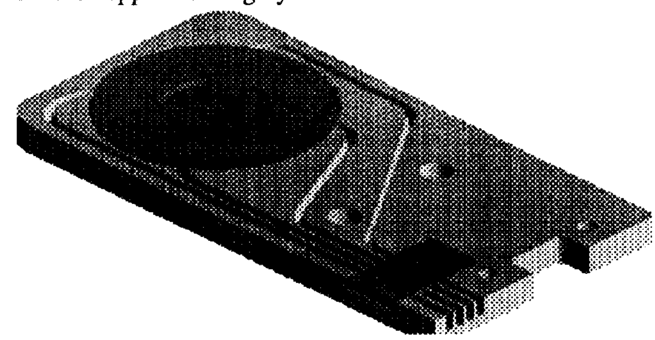

Figure 5. Down stream segmented aperture.

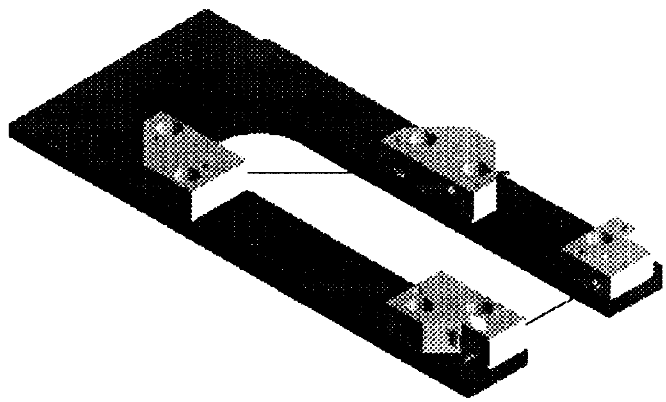

Figure 6. Three channel wire scanner.

Figure 6 shows the wire scanner head without the actuator. The wires are located in a ceramic block and held in place by gold plated pins. The pins have a jewelers sapphire in the tip which locate the wire in the housing. The wire is crimped with 50 grams of tension and the signal is read out through a flex circuit on the back side of the frame. If wire heating by the beam will be a problem at this energy a future design will have a spring mechanism for maintaining tension on the wires.

Figure 7 shows a typical waveform produced by the test pulse circuit for the current toroid electronics. Here a test pulse is injected into the current toroid located in the vacuum chamber and the induced pulse through the transformer and 16 meters of cable is digitized and displayed. This graph shows the rise time of the test pulse to be much less than the rise time of the actual beam (see figure 9) and therefor the electronics is not the limiting factor in this measurement.

III. PERFORMANCE WITH BEAM

The first beam through the RFQ was achieved on April 8, 1993. Examples of signals from the entrance and exit current toroids of the RFQ are shown in figures 8 and 9. The entrance current toroid has 2 and 4 MHz pickup from the RF volume source which is located 0.5 meters away. The coupling mechanism for this signal is unclear. The small notch at 15 μs corresponds to the start of plasma formation, at this point the RF noise changes from 2 to 4 MHz. In figure 9 the average input current waveform can be seen after software filtering. The RFQ unfiltered output current is shown for comparison.

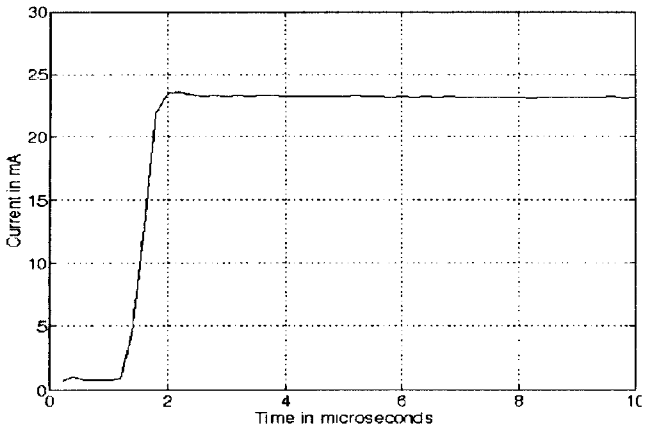

Figure 7. Test pulse for the current toroid.

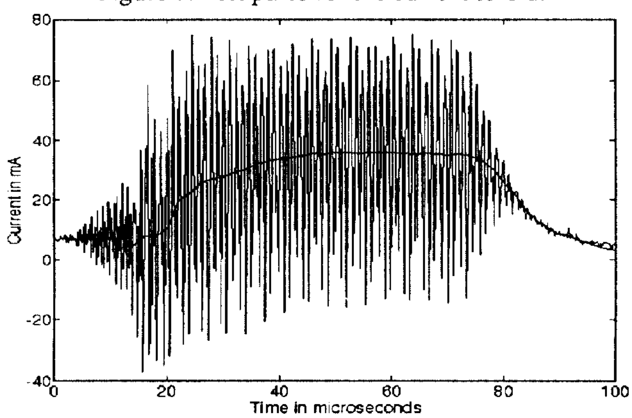

Figure 8. Input current toroid waveform.

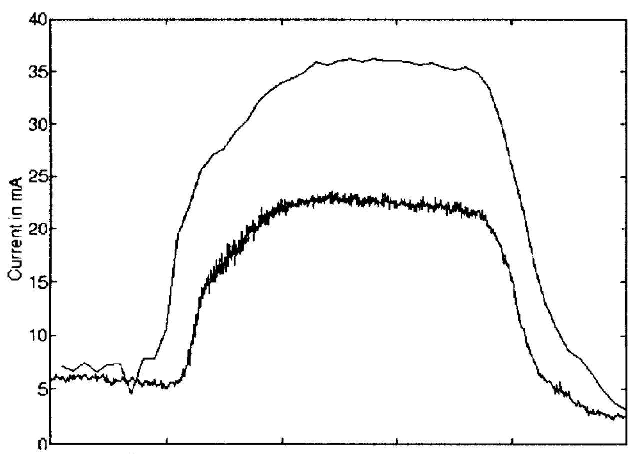

Figure 9. Input and output current toroid waveform.

IV. CONCLUSION

Our plan is to continue commissioning the RFQ instrumentation in the next 4 months. We have to bring the apertures, Faraday cup and wire scanners on line. Damage to the instrumentation at the output of the RFQ due to the 2.5 Mev beam will be the major concern. It is expected at maximum current density, that the wire from the wire scanner will not survive a single beam pulse. Single beam pulse damage can not be mitigated by water cooling. At 2.5 Mev the beam has a diameter of about a millimeter at the location of the instruments and is absorbed in a layer approximately 50 μm deep. The aperture has an opening angle designed to minimize single shot damage by maximizing the surface area hit by the beam. The toroid at the present time is closely matched to the input toroid. When the matching section from the RFQ to the DTL is installed this toroid will be replaced with a small toroid mounted on an actuator(see Figure 10) and installed in the RFQ end wall.

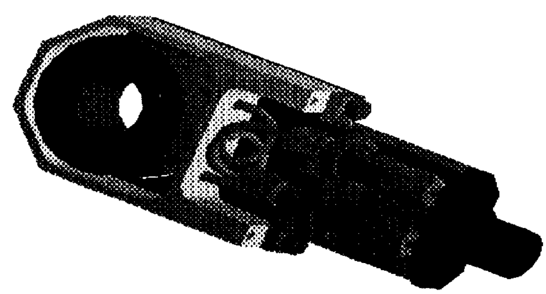

Figure 10. Current toroid head.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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