

## Finalized Design of the SSC RFQ-DTL Matching Section\*

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### Abstract

The RFQ-DTL matching section has four variable field quadrupole magnets in a FODO lattice to match the 2.5-MeV, 27-mA,  $H^-$  beam from the RFQ to the acceptance space of the DTL, as well as to provide beam steering. In addition, there are two rf buncher cavities to provide longitudinal phase space tuning. An ensemble of beam diagnostics including input and output beam current toroids and beam position monitors, a wire scanner for beam profile measurements, a slit and collector device for beam emittance measurements, and a Faraday cup is used to quantify the matching section performance. The finalized design of the major components of the RFQ-DTL matching section is presented as well as the status of its construction.

### I. INTRODUCTION

The SSC Linac [1] consists of an ion source and three different accelerating structures including a radio frequency quadrupole (RFQ), a drift tube linac (DTL), and a coupled cavity linac (CCL). In principal, the first DTL tank can be connected directly to the RFQ. However, the RFQ and the DTL have different beam acceptance spaces, and the resulting mismatch would lead to emittance growth in the beam. Also, any alignment error between the RFQ and the DTL could not be corrected, which again would lead to emittance growth. Given the stringent beam brightness requirements [1] for the SSC Linac, it was felt imperative to have a matching section to properly condition the beam from the RFQ into the first DTL tank.

The RFQ-DTL matching section has three principal elements (see Figure 1) with which to accomplish this task: (1) variable field permanent magnet quadrupole (VFPMQ) magnets for transverse focusing and beam steering, (2) double-gap RF buncher cavities for longitudinal phase space tuning, and (3) beam diagnostics to monitor the properties of the beam. The main design challenge is to fit the above elements into an axial distance of only 540 mm. The physics design [2] and preliminary mechanical design [3] of the

matching section have been presented in previous papers. Its design has now been finalized, and this paper will concentrate on the major components of that design as well as give an update on its construction.

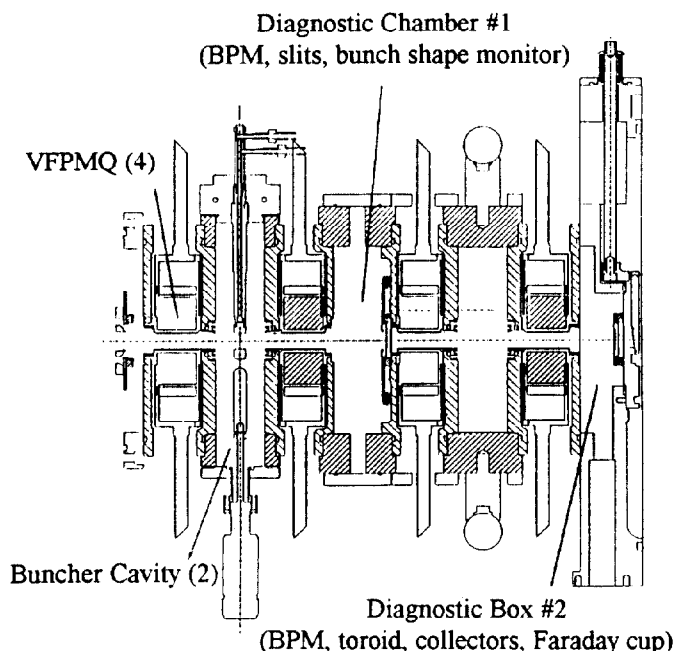


Figure 1. Side view of the RFQ-DTL matching section.

### II. VARIABLE FIELD PERMANENT MAGNET QUADRUPOLES

The matching section has four VFPMQs in a FODO lattice with the first quad oriented to be horizontally focusing for the nominal 2.5-MeV, 27-mA,  $H^-$  beam exiting the RFQ. The main design features for these quads are shown in Figure 2. This concept was originally proposed by Halbach [4] and uses four mild steel pole pieces to shape the field, while its strength is varied by a  $90^\circ$  rotation of an outer ring of magnets. For the matching section VFPMQs, NeFeB magnet material is used while the hyperbolic pole tips are constructed using C-1006 carbon steel. Rotation of the outer ring is accomplished using a stepper motor driven worm gear, while a precision linear translation stage is used to move the

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VFPMQ by  $\pm 2$  mm in the focusing direction to obtain beam steering.

A prototype VFPMQ based upon the design in Fig. 2 has been built, although without the linear translation stages or any offset capability. A rotating coil [5] was used to measure the gradient-length (GL) product and harmonic content of the quad. The measured GL product shows excellent agreement with theory (see Figure 3). The measured harmonic content at maximum field strength was found to be less than 0.5% of the quadrupole field component at 80% of the aperture for each of the harmonics (up to  $n=6$ ), which also agrees well with theory.

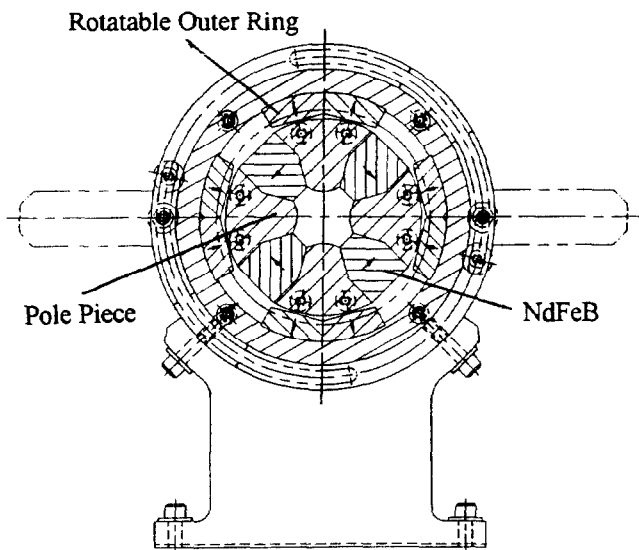


Figure 2. Design of the prototype VFPMQ.

### III. RF BUNCHER CAVITIES

A cut-away view of one of the double-gap buncher cavities is presented in Figure 4. It is a quarter-wave rectangular copper cavity having a cylindrically shaped center conductor that supports a 16 mm I.D. drift tube through which the beam passes. Each gap in the cavity develops a voltage of 100 kV with a RF power input of 25 kW at the 428 MHz resonant frequency. The cavity  $Q \approx 5000$ , and its shunt impedance is 800 k $\Omega$ . A plug tuner provides coarse frequency adjustment over a 200 kHz range, while fine tuning of the cavity resonant frequency is obtained by temperature stabilizing the cavity walls and center conductor with low conductivity water from the RFQ temperature control unit (TCU).

Each cavity is powered by a 50 kW planar triode amplifier [6]. This power is transmitted down standard  $1\frac{5}{8}$ -

inch rigid coax line and is coupled into the cavity through a tapered section which consists of a transition from  $1\frac{5}{8}$ -inch to  $\frac{7}{8}$ -inch coax line, an axial ceramic vacuum window, and a coupling loop inserted into the cavity. Specific details of the design of this tapered section are given in another paper [7].

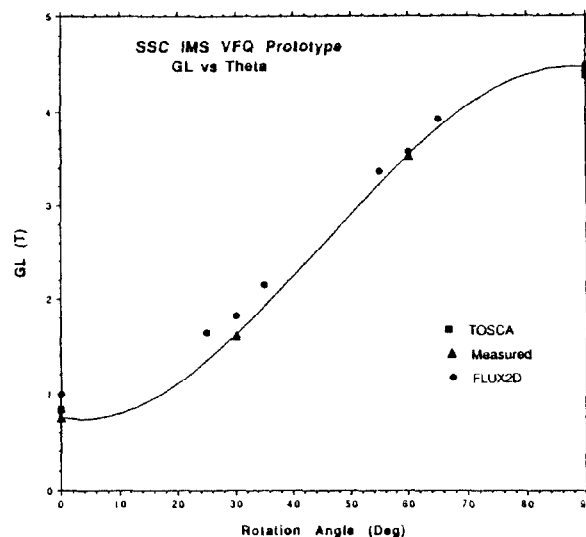


Figure 3. Comparison of measured GL product with computer results for prototype VFPMQ.

### IV. BEAM DIAGNOSTICS

The performance of the RFQ-DTL matching section is quantified by an array of beam diagnostics (see Figure 1). This array consists of three beam position monitors (BPMs) for measuring the transverse displacement of the beam and its relative phase with respect to the buncher cavities, input and output current toroids to measure the total beam current, a 3-wire wire scanner to measure the x, y, and coupled x-y beam profiles, a segmented Faraday cup to measure beam position and current as well as to serve as a beam stop, and a separate x and y slit and collector to measure the transverse emittance of the beam. All of these diagnostics except the BPMs are actuated into place via actuators having better than 0.1 mm resolution. In addition, the slits and the Faraday cup are water cooled since they must withstand nearly the full power density of the 10 Hz beam.

Further details on these diagnostics can be found in Reference 8. The 128-wire collector array and its associated electronics [9] are in particular a unique design offering substantially improved resolution and enhanced data acquisition capabilities over past designs. Finally, two diagnostic ports in the matching section have been provided to accommodate a bunch shape monitor [10] now under development.

## V. STATUS

Parts for the SSC RFQ-DTL matching section are scheduled to begin arriving in early June of this year. Bench testing of the device should commence in July, while beam commissioning is scheduled to begin at the SSC Central Facility in August. This fall, the ion source, RFQ, and RFQ-DTL matching section will be moved to the SSC Linac tunnel for installation and operation prior to delivery of the first DTL tank in early 1994.

## VI. REFERENCES

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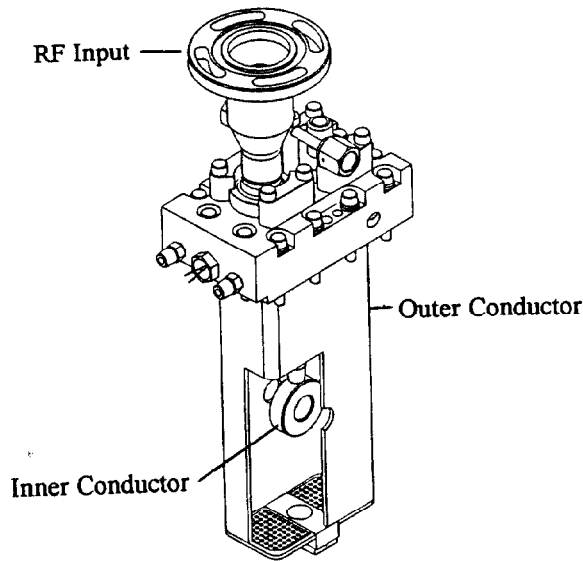


Figure 4. RF buncher cavity for RFQ-DTL matching section.