Brookhaven National Laboratory
Brookhaven Science Associates
Collider-Accelerator Department

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Title: **Specification for EBIS Radio Frequency Quadrupole**

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Revision Record

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1.0 Scope of Work

1.1 The objective of this contract is to design and manufacture a four rod type radio frequency quadrupole (RFQ) for the bunching, acceleration, and transverse focusing of low energy, light and heavy ions. The RFQ will provide high transmission efficiency of beam, have low transverse emittance growth, and small energy spread of the output beam.

2.0 Applicable Documents

2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the invitation to quote. Exceptions shall be approved in writing by BNL.

BNL-QA-101 Supplier Quality Assurance Requirements

3.0 Requirements

3.1 Basic Description

3.1.1 The RFQ shall be a 4-rod type for bunching, acceleration, and transverse focusing of low energy, light and heavy ions.

3.1.2 The RFQ will be installed in the beam line shown in Figure 1. The input beam to the RFQ will be from an Electron Beam Ion Source (EBIS).

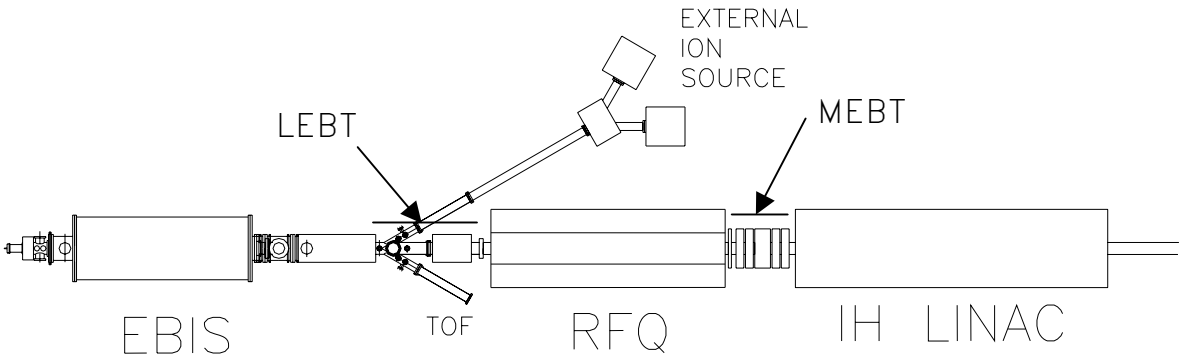

Figure 1: EBIS Facility Beam Line (Upstream)

3.2 Performance Requirements

3.2.1 Basic Parameters:

Parameter		Units
Operating Frequency	100.625	MHz
Design Beam Current	10	mA
Maximum Beam Current	> 20	mA
Charge-to-Mass (q/m) Ratio Range	0.16 to 1.0	
Repetition Rate, Max.	5	Hz
Pulse Width	≤ 1.0	ms
Input Energy	17.0	keV/u
Input Emittance	0.35	π mm mrad, normalized, 90%
Acceptance	≥ 1.7	π mm mrad, normalized, 90%
Output Energy	300	keV/u
Emittance Growth	≤ 20	%
Output Emittance, longitudinal	≤ 34	π MeV deg, 90%
Transmission Efficiency	> 90	%
Length	≤ 4.4	m
Power Consumption, Peak (no beam)	≤ 180	kW
Tuning Range	≥ 300	kHz

3.3 Design Requirements

3.3.1 The RFQ assembly consists of the vacuum tank of stainless/copper construction, rod electrodes and support posts, tuning device(s), power coupler, RF pickup probes and ports for vacuum pumps, water cooling, and other ancillary devices.

3.3.2 The RFQ shall be designed such that the transverse emittance of the output beam is symmetric in both planes, that is, having equal Twiss parameters for the X-plane and Y-plane emittances.

3.3.3 Ancillary Devices, Connections and Ports.

3.3.3.1 Tuner(s). The RFQ shall include dynamic tuners capable of changing the frequency within ranges expected from potential thermal and mechanical effects. Static tuners for frequency adjustment shall be provided, as required.

3.3.3.2 Tuner Instrumentation. The tuner system shall supply output signals including, but not limited to, the following:

1. Two limit switches to define the limits of the tuner travel.
2. Tuner position analog output.

3.3.3.3 RF Pickup Probes. The RFQ shall have ports for mounting a minimum of two RF pickup probes used to monitor the voltage, phase, and frequency. The pickup probes

will provide feedback for tuners and power amplifier. The pickup probes will be included as part of the shipped RFQ assembly.

3.3.3.4 Power Coupler(s). The RFQ requires a power coupler to bring power from the amplifier. The power coupler(s) shall be included in the delivered system. The coupler shall be designed for 3-1/8 (3.125) inch coaxial transmission line. The input coupler shall be designed to couple critically for 200 kW RF input power and be capable of operation at twice this power level.

3.3.3.5 Vacuum Pump Ports. The use of two 1500 liter/sec cryo pumps to achieve the specified vacuum for the RFQ has been planned by BNL. The number and location of vacuum pumps mounted in the RFQ tank shall be verified prior to detail design and manufacture. The port flange shall be a conflat type, size NW250CF. The port tube size shall be 150 mm diameter minimum.

3.3.3.6 Vacuum Gauge Ports. Vacuum gauges having 70 mm diameter conflat flange ends will be used by BNL. Vacuum ports suitable for this type connection shall be installed in the RFQ, with the locations agreed to by BNL. The use of adapters between the RFQ and the gauge is permissible. Adapters shall be supplied with the delivered assembly.

3.3.3.7 Water Cooling Connections. The type of connections for water cooling shall be coordinated with BNL.

3.3.3.8 Port and Connection Seals. Seals for ports and openings shall be standard commercially available items to the extent practical.

3.3.4 Vacuum Performance

3.3.4.1 Vacuum Level. The fully assembled RFQ shall be designed to achieve a vacuum level of 7.5×10^{-8} torr without RF power and 2×10^{-7} torr with RF power.

3.3.4.2 The RFQ shall not be contaminated with oils or other substances with atomic masses of greater than 40. The sum of the partial pressures between atomic mass 40 and 100, excluding 44, shall be less than 0.01 of the total system pressure.

3.3.4.3 Bakeout Temperature. The assembly shall be bakeable, with or without vacuum, to temperatures of up to 150 degrees C.

3.3.5 Critical alignment parts that are disassembled for shipment shall be designed for accurate reassembly by dowel pinning or other methods.

3.3.6 Tooling and Fixtures. Special alignment targets and tooling required for the installation of the RFQ at BNL and manufactured as a part of this contract shall be supplied.

3.3.7 Support Stand. At BNL the RFQ will be installed on a structural stand that places the beam center line at 60 inches (152.4 cm) above the floor. The RFQ must be mounted to the stand while it is moved into the final beam line location. Some method of horizontal adjustment shall be designed into the stand. Vertical adjustment may be incorporated into the design or may be made at the leg base plates at the time of installation. Leg base plates will be approximately 2 inches (5 cm) above the floor to allow for grouting. The stand will have adequate lifting eyes and forklift provisions for shipping and installation.

3.3.8 Lifting fixtures and eyelets shall be supplied on the RFQ tank, as required to safely move and tranport the assembly without the stand. All lifting equipment and fittings shall have a margin of safety of 3:1, and calculations shall be provided proving that this requirement has been achieved.

3.3.9 General Electrical Installation Requirements. The electrical installation shall facilitate operation of the RFQ at both the factory test facility and later at BNL.

3.3.9.1 Grounding. The system shall be provided with the capability to connect all electrical components to BNL's grounding system.

3.3.9.2 Connectors. All appropriate connectors for control and instrument components shall be provided. Connector types and configuration shall be subject to review and acceptance by BNL.

4.0 Quality Assurance

4.1 The quality assurance requirements of BNL-QA-101 that apply to the RFQ include the following: Section 3, 3.1.1 (manufacture only), 4.2, 4.4, 4.4.1-3, 4.5 (except 15 days notice), 4.6, 4.10, 4.10.1-2, 4.11, 4.12, 4.16, 4.19, 4.31, 4.34, and 4.40. The QA system specified in section 3.1.1 applies to the manufacturing subcontractor of the RFQ. QA system documentation shall be available to BNL for review.

4.2 Pre-Shipment Test Requirements. Prior to shipment to BNL, preliminary tests shall be conducted. All the components and calibrated test equipment needed to perform the preliminary tests shall be included, regardless of whether the components will be part of the final delivered RFQ. The Pre-Shipment Tests are listed below.

4.2.1 Vacuum Tests.

4.2.1.1 Leak Rate. Vacuum vessel shall be leak tested with a helium mass spectrometer which has a minimum sensitivity of 2×10^{-10} atm-cc/sec (1.5×10^{-10} mbar-lit/sec). The leak rate shall be less than 2×10^{-10} atm-cc/sec with the chamber internally under a vacuum of less than 1×10^{-5} torr (1.3×10^{-5} mbar) and externally pressurized to 1 atmosphere minimum. All internal water cooling joints shall be included in the vacuum test.

4.2.1.2 Vacuum Performance. The fully assembled RFQ shall achieve a vacuum level of 7.5×10^{-8} torr without RF power.

4.2.1.3 RGA Measurement. The partial pressures of the evacuated assembly shall be measured with a residual gas analyzer. The sum of the partial pressures between atomic mass 40 and 100, excluding 44, shall be less than 0.01 of the total system pressure.

4.2.2 Low Power RF Testing. Low power RF testing shall be performed for the measurement of basic performance parameters, such as frequency, field, and Q value. The RFQ shall be tuned to the frequency and field required for testing.

4.3 Acceptance Testing and Performance Evaluation at BNL

4.3.1 Upon delivery the RFQ will be installed in the Test Line at BNL. The RFQ will be assembled, aligned, and operated to evaluate performance with the Electron Beam Ion Source (EBIS).

4.3.2 Tests will be conducted to measure operational performance versus model predictions and specifications. The parameters to be evaluated include, but are not limited to, the following:

Conditioning and HV Evaluation
Stable Operation (8 hrs.) at Continuous Rated Load
Beam Performance Ratings

5.0 Installation Site

5.1 Utilities. The following utilities for the RFQ system are available at the BNL installation site:

1. Electric power:
   a) 480 VAC, 60 Hz, 3-phase, 3-wire
   b) 208 VAC, 60 Hz, 3-phase, 5-wire
   c) 120 VAC, 60 Hz, 1-phase
2. Cooling water.
3. Compressed air.
4. Nitrogen gas.

6.0 Marking

6.1 Nameplate. A nameplate shall be permanently attached to the RFQ that has the following information: manufacturer's name, manufacturing date, drawing number, purchase order number, and weight.