Brookhaven National Laboratory
Brookhaven Science Associates
CAD Department

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Title: **Specification for the EBIS Linac**

QA Category: A-2

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Revision Record

Rev. No	Date	Page	Subject
A	12/20/06	3	Paragraph 3.2.1, 4.3.2 (e): Peak Power 200kW was 125kW
A	12/20/06	3	Paragraph 3.3.2: Add 'Shielding' requirements.
A	12/20/06	2,3	Paragraph 3.1.2 and 3.3.3.1: Delete quantity 'two' for quadrupole triplet lenses. Specify vacuum test.
A	12/20/06	4	Paragraph 3.3.3.6: Change vacuum pump port designation from 'size NW250CF' to '250 mm O.D. flange'.
A	12/20/06	4	Paragraph 3.3.3.9: Preferred design of large openings to provide for both metal and Viton seals. Add Viton requirements.
A	12/20/06	5	Paragraph 3.3.7: Clarify support stand requirements. Horizontal adjustment to be +/-18 mm (instead of 25 mm) independently upstream and downstream.

1.0 Scope of Work

1.1 The objective of this contract is to design and manufacture an Interdigital-H (IH) type Linac for the acceleration and focusing of low energy, light and heavy ions.

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 IH Linac will provide high transmission efficiency of beam, have low transverse emittance growth, and small energy spread of the output beam. The structure will be a single cavity and designed for a fixed output velocity independent of the q/m of the input beam by adjusting the cavity input rf power.

3.1.2 Internal quadrupole triplet lens(es) will provide transverse beam focusing.

3.1.3 The Linac will be installed in the beam line shown in Figure 1.

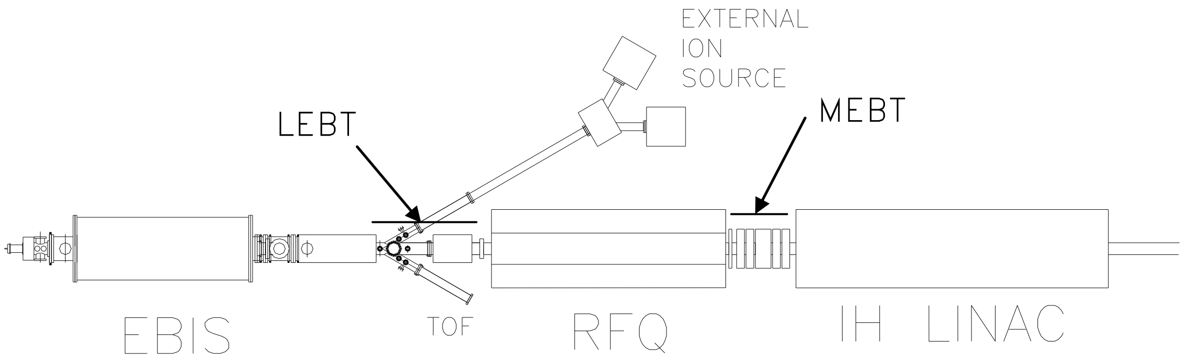

Figure 1: EBIS Facility Beam Line (Upstream)

3.2 Performance Requirements

3.2.1 Basic Parameters:

Parameter		Units
Operating Frequency	100.625	MHz
Design Beam Current	5	mA
Maximum Beam Current	> 10	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	0.300	MeV/u
Input Emittance	0.55	π mm mrad, normalized, 90%
Input Emittance, longitudinal (90%)	172	π keV/u-degree
Output Energy	2.0	MeV/u
Output Energy Spread (90%)	< ±2.0	keV/u
Transmission Efficiency	> 90	%
Acceptance	≥ 4.3	π mm mrad, normalized
Transverse Emittance Growth	≤ 20	%
Longitudinal Emittance Growth	≤ 25	%
Length	≤ 4.0	m
Tuning Range	≥ 300	kHz
Power, Peak (no beam, q/m=0.16)	≤ 200	kW
Sparking Rate	$< 10^{-4}$	sparks/pulse

3.3 Design Requirements

3.3.1 The Linac assembly consists of a shielded, cylindrical cavity (tank) of copper plated, mild steel construction, copper drift tubes/support posts, internal tank quadrupole lens(es), tuning device(s), power coupler, RF pickup probes and ports for vacuum pumps, water cooling, and other ancillary devices. The cavity shall be an assembly of three parts: a center frame from which the drift tubes are mounted, and an upper and lower half shell. The lower shell shall be designed with support points for mounting to a support stand. The mounting surfaces on the center frame are machined very precisely for accurate alignment of the small drift tubes.

3.3.2 Shielding. The shielding shall attenuate radiation levels to as low as reasonably achievable. In no case shall the dose equivalent rate for continuous exposure exceed 0.5 millirem per hour at a distance of 30 cm from the cavity. The maximum dose rate during a fault condition shall not exceed 5.0 rem per hour. These dose rates apply to the range of performance parameters specified in paragraph 3.2.1.

3.3.3 Components, Ancillary Devices, Connections and Ports.

3.3.3.1 Focusing Lens(es). At least one internal, magnetic quadrupole triplet lens shall be provided for transverse focusing. The quadupole magnets should be designed for pulsed operation, so that neighboring 5 Hz beam pulses may be different ion species. Steering coils shall be designed into the lens, mounted in the center quadrupole, and independent of the quadrupole coils. The lens assembly shall be vacuum leak tested prior to installation in the cavity. The alignment of internal lenses shall be performed before the tanks are closed and installed.

3.3.3.2 Tuner(s). The Linac shall have dynamic tuners (plungers) capable of adjusting the resonance frequency within the range specified. Static tuning features in the cavity for frequency adjustment shall be provided as required. The master tuning device located near the midplane of the cavity will be connected to the resonance control loop. Another identical tuner will remain in a fixed position and will be used as a backup to the master device, or to do fine tuning of the gap voltage distribution, optimizing the beam quality at the tank exit.

3.3.3.3 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.

3.3.3.4 RF Pickup Probes. The Linac shall have ports for mounting a minimum of four 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 Linac assembly.

3.3.3.5 Power Coupler(s). A power coupler(s) to transmit power from the amplifier 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.

3.3.3.6 Vacuum Pump Ports. The use of two 1500 liter/sec cryo pumps to achieve the specified vacuum for the Linac has been planned by BNL. The number and location of vacuum pumps mounted in the Linac tank shall be verified prior to detail design and manufacture. The port flange shall be a conflat type, 250 mm O.D. flange. The port tube size shall be 150 mm diameter minimum.

3.3.3.7 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 Linac, with the locations agreed to by BNL. Adapters used between the Linac and the gauge is permissible, and shall be supplied with the delivered assembly.

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

3.3.3.9 Port and Connection Seals. The seals and connection types for ports and openings shall be standard commercially available items to the extent practical. Conflat type flanges are preferred. The upstream and downstream beam ports shall have conflat type flanges. The seal designs of large openings, such as the upper and lower cavity shells, are preferred to have the capability of using both metal seals and Viton o-ring seals. O-rings shall be Viton and vacuum-baked prior to installation. The seals shall be installed with clean and dry without additional vacuum sealing grease.

3.3.4 Vacuum Performance

3.3.4.1 Vacuum Level. The fully assembled Linac 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 Linac 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 Linac at BNL and manufactured as a part of this contract shall be supplied.

3.3.7 Support Stand. At BNL the Linac will be installed on a structural stand that places the beam center line at 60 inches (152.4 cm) above the floor. The Linac must be mounted to the stand while it is moved into the final beam line location. A method of horizontal and vertical adjustment shall be designed into the stand. The coarse horizontal adjustment shall be capable of ±18 mm, made independently at the upstream and downstream support points. Coarse vertical adjustment will be made at the time of installation using anchor studs at the leg base plates or by using adjustable pads. Fine horizontal and fine vertical adjustments shall be capable of ±0.1 mm resolution. Leg base plates, if used, 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 Linac tank, as required to safely move and transport 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 Linac at both the Pre-Shipment 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.

3.4 Manufacturing Practices.

3.4.1 Brazing. All brazed joints shall be full penetration and suitable for high vacuum. Braze joint quality shall be in accordance with the following conditions:

1. No cracks visible with a 10X magnifier shall be permitted at any joint inside the cavity subjected to vacuum.
2. Finished joints shall be free of flux, voids, foreign particles, or material inclusions.
3. After completion of brazing, the part shall be allowed to cool down in a vacuum or inert environment until the part is below 80 degrees C.

3.4.2 Welding.

3.4.2.1 All weld joints shall be on the vacuum side of the weld joint or shall be 100% penetration welds. Welds that cannot conform to this requirement shall be submitted to BNL for approval.

3.4.2.2 All parts shall be cleaned prior to welding. Cleaning of the tank after welding is not permitted.

3.4.3 Cleaning. The inner cavity surfaces and parts shall be clean completely of oil or machining fluids in order to guarantee an oil free vacuum and low outgassing rate. The procedures for cleaning copper and stainless steel parts prior to welding, brazing, or assembly shall be submitted to BNL for review and approval. Cleaning of cavity after welding and assembly is not permitted.

4.0 Quality Assurance

4.1 The quality assurance requirements of BNL-QA-101 that apply to the Linac 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, 4.10.1-3, 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 Linac. QA system documentation shall be available to BNL for review.

4.2 Pre-Shipment Test Requirements. Prior to shipment to BNL, preliminary tests listed below shall be conducted.

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 He/sec (1.5×10^{-10} mbar-lit He/sec). Excluding permeation through elastomer seals, the leak rate of metal flange seals, welds, and braze joints shall be less than 2×10^{-10} atm-cc He/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 Linac shall achieve a vacuum level of $7.5 \text{ X } 10^{-8}$ 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 Linac shall be tuned to ensure the following:

1. Gap voltage distribution is within ±1% of the calculated distribution over the length of the structure;
2. Power coupler matching;
3. Q value at the operating frequency and temperature.

Longitudinal field distribution measurements shall be performed by bead pull testing, or an equivalent field perturbation technique, to show correlation with the physics design. The Q value shall be greater than 15,000.

4.2.3 Alignment Inspection

4.2.3.1 Longitudinal and transverse positional accuracy of the drift tubes shall be verified prior to testing.

4.3 Acceptance Testing and Performance Evaluation at BNL

4.3.1 Upon delivery, the Linac will be reassembled, 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:

Vacuum performance
RF power conditioning
Stable operation (8 hrs.) at continuous rated load
Beam performance ratings: (initial testing with He^+ beam)

a). Output energy - 2.00 MeV/u ±1%
b). Output energy spread - (TBD, from physics design)
c). Output bunch length (TBD, from physics design)
d). b. and c. together will be used to verify that the longitudinal emittance is consistent with a value $\leq 172\ \pi$ keV-deg/u, 90% .
e). Linac transmission vs. RF power. This will be measured to verify that the transmission is > 90% at a power of ≤ 200 kW + beam loading, scaled to appropriate q/m.
f). Output transverse emittance. Using the measured input emittance distribution, the output emittance growth should agree with the calculated growth to within 25%.

5.0 Installation Site

5.1 Utilities. The following utilities for the Linac 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 Linac that has the following information: manufacturer’s name, manufacturing date, drawing number, purchase order number, and weight.