INTEGRATED DESIGN OF THE SSC LINAC INJECTOR

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Abstract

The Ion Source, Low Energy Beam Transport (LEBT), and Radio Frequency Quadrupole (RFQ) of the Superconducting Super Collider (SSC) Linac act as a unit (referred to as the Linac Injector), the Ion Source and LEBT being cantilevered off of the RFQ. Immediately adjacent to both ends of the RFQ cavity proper are endwall chambers containing beam instrumentation and independently-operated vacuum isolation valves. The Linac Injector delivers 30 mA of H^- beam at 2.5 MeV. This paper will describe the design constraints imposed on the endwalls, aspects of the integration of the Ion Source and LEBT, including attachment to the RFQ, maintainability and interchangeability of LEBTs, vacuum systems for each component, and the design of necessary support structure.

Introduction

The overall SSC Linac design incorporates a modular approach, which maximizes the use of well established, low risk RF cavity technologies. A unique feature of this Linac is the serviceability of individual components, while the other components remain under vacuum. This is especially important for the RFQ because periodic maintenance and upgrading of the Ion Sources and LEBTs is likely during the operational life of the SSC.

Ion Source and LEBT

A Magnetron Ion Source and an Einzel lens LEBT system is one of the candidates for the Linac Injector. This combination was chosen initially because of its reliability and simplicity of mechanical integration into a compact package capable of attachment to the RFQ. The vacuum system providing the 2000 l/s pumping requirement can be mounted within the space constraints of the mobile equipment cart. Another candidate is a RF Volume Source and Helical Electrostatic Quadrupole (HESQ) LEBT. The parameters of the Ion Source and LEBT are defined in Table 1.

Vacuum Enclosure

The Ion Source and LEBT are installed in a single vacuum vessel, divided into two chambers, which allows differential pumping. A conductance restriction barrier between the chambers is created by the extraction cone aperture, its mounting plate and a flexible skirt that extends to the inside diameter. By eliminating the extra flange connection necessary for separate Ion Source and LEBT vacuum enclosers, a Faraday cup could be installed between the Ion Source and LEBT. This approach also maximizes the cross section of the vacuum manifolds for improved conductance at the chambers.

Table 1
Ion Source and LEBT Parameters

Ion Type	H^-
Output Energy	35 keV
Output Beam Current	30 mA
Pulse Length	100 μs (nominal)
Repetition Rate	Single shot to 10 Hz
Output Transverse Normalized Emittance	< 0.18 π mm-mrad (rms)
Transmission (LEBT)	> 99%
Output Transverse Emittance	< 0.20 π mm-mrad (rms)

Alignment

Transverse alignment of the Ion Source/ LEBT is provided by a ± 1 mm adjustment range of the chamber across the RFQ's endwall flange. To guarantee alignment repeatability, brass bushings are matched drilled and pinned. The LEBT transverse and axial adjustment is made through six small access ports from outside the vacuum chamber. Tilt of the ion beam entering the LEBT can be varied discretely at 0, ± 1°and ± 2° to obtain the optimal beam into the LEBT, along with ± 2 mm range of transverse alignment adjustment between the Ion Source and LEBT. This is accomplished by using a uniquely machined Lexan isolation flange for each tilt angle, corrected for the proper amount of offset required to locate the extraction cone aperture on the LEBT's centerline.

Beam Instrumentation

Beam instrumentation consists of two current toroids; a large diameter toroid is located at the exit of the LEBT, and a small diameter toroid is incorporated into the extraction cone. A Faraday cup deployed in the beam by a rotary actuator is located between the extraction cone and the first element of the LEBT.

Support Frame and Equipment Cart

The Source, LEBT and RFQ are bolted together forming a single rigid unit that is supported by the RFQ stand. A separate frame is provided to support the weight of the vacuum sys-

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tem for the Source and LEBT. Vacuum loads at the enclosure are cancelled by using two pairs of opposing bellows. The support frame is configured to provide clearance and access to components. In addition adjustable mounting locations for turbopumps are provided in case a different Ion Source/LEBT combination is installed. The frame is bolted to a welded aluminum equipment cart that integrates all major subsystems for off-line mobility.

Vacuum System

The vacuum system for the Source and LEBT consists of four 900 l/s (H_2) turbopumps, isolated with automatic gate valves and roughed with two backing pumps. One turbopump is for redundancy - it guarantees availability of the source should a pump fail. There are also four vacuum controllers with individual sets of roughing and high vacuum gauges. The gas loads consist of the hydrogen flow, surface outgassing and elastomer seal permeation. All active vacuum system components are hard-wired to the Ion Source Supervisory Control unit.

Radio Frequency Quadrupole

The RFQ of the Linac bunches and accelerates the H^- beam received from the LEBT from 35 keV to 2.5 MeV. The RFQ accelerator is the accelerator of choice between the Ion Source and drift-tube Linac instead of the Cockcroft-Walton high-voltage column used in earlier facilities. A considerable amount of RFQ design and operational experience now exists at many laboratories around the world. The basic design parameters are defined in Table 2.

Table 2
Basic Cavity Parameters

Type	**4-Vane**
Frequency	**427.617 MHz**
RF Peak Power	**278 KW**
Cavity Operating Temp	**40.5 ° C**
Design Vacuum Level	**6.0 X 10^{-5} Pa**

Cavity

The RFQ cavity (along with slug tuners, monitors, and drive loops) was designed and fabricated by Los Alamos National Laboratory, in a collaborative effort with the Superconductive Super Collider (SSC) Laboratory, and is manufactured of TeCu. It is a two-section design; each section is made of four identical quadrants, electroformed together to create a single structure. This approach was chosen because it required no development effort, had great reliability and little risk, and allows very stable RF tuning. There are two drive loops, located at the half-power point of the cavity. There are eight monitor loops, located at 90° intervals near each end of the cavity.

Support Stand

The support stand for the cavity is a six-strut design, selected for the simplicity of design, and ability to nearly independently adjust one strut without changing the alignment of the other struts. Each strut utilizes a differential thread, to allow fine adjustments in the position of the cavity. There are three vertical struts, two lateral struts and one longitudinal strut. The stand is designed to support not only the 333 Kg of cavity weight, but a cantilevered load induced by the Ion Source and LEBT. The six-strut design allows thermal expansion of the cavity created during the rise of the cavity from ambient temperature to the operating temperature of 40.5° C.

The stand also supports the vacuum system of the RFQ assembly, and the water inlet and outlet manifolds, used in conjunction with the Temperature Control Unit.

Vacuum System

The vacuum system for the RFQ System consists of two parallel 450 l/s (N_2) turbopumps with backing pumps, and gate valves to isolate each turbopump from the cavity. There are also two parallel vacuum controllers, with associated sets of roughing and high vacuum gauges. There is a manifold on each end of the cavity, mounted to the support stand, and connected to the cavity with bellows. A gate valve and turbopump are mounted under the manifold. Thus, all of the vacuum system weight is supported by the stand. The system will reach the operating vacuum level within a few hours. The gas loads consists of cavity/manifold surface outgassing, elastomer seal permeation, and the gas load from the LEBT. All active vacuum system elements (turbopumps/controllers, gate valves, backing pumps, beamline isolation valves, vacuum controllers, etc.) are connected to the RFQ Supervisory Control, and hard-wired as necessary for system safety.

Temperature Control Unit

The Temperature Control Unit (TCU) for the RFQ System maintains the cavity at a nominal operating temperature of 40.5° C. An elevated temperature was chosen to insure that adding heat was the only control mechanism needed. This simplifies the design, and increases reliability by eliminating a chiller system. During initial setup, and as a maintenance/monitor diagnostic, eight thermal sensors are affixed to the cavity (one to each of the eight quadrants) to verify proper temperature of each quadrant and adjust the water flow rate, if required, with a manual valve.

In normal operation, the TCU sends heated low conductivity water (LCW) to a manifold and the to the cavity. The supply water temperature, measured exiting the centrifugal pump, is compared to a selected setpoint, and corrected as necessary either by activating the TCU heater, or adding relatively cool water from the primary LCW supply. The eight sensors on the cavity are used only to advise of out-of-range temperature values.

RFQ Cavity Endwall Chambers

Longitudinal space limitations dictated by the low emittance requirement of the SSCL Linac have compelled the designers of the Injector system to combine instrumentation and gate valves within the RFQ cavity endwalls. These chambers have been machined from solid 304L VAR (vacuum-arc remelt) stainless steel using the ram Electric Discharge Machining (EDM) process. This has resulted in an endwall design which consumes less than 30mm of beamline space at the entrance end, and less than 33mm at the exit end.

The primary function of the endwall is to complete the RFQ resonant cavity enclosure. To this end the surfaces facing the interior of the cavity have been plated with copper, vapor-deposited, and equipped with stabilizer rods machined from the same tellurium-copper alloy that comprises the cavity structure. On the opposite side of these surfaces begins the instrument chambers.

Beam Instrumentation

The features in the instrument spaces at each end of the cavity include four instrument ports oriented in a right cross configuration, providing radial access to a shared beamline space. Available instrument space is approximately 16mm measured on beam axis (Z), by 48mm transverse. Linear actuators for positioning wire scanners, apertures and a Faraday cup, will slew 130mm radially from their integrated mounting flanges on the periphery of the chambers. Ports are oriented at 45° angles with respect to the vertical, and are equipped with round and diamond alignment pins for accurate positioning. Metal seals will be used between instrumented linear actuators and the chambers.

Isolation Gate Valves

Electrically controlled, pneumatically operated gate valves have been designed (in cooperation with VAT Valves), to operate independently of diagnostics in dedicated space at the RFQ cavity ends. The isolation valves will close radially from a mounting position on the perimeter of the endwall chamber assembly between adjacent instrument ports. They can be operated while instruments are deployed without interference.

Tuning

A 14-mm hole in each quadrant of the endwalls permits measuring the field distribution along the RFQ using the bead pull technique with the endwalls installed. The RFQ endwalls mounting scheme permits the adjacent accelerator components, the Low Energy Beam Transport or the Drift Tube Linac Matching Section, to be demounted while they or the RFQ remain under vacuum.

Manufacturing

The endwall chamber assemblies were machined, plated and inspected at Allied Signal Aerospace Company's Kansas City Division manufacturing facility, to prints provided by SSCL. Among the many manufacturing difficulties which were overcome as work progressed include rejection of the original material due to inclusions and voids (discovered during ultrasonic testing of the raw blanks), meeting the high tolerances demanded of the diagnostic port and RF surface machining, the drilling and tapping of sixty-six holes and twelve alignment pin holes (in each endwall structure), and the generally difficult character of the stainless steel material used. Large volumes of the parent material were removed, mostly by the ram EDM process.

Status and Schedule

The present SSC schedule calls for first beam through the RFQ on the test stand in Central Facility by November 1992. In support of this we are planning on installing the RFQ in September and performing beadpulls and RF conditioning in October. The Ion Source and LEBT development tests are ongoing, the integration of a Magnetron/Einzel lens LEBT combination to the RFQ is scheduled for late October.

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