SUPERCONDUCTING ACCELERATOR ACTIVITIES AT TRIUMF/ISAC

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Abstract

TRIUMF is proceeding with a major upgrade to the ISAC project, ISAC-II, that includes the addition of 43 MV of heavy ion superconducting linear accelerator. A SCRF laboratory consisting of clean assembly and rinse area plus an rf test area is operational with an active program for cavity, coupling loop and tuner developments. The paper will describe the superconducting program at TRIUMF including the design of the medium beta cryomodule and a summary of the activities in the SCRF laboratory.

1 INTRODUCTION

The ISAC-I post-accelerator, now fully commissioned, combines a heavy ion RFQ and DTL, both operating cw and at room temperature. A major upgrade to the ISAC radioactive beam facility at TRIUMF, the ISAC-II project, is now under construction. The installation requires the addition of a superconducting heavy ion linac as an energy booster to the ISAC-I accelerator complex[1]. An initial installation of 25 MV will be completed in 2005 with a further 18 MV added by 2007. In the final configuration the accelerator will accelerate radioactive ions of $3 \leq A/q \leq 10$ to a final energy of 6.5 MeV/u for $A/q \leq 7$. A superconducting rf program is now underway at TRIUMF.

The superconducting linac is composed of two-gap, bulk niobium, quarter wave rf cavities, for acceleration, and superconducting solenoids, for periodic transverse focussing, housed in several vacuum insulated cryomodules. The linac has been grouped into low, medium and high beta sections corresponding to cavities with design velocities of $\beta_o = 4.2\%$, $\beta_o = 5.7, 7.1\%$ and $\beta_o = 10.4\%$ respectively. The two cavity types in the mid beta section, composed of eight $\beta_o = 5.7\%$ and twelve $\beta_o = 7.1\%$ cavities, are now being fabricated in industry. A prototype of the $\beta_o = 7.1\%$ cavity[2] has been designed in a collaboration with INFN-LNL, and fabricated in Italy. The linac has been designed assuming design gradients of 5 MV/m in the low beta section and 6 MV/m in the medium and high beta sections. These correspond to peak surface fields of 25 and 30 MV/m respectively. A schematic of the various cryomodule layouts in the full installation is shown in Fig. 1. The first stage installation comprises all the medium beta cryomodules and the two six cavity high beta modules. A new building is under construction to house the expansion.

2 CRYOMODULE DESIGN

A prototype of the medium beta cryomodule, shown in Fig. 2, is now in the design phase.

The vacuum tank consists of a stainless steel rectangular box and lid. All services and feedthroughs are located

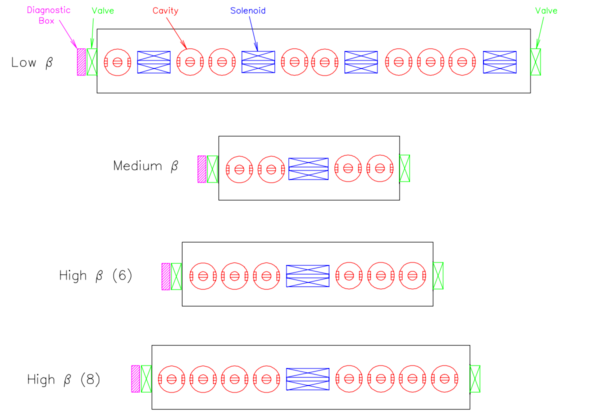

Figure 1: Proposed cryomodule layout for the three sections of the ISAC-II SC linac.

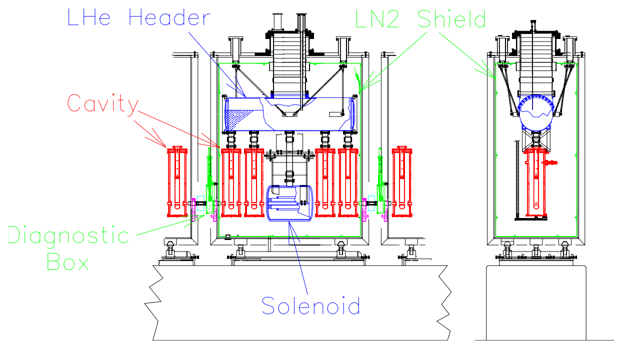

Figure 2: Medium beta cryomodule for ISAC-II.

on the lid. Unlike elliptical cavity systems a common vacuum is shared between the thermal isolation space and the cavity/beam space. For this reason the vacuum system is completely oil free with a 340 ltr/sec magnetically levitated turbo pump and scroll backing pump. Each cryomodule has independent gate valves at each end of the beam tubes to allow isolation of a cryomodule unit in case of failure. The initial assembly will be done in a clean room as will all subsequent servicing to the unit. The intermodule space consists of a slim diagnostic box and bellows. An $x - y$ steering magnet fits around the bellows.

A 200 litre LHe reservoir is mounted from the lid from supports thermally anchored with LN2. The LHe tank provides a mounting surface for a common support frame for the cavities and solenoid. The goal is to position the cavities and solenoids to an accuracy of 250μm. During nominal operation a liquid nitrogen load of about 4 liquid liters per hour is estimated from heat radiation and conductivity load and from experience with our test cryostat. The nitrogen plumbing is done in 1 inch (25 mm) serial stainless steel tubing clamped to 0.065" (1.5 mm) thick copper sheet and spaced in 16 inch (400 mm) intervals. The rf coupling loop is thermally isolated from the cavity and anchored to LN2 through a separate heat exhange loop. Each cryomodule will require one valve box with three valves; an IN valve and OUT valve and a BYPASS valve. A warm valve for cooldown is installed outside the valve box.

Pre-cool mode The cryomodule is initially pre-cooled by radiation from the LN2 shield. The main pre-cool comes from a helium distribution system in the helium space that delivers helium to the lowest point in each of the helium spaces. Pre-cooling is done one cryomodule at a time. The cold return valve is closed during the first stage of cool down and opened when liquid helium is indicated in the cryomodule reservoir. The estimated time to completely cool down a single cryomodule to liquid helium temperatures is under 24 hours.

Operation mode In operation (nominal) mode the cryomodule supply valve is open. The dual phase helium enters the cryomodule helium supply tank just above the existing liquid surface. The gas part leaves through the return pipe/coupling and return transfer line/valve box to the refrigerator for reliquification. The liquid part adds to the liquid in the tank. Two level probes are located in opposite ends of the cryomodule LHe supply tank. The level is controlled by heaters immersed in the liquid and by the flow from main supply dewar / refrigerator.

2.1 Solenoids

Focusing in the SC LINAC is provided by 9 Tesla 26 mm diameter bore SC solenoids of lengths 16, 34 and 45 cm corresponding to the low, medium and high beta cryomodules respectively. Since the solenoid fringe field could affect the operation of the cavities, the magnets are equiped with active compensation using bucking coils. The operating field at the cavities is specified to be less than 0.1 Tesla. The magnets are mounted in a liquid Helium pressure vessel fed from the common Helium header. Power leads run from the solenoid through the common Helium header to feed-throughs at the top of the cryo-module. A contract is about to be signed for the five medium beta and three high beta solenoids with delivery of a prototype this fall.

3 SCRF DEVELOPMENTS

A temporary superconducting rf test lab of ~ 100 m^2 is set-up in a space rented by TRIUMF in a neighbouring laboratory complex. It is intended that the space will be occupied for at least two years until the SCRF area in the new ISAC-II building is available for occupancy. The laboratory includes a test area with a sunken cryostat pit 1 m in diameter and 2 m deep for high field rf testing, and clean areas for cavity assembly (Class 1000) and high pressure water rinsing (Class 100).

3.1 Test Cryostat

The test cryostat vacuum vessel is 2.4 m high by 0.8 m in diameter. A LN_2 side shield holds a volume of 200 litres and is directly connected to a copper bottom shield baffled to allow adequate conductance for pumping. A top shield of copper is bolted to a copper flange at the top of the LN_2 vessel with bolt access available through six KF-50 flanges on the top plate. This copper flange is cooled by a copper cylinder inserted in the LN2 vessel to a depth of 65 cm. The top plate assembly consists of two large flanges that allow separate removal of either the helium dewar/cavity assembly or the LN2 vessel. The LHe vessel holds a volume of 48 litres. Mechanical feedthroughs for the rf coupling loop and mechanical tuner are located on the top flange. The cryostat is equiped with a fine pitch leak valve that connects the helium reservoir to the cryostat vacuum to allow spoiling the vacuum with pure helium during rf conditioning. Breakouts for up to ten temperature sensors are available. A 'dummy' full scale medium beta cavity has been fabricated in copper for cryostat tests and to establish test procedures and initial cryostat thermal loads. The static heat load for the complete test assembly including cavity is ~ 1 W.

3.2 High Pressure Water Rinse (HPWR)

High purity water is supplied through an on-line staged filtration system capable of delivering 20 ltr/min of 18 MΩ water to the high pressure pump. Particulate filtration, to 0.2μm, and organic filtration stages are followed by three deionizing beds in series. The purified water is pressurized to 2000 psi, passed through a 0.5μm high pressure particulate filter and delivered to the cavity through a 2 m long rotating wand outfitted with a nozzle with several spray jets. The wand is inserted into the cavity manually. The cavity rests on its side on teflon wheels to allow manual rotation of the cavity during the rinse (Fig. 3). Present treatments are thirty minutes long. Following the rinse the cavity is immediately fitted with dust caps and dried for 24 hours while applying moderate baking with heat lamps. An automatic rinse sytem is now in preparation to allow a more controlled, less labour intensive procedure.

3.3 Cold Tests

First cold tests were completed in April 2002. Parallel developments of cavity performance, rf controls, cryogenic studies, cleaning procedures and mechanical tuners are ongoing.

Cavity Performance and Characterization A summary plot of the measured cavity performance is given in Fig. 4. In initial tests field emission reduced the Q sharply at field levels above 4 MV/m ($E_p \geq 20$ MV/m). HPWR treatments gave marked reductions in field emission. Helium conditioning at 4×10^{-5} torr for thirty minutes at 9 MV/m gave a further improvement so that we could push the cavity right out to the quench limit ($E_a \geq 9.5$ MV/m,$E_p \geq 48$ MV/m) without significant

Figure 3: The manual high pressure water rinse system shown with the copper ‘dummy’ cavity.

field emission. The best results match those attained in initial tests at Legnaro with the exception that the Q values are lower by a factor of two. One possible explanation is that there is trapped magnetic flux that limits the performance since we have not yet added any magnetic shielding to the cryostat. We are obtaining a mu metal shield for the cavity to help improve the Q. Another explanation is possible hydride contamination, ‘Q disease’, that may have occured during a vacuum accident when the cavity warmed to 100○ for more than 24 hours.

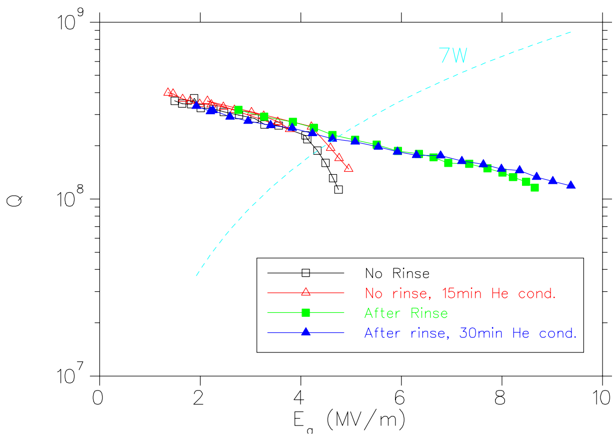

Figure 4: Measured cavity performance during cold tests at TRIUMF.

RF Controls The ISAC-II prototype rf control system[3] is based on the self-excited loop. It consists of two modules: an RF module and a DSP module, housed in a VXI mainframe. A pair of Motorola DSP56002 digital signal processors provide the low level amplitude, phase and tuning regulation. A special circuit is used to pulse through multipactoring. A rack mounted PC provides supervisory controls for these modules. An Apache HTTPD server running on the same PC acquires data from several GPIB-enabled instruments such as power meter, frequency counter, frequency synthesizer and a digital oscilloscope. These data and the computed Q and Ea values can be displayed and plotted in any Web browser. During the series of tests this year the controls system regulated the cavity in both self-excited and frequency locked mode. In one test the cavity frequency was detuned by 10 Hz by increasing the pressure in the helium space ($df/dp \simeq$ 1Hz/Torr) while overcoupling to produce a 10 Hz bandwidth. The control system managed to maintain lock both during the slow pressure change and when the pressure was suddenly released. Future developments will include the addition of a mechanical tuner to the control loop.

Mechanical Tuner The mechanical tuner alters the resonant frequency of the cavity by deflection of a niobium tuning plate that encloses the cavity on the bottom high field end. Presently a flat plate is being used but we are developing a plate spun with undulations and radial slots to allow a larger tuning range. A prototype plate has already been spun from reactor grade niobium. The plates each give a tuning sensitivity of 7 Hz/μm. The ‘oil can’ spun plate increases the tuning range from about 15 kHz to at least 40 kHz while significantly reducing cavity stresses due to plate distortion. The mechanical tuner (Fig. 5) is a lever mechanism that acts directly on the center of the tuner plate through a zero backlash hinge and stiff rod connected through a bellows to a precision linear stepper motor (Kollmorgen) located outside the vacuum on the top of the cryostat. A warm mock up table has been constructed to provide initial testing of the tuner/motor prior to cold tests.

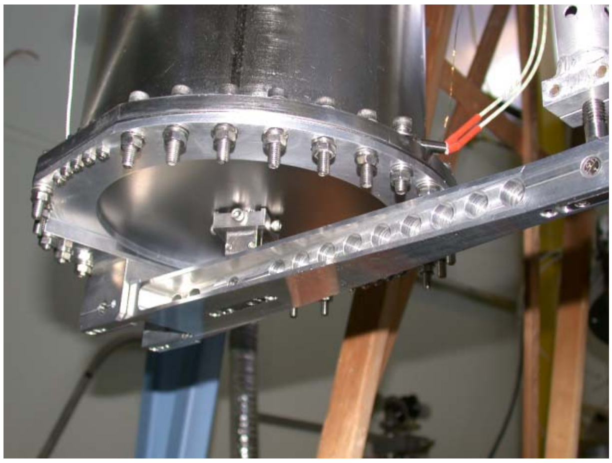

Figure 5: The prototype mechanical tuner.

4 REFERENCES

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