THE 1.3 GHz SUPERCONDUCTING RF PROGRAM AT TRIUMF

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Abstract

TRIUMF is proposing to build a 50 MeV electron Linac as a driver to produce radioactive ion beams through photo-fission. The present design calls for the use of nine-cell 1.3 GHz Tesla type cavities. A 1.3 GHz Superconducting RF (SRF) program has been initiated with the goal to produce and test one nine cell cavity by the end of 2009. The program will use the existing clean room and SRF test facilities that support the ISAC-II heavy ion superconducting Linac. A vertical cryostat has been modified with a new insert to allow single cell testing. A single cell fabrication program is being initiated with a Vancouver company. A RRR measurement program is on-going to test cavity welds. The goal of the 1.3 GHz upgrade is to produce cavities for the 'in house' project as well as broaden TRIUMF's technical base for future potential collaborations.

INTRODUCTION

Existing Program at 100 MHz

A cavity testing program was initiated at TRIUMF in 2002 in support of the construction of a superconducting heavy ion Linac.[1] A test cryostat was used for single cavity characterizations, LLRF controls and RF ancillary development. Since then over 40 vertical cold tests have been completed to characterize a production series of twenty 106 MHz quarter wave bulk niobium cavities. In addition five full cryomodules have been assembled and ten cryomodule cold tests have been completed prior to installation of the modules in the Linac vault. TRIUMF has built a core competency in 100 MHz SRF technology while producing the ISAC-II heavy ion Linac. Due to the incorporation of modern processing techniques and clean room assembly, largely developed in the $\beta = 1$ community, the accelerating gradients achieved in the TRIUMF Linac are significantly higher than those found at other existing heavy ion machines. Presently a new series of cavities at 141 MHz is in production at PAVAC Industries of Richmond BC after a successful prototyping of two cavities.[2] Twenty cavities will be assembled in cryomodules for installation by the end of 2009.[3]

e-Linac Project

The aim of the ISAC-III (ARIEL) proposal[4] is to generate additional radioactive ion beams (RIBs) on target to produce more physics. Presently a 500 MeV proton beam from the cyclotron at 100μA produces radioactive isotopes through fission and spallation from a thick target. It is proposed to increase the RIBs available by adding an independent and complimentary driver: a high-power 50 MeV electron Linac.[5] The electron linac would operate at 1.3 GHz and use, where possible, existing ILC technology to reduce development time.

EXISTING FACILITIES

The existing ISAC SRF facilities consist of the following areas as shown in Fig. 1:

- Preparation area: A staging area for receiving parts intended for use or assembly in the clean room. The room contains two large tanks one for ultrasound cleaning and one for rinsing. These tanks are used for cleaning of parts before sending to the assembly area.
- Clean room: This is divided up into sections depending on the level of particulate control required. The eastern area including the HPWR and assembly areas are cleanest (Class III). The cavity test area with an overhead crane has the next level of particulate control and protocol (Class II) and the RF measurement area is the third isolated area with a third protocol (Class I). The clean rooms are not commercial installations but home-made with large HEPA filter installations in the ceiling and return air ducts near the floor located around the room. Air pressure control is maintained to force HEPA filtered air to flow from the cleanest areas to the less clean areas. Particle counts are typically below 100 in Class III and below 1000 in Class II.
  - HPWR Rinse Area: Houses a fume hood for light chemical cleaning and a horizontal rinse stand to allow semi-automatic rinsing of quarter wave cavities. Filtered 18 MOhm water is delivered at high pressure as the cavities are rotated.
  - Assembly Area: Single cavities and whole cryomodules are assembled in clean conditions in preparation for cold tests.
  - RF measurement area: Houses the LLRF control racks and RF measurement equipment for cavity characterizations during vertical tests.
  - Cavity Test Area: Equipped with a test pit for x-ray shielding during RF tests. It is sufficient to contain both the single cavity test cryostat and the medium beta cryomodule, with dimensions 4m long x 2 m wide x 2.5m deep. An overhead crane is available for lifting the cold mass into

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either the cryostat or the cryomodule. All signals from the test are gathered to the local racks and communicated to the EPICS control system.

- RF Controls Lab: Lab space for the development and production of the LLRF controls
- BCP Chemical Lab: A BCP facility with large walk-in fume hood allows full cavity etching for either the heavy ion cavities or a TESLA style nine-cell elliptical cavity.

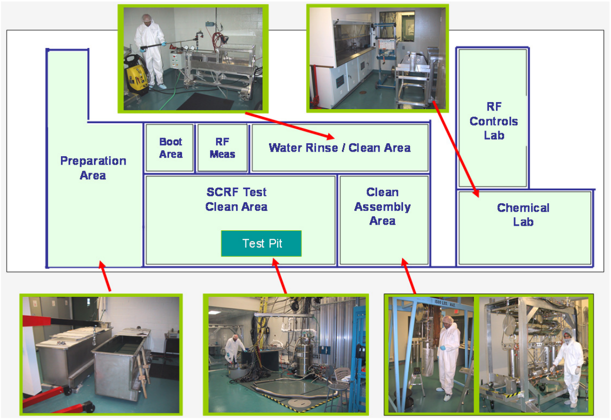

Figure 1: The SRF facilities in ISAC.

1.3 GHz PROGRAM

The cavities that will be developed for the e-Linac are 1.3 GHz elliptical cavities similar to those developed in DESY for the Tesla project and used at FLASH. We have presently received one single cell cavity as part of a collaboration with Fermilab. Two single cells and one nine-cell are also expected from DESY. The 1.3 GHz program will use the lab space already developed for the heavy ion cavity production. New vertical cryostats for both single cell and nine cell cavity testing are required. Presently a vertical cryostat from another application has been modified for single cell cavity testing. The cryostat consists of a vacuum chamber, an annular nitrogen bath just inside a vacuum chamber wall and a helium bath inside the nitrogen chamber with an inner diameter of 28 cm. The cryostat was first assembled for cryogenic and vacuum tests. In this case the top plate assembly consisted of temperature staging baffle plates, extension tubes to the cold mass, a Helium level sensor and cryogenic temperature sensors. The cold mass consisted of a copper plate with a 50 W heater. Hermetically sealed vacuum pumps were procured for sub-atmospheric pumping of the helium space. The pumping station consists of four interconnected pumps mounted in a metal frame and includes all the necessary power, control electronics, and valves. The pumps that are used are: (1) a Pfeiffer Balzers WKP 4000 SP roots pump, (2) a Pfeiffer Balzers WKP 500 A SP roots pump, (3) an Alcatel ZT 2060 H pump, and (4) an Alcatel 2063 H1 pump. The cryostat is first cooled with LN2 in the side shield before filling with LHe at atmospheric pressure. The bath pressure and helium temperature are then monitored as the pumps are activated (Fig. 2). The cryostat reached a temperature of 2°K after $\sim$25 minutes of pumping. A minimum temperature of 1°K (determined by pressure measurements) was reached after 45 minutes of pumping corresponding to a pressure of 130 mTorr. The helium level dropped by 8.5 inches, from 35.5 inches to 27 inches, corresponding to 13.6 liters in 15 minutes or 55 litres/hour. The variation in level was 23 litres/hour at 2°K corresponding to a gas evolution from a 17 W load. Since LHe has a density of 140 g/litre at 2°K this corresponds to a mass flow of 0.9 g/s. The static load on the cryostat was measured at 2.7 W. The pumping speed was further tested by activating the heater on the copper cold mass. The heater was raised until at $\sim$15 W active load the temperature reached an equilibrium near 2°K. The exhaust valve was also used to help throttle the pumping speed to control the temperature.

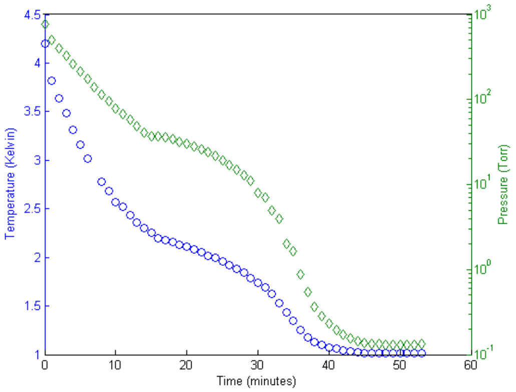

Figure 2: Temperature and pressure during pumpdown.

A top plate for single cell tests has been fabricated and assembled. A variable coupler has been designed to provide sufficient flexibility for single cell cavity rf tests. A capacitive coaxial coupler with antenna diameter 9.2 mm is equipped with a welded bellows to provide 74 mm travel and coupling in the range of $Q_{\rm ext} \sim$ 1e7 to 5e10. The test coupler is now being fabricated.

Additional test ancillaries include an RF amplifier, RF pickup, a low level RF system and diagnostic equipment. To avoid trapped flux significantly reducing the surface resistance the background field in the cavity should be suppressed to $<$10 mG. This will be accomplished by adding two layers of mu-metal; a warm layer of 1 mm thick material just inside the vacuum chamber and a cold layer of 1 mm Cryoperm material as a cylinder surrounding the cavity in the helium bath. In addition a steel pipe will be added around the cryostat to shield radiation but will also suppress environmental magnetic fields.

An apparatus for measurement of Niobium RRR has been assembled with electronics developed in house. It allows a fast measurement but is limited to only one sample per cool-down. The cryogenic hardware consists of a standard liquid helium 100 litre storage dewar. A sample is mounted into a cylindrical cartridge then introduced into the dewar using a long dipstick. The natural stratification of the He gas above the liquid surface and the insertion depth of the dipstick determine the sample temperature. Samples are typically 3 inches long and 1/4 inches wide. A four probe technique is used to measure the resistance just above the transition temperature of niobium, with the current injected at the ends of the sample and the voltage taps being located inwards. The samples are driven by a 100 mA, 3 Hz sine-wave current to average out thermally induced emf. The voltage across the sample is read through a nanovoltmeter designed in house and an AGILENT 35670 spectrum analyzer.

The 1.3 GHz cavity tests will be conducted in the existing test pit in the Class II area. An LHe feed from the central helium refrigerator is available. The vacuum pumps for sub-atmospheric operation at 2°K will be located in a nearby service room and connected to the EPICS controls system for remote start/stop. During initial operation the exhaust gas will be vented to atmosphere; in subsequent operation the exhaust will be first purified and then sent via return piping to the compressor.

Plans are in place to design and acquire a new vertically oriented HPWR facility and a tuning stand to allow plastic deformation of individual cells and field measurement with a bead pull. In addition a horizontal test cryomodule for testing fully dressed cavities will be designed and fabricated. After testing, the cavities will be assembled in horizontal strings for either single cavity tests in the horizontal test cryomodule or for installation in the e-Linac. These string assembly frames would reside in the Class III clean assembly area.

CAVITY FABRICATION

The Tesla cavity consists of nine-cells with the entrance and exit cells welded to beam tubes and end flanges to make a continuous beam pipe. The entrance and exit beam tubes are also outfitted with ports for coupling in the RF power and coupling out a pick-up voltage for cavity regulation as well as coupling out HOMs from the cavity. The tubes for the beam pipes and the coupler ports are made by sheet rolling or back extrusion and are joined to the cavity by EB welds.

A cavity fabrication program has been initiated at PAVAC Industries, a local machining and EB welding firm in the Vancouver area. A set of forming dies has been sourced from RRCAT in India through a collaboration agreement with FNAL. The forming dies for the inner cells have been delivered and the two outer die sets are soon to arrive. Cavity fabrication will begin with forming studies on copper followed by the welding of copper half-cells into dumb-bells to establish weld fixtures and tooling and RF frequency defining steps. The plan is to complete two single cell niobium cavities by Spring 2009 and one nine cell cavity by the end of 2009.

PROJECTS

The funding for the e-Linac may be announced in early 2010. In the meantime several initiatives allow us to move forward with the elliptical cavity program. We have recently signed an MOU with VECC in Kolkata. VECC also has plans to build an e-Linac for photo-fission and are working with TRIUMF on research and development towards that goal. An initial step will be the construction and beam test of an injector module capable of accelerating 10 mA of electrons to 5 MeV and reduced currents up to 10 MeV. The design, fabrication, installation and test of the injector module will test all technical aspects of the e-Linac program. A test area in the ISAC-II complex has been identified as a beam test area. An electron gun has been sourced from J-Lab and will be installed in the coming months followed by a room temperature buncher and matching optics. Beam dynamics and RF modelling studies of the e-Linac front-end will define the injector module by June 2009. Parallel cavity prototyping studies and cryomodule design and fabrication would continue through to the end of 2010 with a beam test scheduled for spring 2011.

TRIUMF has also entered into a collaboration with CERN on the Superconducting Proton Linac.[6] Two cavity types, a $\beta = 0.65$ and a $\beta = 1$ five-cell elliptical cavity are called for in the design. Both cavities will operate at 704 MHz. TRIUMF will initiate modelling, engineering and prototyping studies on the $\beta = 0.65$ cavity with the goal to produce a cavity in Canadian industry by the end of 2010.

SUMMARY

A 1.3 GHz program for production of nine cell elliptical cavities has started at TRIUMF. Upgrades necessary for 1.3 GHz cavity fabrication and processing are underway in the existing SCRF infrastructure. Fabrication of a one cell in collaboration with PAVAC industries has begun with delivery and testing of a nine-cell cavity scheduled for the end of 2009.

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