A SUPERCONDUCTING RF VERTICAL TEST FACILITY AT DARESBURY LABORATORY

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Abstract

A superconducting RF vertical test facility (VTF) has been constructed at Daresbury Laboratory for the testing of superconducting RF cavities at 2K. When fully operational, the facility will be capable of testing a 9-cell 1.3 GHz Tesla type cavity.

The facility is initially to be configured to perform phase synchronisation experiments between a pair of single cell 3.9GHz ILC crab cavities. These experiments require the cavities to operate at the same frequency; therefore a tuning mechanism has been integrated into the system.

The system is described, and data from the initial operation of the facility is presented.

INTRODUCTION

The Accelerator Science and Technology (ASTeC) Radio Frequency (RF) group at Daresbury Laboratory is in the process of setting up the necessary facilities for the production and testing of superconducting RF cavities.

The facilities will include a chemical etching station, high pressure rinsing station, a clean room assembly area and a vertical test facility.

Facilities are also being developed for testing of other RF components, including a coupler test stand, and an IOT / klystron test stand.

This paper focuses on the vertical test facility, which has initially been configured for validation of single cell 3.9GHz dipole mode cavities suitable for use as an ILC crab cavity. This cavity was designed in a collaboration between Daresbury Laboratory and Lancaster University as part of the Cockcroft Institute.

The tests on the ILC crab cavities involve synchronising the phase of two independently powered cavities. To achieve this, the cavities must be resonant at the same frequency. For this reason, a simple tuning mechanism has been integrated into the system.

SYSTEM DESCRIPTION

The purpose of a VTF is to allow investigation into the performance of a superconducting cavity prior to integrating it into an operational cryomodule. To perform this task, the Daresbury Laboratory VTF:

- Exposes the superconducting cavity to stable operational cryogenic temperatures, by supporting it within a cryostat filled with liquid helium, and vacuum pumping the helium bath to achieve the correct temperature.
- Shields the cavity from the earth’s magnetic field.
- Applies phase locked RF power to the cavity in a controlled manner.
- Protects personnel from harmful ionising radiation. By use of appropriate shielding and interlock systems.
- Allows some tuning of the RF cavities.

Figure 1: Daresbury Laboratory Vertical Test Facility

Cryostat / Cryogenics

The cryostat is a 3m tall vessel manufactured by AS Scientific, capable of containing a maximum of 300 litres of liquid helium.

This system does not include a liquid nitrogen heat shield, rather it utilises 3 self cooled radiation shields, which are cooled by gaseous helium passing the walls of the cryostat as the helium fill is taking place. The rate of cooling of these shields can be controlled using a valve which directs gas flow around the neck of the cryostat, rather than through the main exhaust port in its centre.

At the present time, the cryogenic systems are operated manually, with the helium fill being a manual siphon from a dewar. A series of manual valves are used to control the exhaust helium and the pump down to 2K.

The pump down to 2K is achieved using a rotary backing pump, with a roots blower providing additional capacity.

Magnetic Shielding

During cool down, any magnetic flux present as the cavity becomes superconducting will be trapped, consequently degrading the cavity Q. Therefore, the cavity must be shielded from external magnetic fields. To achieve this, the cryostat is fully enclosed within a mu-metal magnetic shield, to eliminate the earth's magnetic field to as low a level as practically possible. This has been measured at 15mG

Radiation Protection

Any cavity capable of generating high peak electric fields can be susceptible to field emission of electrons and subsequent bremstrahlung x-ray production.

A study was performed by the Daresbury Laboratory health physics section [1] to evaluate the level of shielding required to test the 3.9GHz ILC cavities. This study concluded that due to the low peak field (2MV/m) and short active length (30mm) of the cavity, the self shielding provided by the walls of the cavity and the cryostat itself, were sufficient to attenuate any radiation induced by the cavity.

For additional protection for personnel, an interlocked radiation monitor has been installed in the vicinity of the cryostat. In the event of the radiation level exceeding 5μSv/h, an RF relay removes the drive from the power amplifier.

The Cavity Support structure

The cavities are secured to a base plate, which is suspended from the lid of the cryostat by 4 stainless steel rods running down its entire length. These rods also support a series of thermal radiation baffles to prevent heating by radiation from the lid, and styrofoam blocks to control gas flow.

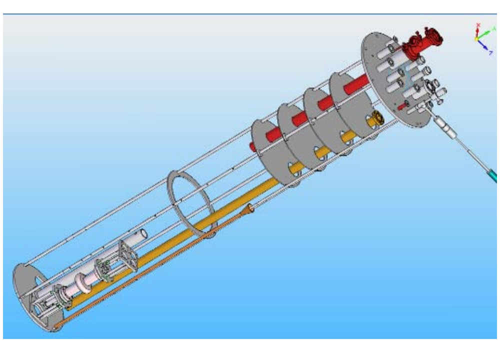

Figure 2: Cavity Support Structure

Various Cernox temperature sensors are placed along the length of the support structure, and a heater is placed at the lowest point to expedite the boil off of helium at the conclusion of experiments. The depth of the helium is also measured using a helium depth indicator.

A unique feature of the ILC crab cavity phase synchronisation experiment is the requirement to tune one of the cavities within the vertical test stand. The maximum tuning force required on the cavity has been estimated at 500N to produce 500 kHz of tuning.

To achieve this, the cavities are assembled into a load cell, which is secured at one end by the base plate. The other end of the load cell is fixed to a lever. The fulcrum of the lever is fixed to a central support rod, and the other end of the lever has a cable attached, allowing force to be applied to the cavity. This cable is taken outside of the cryostat through the lid (via a bellows and blanking plate to maintain vacuum seal), through a pulley, and is tensioned by hanging steel weights on its end. This arrangement is shown in Figure 3.

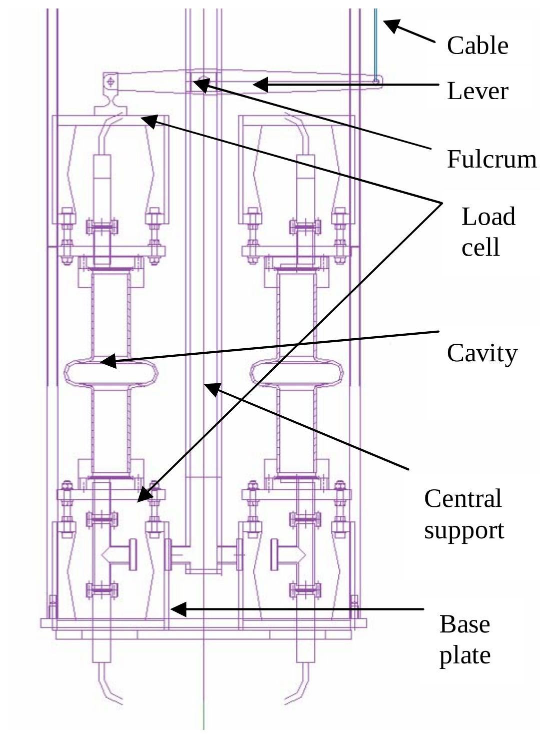

Figure 3: Cavity Tuning System

DAQ / software

A Labview system has been developed to automatically capture, display and archive all measured parameters of the system. These are displayed on a touch screen panel which includes an overall synoptic of the test stand, and allows parameters to be displayed in chart form to study trends.

This has been achieved using networked Compact Fieldpoint modules from National Instruments

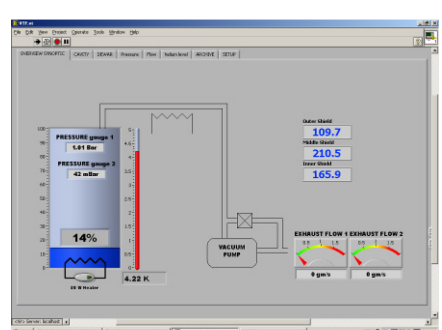

Figure 4: Labview DAQ system screenshot

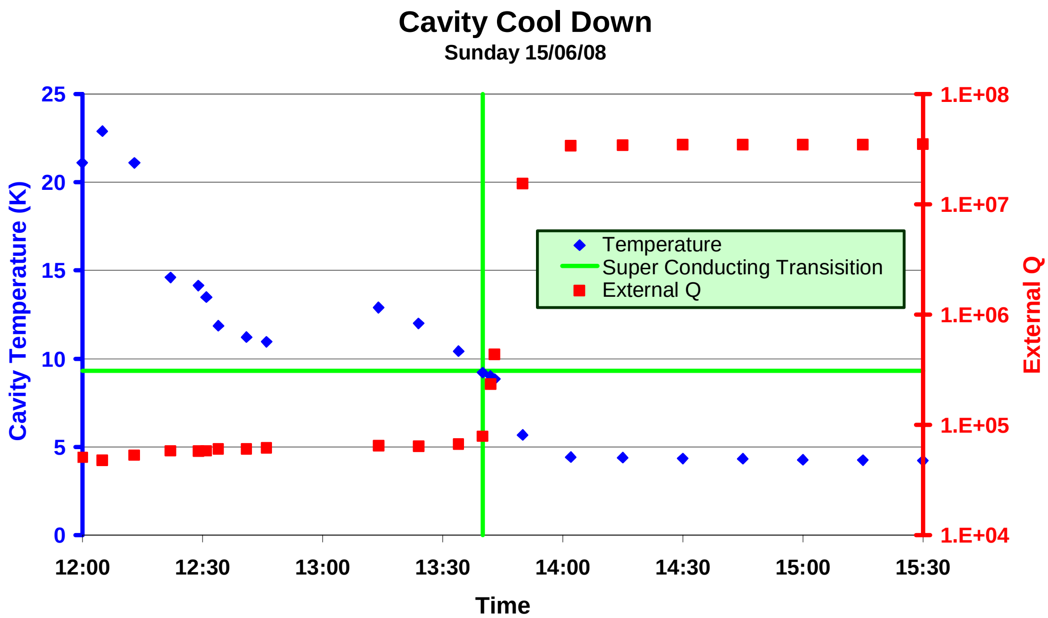

Figure 5: Cool down showing transition to superconducting state

FIRST RESULTS

The system has initially been configured with a single ILC cavity installed in the cavity support structure. This has allowed the verification of the cryogenic and DAQ systems, and allowed initial measurements on the cavity to be performed.

Cool Down

The first cool down of the cryostat was performed on 15th June 2008. The initial fill used 500 litres to cool down the assembly and fill with helium. Figure 5 shows the cavity cooling below the superconducting transition at ~9K, and the subsequent rapid increase in cavity Q.

The static heat loading has been measured to approximately 1 Watt. This is consistent with the expected load.

The liquid helium bath was then pumped on to lower its temperature to 2K taking 2 hours to reach the necessary pressure of ~31mbar.

Cavity Measurements

The cavity external Q of the ILC crab cavity has been measured at 4.2K using a vector network analyser. This yielded a result of 3.8E7 which closely matches the expected value of Qe.

Further cavity measurements are ongoing as this paper is written.

CONCLUSIONS AND FUTURE WORK

The VTF at Daresbury Laboratory has been successfully tested by cooling a single cavity to 2K, without the tuning mechanism.

The next phase of testing will involve the integration of a pair of cavities, and the implementation of the tuning mechanism. This will be implemented in August 2008.

At the conclusion of the testing of the ILC crab cavities, the test stand will be upgraded to give it the capability of testing 9-cell TESLA cavities. To achieve this, the test stand will require significantly improved radiation shielding, and automation of the cryogenic systems. The current location of the test stand prevents any additional radiation shielding being installed. For this reason, the test stand will be moved to a more suitable location. This work is planned to begin during 2009.

REFERENCES

[1] M.Holbourn, “Radiation Protection advisors note RPAN:2007/03”, Daresbury Laboratory internal memorandum