RF Cavity Processing and Testing Plan for MICE

Derun Li*, Allan DeMello†, S P Virostek†, and Michael S. Zisman*

*Accelerator & Fusion Research Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 U.S.A.
†Engineering Division, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 U.S.A.

E-mail: dli@lbl.gov

Abstract. Fabrication status of the MICE RF cavities will be described. Design of a single-cavity vessel to test the cavities will be discussed, along with the plans for processing and testing the cavities.

1. Introduction

The international Muon Ionization Cooling Experiment (MICE), sited at Rutherford Appleton Laboratory (RAL), is currently under way. At the present time the muon beam line has been successfully installed and commissioned, and components for the remainder of the experiment are being fabricated. Figure 1 shows a layout of the MICE cooling channel.

Figure 2 shows two views of the RFCC module, indicating the locations of its four RF cavities. Each of the cavity irises is terminated with a curved 42 cm diameter Be window. The power is fed into each cavity via a pair of coaxial loop couplers. Tuning is accomplished by pushing or pulling on the cavity via the six tuner arms. The RF cavities compensate for the muon energy loss in the liquid-hydrogen absorbers (located in the center of each FC module), maintaining the longitudinal momentum.

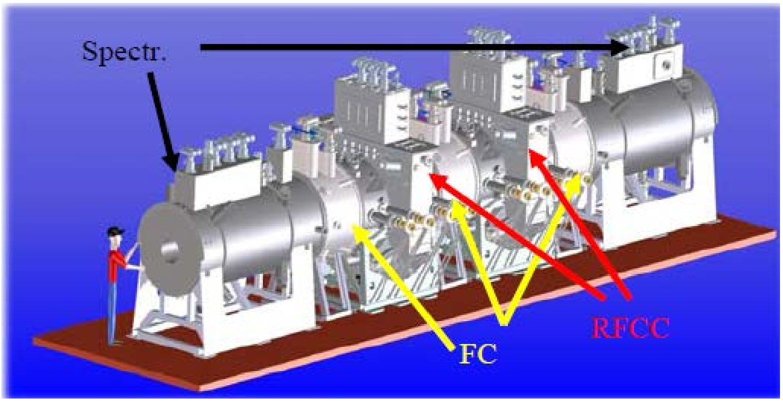

Figure 1. Layout of the MICE cooling channel, showing a cooling cell comprising three Focus Coil (FC) modules and two RF–Coupling-Coil (RFCC) modules. At each end is a spectrometer solenoid magnet containing a scintillating fiber tracker that measures particle coordinates before and after the cooling channel cell.

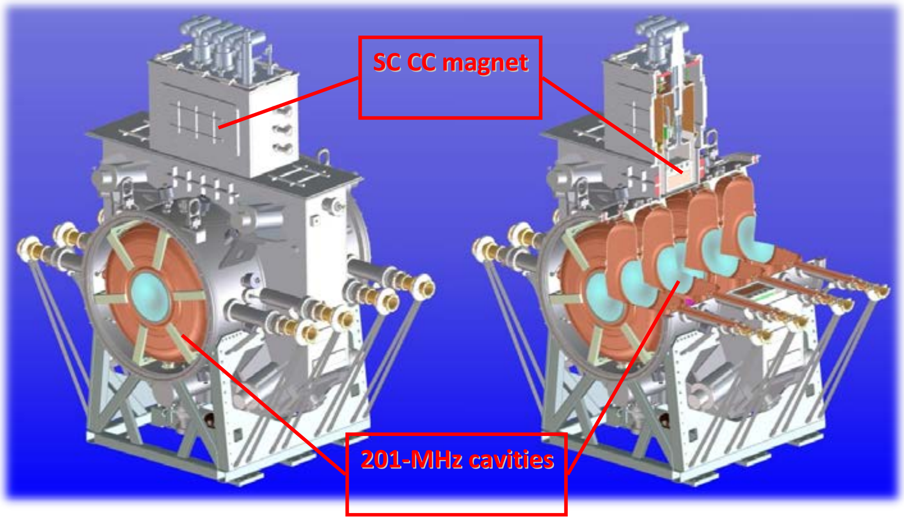

Figure 2. (*left*) drawing of the RFCC module indicating locations of superconducting Coupling Coil magnet and 201 MHz RF cavities; (*right*) cutaway view.

2. Cavity Measurement and Testing

The MICE RF cavities (8 for the two RFCC modules and 2 spares) were delivered to LBNL in December 2010. The actual MICE cavities already have their cooling pipes attached; the cooling pipes are not attached for the two spares so that they can be used for either of the two configurations needed for MICE. To date, five of the cavities have been measured, including both mechanical and RF measurements.

From other vendors, we have received and accepted nine of the 42 cm diameter curved Be windows used to electromagnetically terminate the cavity irises. Ten ceramic RF windows have also been received from a vendor, of which 4 are at LBNL and 6 are with our collaborators at University of Mississippi. Design of the RF input coupler is complete and the device is ready for fabrication.

The tuner design, based on using 6 tuner arms per cavity, operated in a push-pull configuration to tune the cavity frequency via shape changes (similar to the approach used for superconducting cavities), is complete. A prototype of a single tuner arm with its control circuitry has been successfully tested on a dummy load. A full set of six tuner arms for testing the cavities is being fabricated now. The mechanical designs for the cavity supports within the vacuum chamber, and the vacuum chamber itself are also complete.

The remaining step before testing the cavities is to complete their processing, including mechanical polishing, electropolishing, and a high-pressure water rinse. These tasks will be carried out at LBNL under close supervision. To facilitate testing, a single-cavity vacuum vessel has been designed and is now being fabricated.

The measurement program we envision includes the following:

- Physical measurements
  - cavity, tuners, tuning mechanism, support structure
  - vacuum system, cooling water, and integration scheme
- RF measurements (both with and without the Be windows)
  - low-power determinations of RF parameters (f, Q, coupling), tuning range and sensitivity, tuning circuit mechanism and control circuitry
  - high-power processing to high gradient and tests of operational reliability

The high-power measurements will make use of the single-cavity vacuum vessel (see Section 3) to avoid postponing initial testing until the modules are fully assembled in the MICE Hall at RAL.

3. Single-Cavity Vacuum Vessel

3.1. Design

The design goal for this chamber was to keep as many as possible of the features and dimensions of the actual MICE RFCC vacuum vessel, but in a system designed to hold only one cavity at a time. The resultant design is illustrated in Fig. 3.

3.2. Test Plan

The first check will be on the engineering and mechanical design in order to fully define the fabrication process for the real RFCC vacuum chamber. Any required changes in the single cavity vessel would subsequently be incorporated into the RFCC design. Another test will be to make use of the cavity tuning system and its controls to verify the tuning range and reproducibility of the system.

Although the test chamber only accommodates one cavity, it will permit us to develop the techniques for cavity installation, including

- fixturing for installing and aligning cavities using hexapod struts
- Be window installation procedures
- RF coupler connections
- cooling water connections
- vacuum port connections and getter performance
- tuning and actuator circuit connections
- vacuum vessel handling

and to obtain hands-on experience in using them. Finally, the test vessel will serve as a chamber to test and process each of the MICE cavities. For one of the cavities, we intend to explore the effects of LN-temperature operation, as this is a possible option for the cavities at MICE.

4. Preparations for Cavity Processing and Testing

In preparation for RF testing, each cavity will be electropolished at LBNL, followed by a high-pressure water rinse. Figure 4 shows the setup for electropolishing, based on the techniques developed and carried out by JLab staff for the existing MuCool test cavity. Plans call for beginning the electropolishing in October 2011.

The parameters that must be monitored during high-power commissioning and operation include:

- cavity body, water, window, and RF circulator temperatures
- RF amplifier forward and reflected power
- cavity frequency, RF voltage amplitude and phase (referenced to drive power)
- cavity and window region vacuum
- x-ray radiation level
- sparking rate
- status of interlocks (machine protection, personnel protection, RF amplifiers).

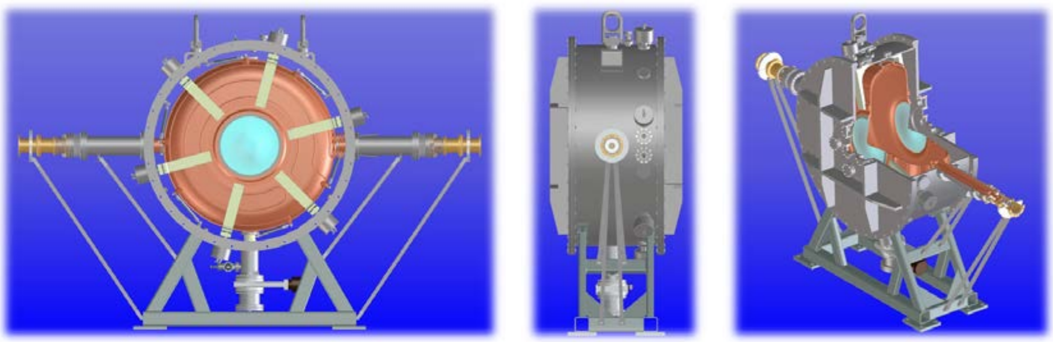

Figure 3. Single-cavity vessel: (*left*) end view; (*center*) side view; (*right*) cutaway view.

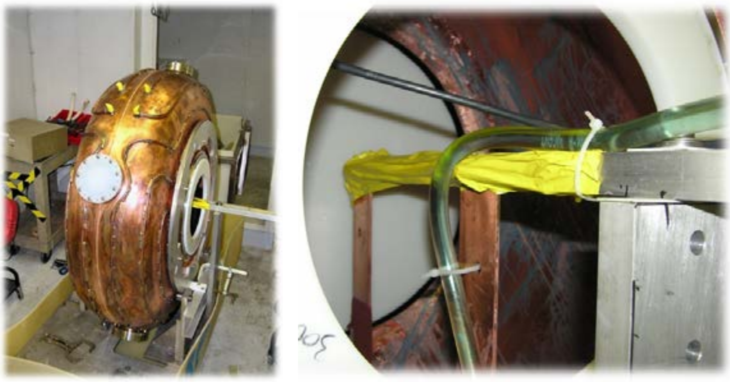

Figure 4. (*left*) RF cavity electropolishing setup; (*right*) close-up of polishing electrode.

The list of low-level RF control points that we expect to use is:

- peak power limit for a given pulse length
- duty factor
- pulse length
- initial frequency and frequency correction increment
- initial power, power increment, and maximum peak power
- delay from sparking event to restart
- reflected power threshold and detection delay
- vacuum burst limits
- temperature limit
- predetermined actions for various types of detected events

Using the information above, we will carry out cavity conditioning for each of the 8 MICE cavities. We will measure the cavity frequency shift as a function of average power and time, particularly that due to heating of the Be windows. Measurements will then be repeated with the active tuners to measure tuning range and sensitivity. If possible, we would like to repeat these measurements in the presence of a suitable magnetic field, either at the Fermilab MuCool Test Area (MTA) or at RAL.

5. Summary

A test plan for the MICE RF cavities has been developed based on using a specially designed single-cavity test vessel, whose fabrication is now under way. In the near term, the plan includes completing RF measurements on the second group of five cavities at LBNL, carrying out the required cavity cleaning and polishing activities, coarse cavity tuning via cavity deformation to set the central frequencies to a common value, and completion of an initial tuner system (6 arms plus actuators) and other required ancillary items for the testing process.

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References

[1] See http://mice.iit.edu/.