ASSEMBLY AND TESTING OF THE FIRST 201-MHz MICE CAVITY AT FERMILAB*

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Abstract

The International Muon Ionization Cooling Experiment (MICE) [1] includes two linear accelerator sections with four RF cavities each within a shared vacuum vessel. Ten cavity bodies have been fabricated for MICE including two spares and one was electropolished at LBNL. A special vacuum vessel was built to house this cavity and form the 201-MHz Single-Cavity Module (SCM). The module and its instrumentation are being assembled and tested at Fermilab for installation and operation in the MuCool Test Area.

MICE RF SYSTEM

MICE is a demonstration of ionization cooling using a full cooling cell surrounded by tracking and particle identification detectors to measure each muon before and after it traverses the cooling cell [2]. It is under construction at Rutherford Appleton Laboratory (RAL). Figure 1 shows the RFCC (RF cavity and coupling coil) module [3, 4] which includes a large-diameter coil around a linac section. Each pair of cavities will be driven by a 2-MW amplifier system for a gradient of 8 MV/m per cavity. Parts of the power distribution network and LLRF system are being procured, developed, built and tested by teams from LBNL, University of Mississippi, Illinois Institute of Technology and Fermilab in the US and Strathclyde University, Daresbury Laboratory, Imperial College and RAL in the UK.

SINGLE CAVITY MODULE

In order to develop the assembly procedure for the RFCC modules and test cavity operation early on at the Fermilab MuCool Test Area (MTA), a special vacuum vessel was designed at LBNL to house a single MICE cavity. The single-cavity vacuum vessel has mostly the same mechanical interfaces as the RFCC module. Figure 2 shows the single-cavity module assembly. Ten RF cavity bodies have been manufactured in industry using techniques developed at LBNL. Cavity half shells were spun from 6mm-thick Cu sheet e-beam welded at the equator. Four ports were pulled around the equator on each cavity for couplers, vacuum pumping and instrumentation. Copper cooling tubes were brazed onto the cavity bodies. Each cavity has a pair of 0.35mm-thick curved beryllium windows for a pillbox-like geometry. Power is brought in through a pair of coaxial loop couplers. The first set of couplers is under fabrication at LBNL. The tuning system comprises stainless steel flexure arms driven by pneumatic actuators [5]. Figure 3 shows the basic design. The actuator body includes two concentric shafts screwed onto threaded holes in the tuner arm. As the shafts are pulled together or pushed apart by pneumatic action, the forces are transmitted to the cavity stiffener rings to elastically deform the cavity body. The actuator cover is attached to a vacuum vessel port with vacuum bellows while the body is thermally isolated from the

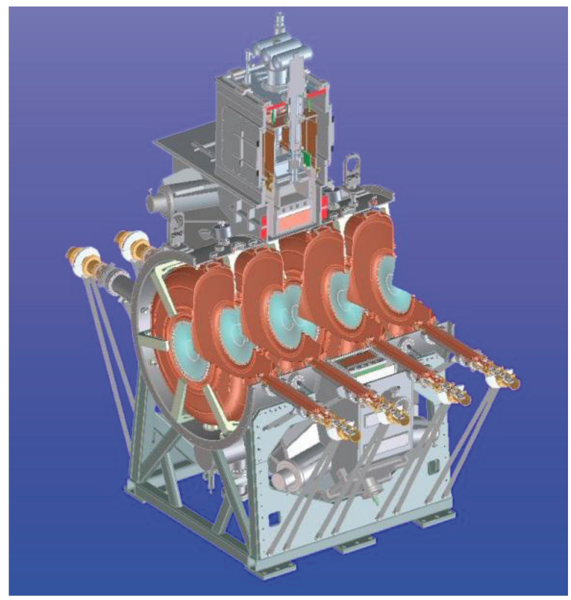

Figure 1: Partial cross section of a MICE RFCC module showing RF cavities, couplers and Be windows.

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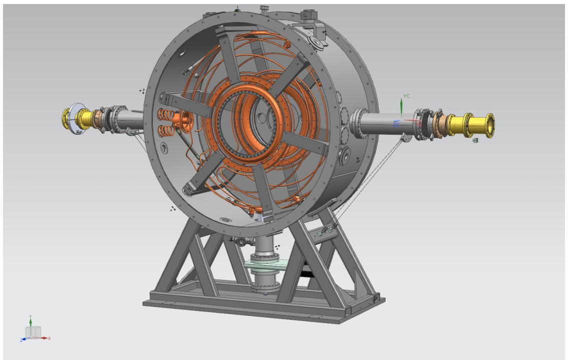

Figure 2: Single Cavity Module assembly view showing parts of the vacuum vessel body, couplers, tuning forks, actuators and cooling tubes. Stiffener and window clamp rings and cavity mounting struts are also visible while the cavity body and Be windows are suppressed for clarity.

vessel. One of the cavities was electropolished at LBNL [6] and sent to Fermilab for installation and testing in this vessel. A prototype tuner arm was mounted on an aluminum test hoop with one sixth the spring constant of the cavity body for initial tests at LBNL. The first set of six production tuner forks and actuators were built at Fermilab and LBNL respectively. The test setup was used at Fermilab to qualify the actuators.

ASSEMBLY STATUS AND PLANS

Clean Room

A class 100 (ISO 5) assembly environment is needed to minimize contamination of the vacuum vessel and cavity interior. The clean room chosen in Lab 6 at Fermilab had been unused for many years but after interior cleaning and curtain repair, it was down to class 10 (ISO 4). Air quality is monitored using a particle counter, all cavity ports are capped during mechanical work and full clean room garb is used by personnel during assembly. Cavity and vessel exterior surfaces were cleaned before and after being moved into the clean room. Flat aluminum cover plates were installed on the cavity in place of the Be windows to keep the interior clean during initial assembly work without risking damage to the thin windows. Covers for the vacuum vessel have to be removed to reduce the size during transport. Transparent plastic plates were used to keep the vessel interior clean during storage and transport.

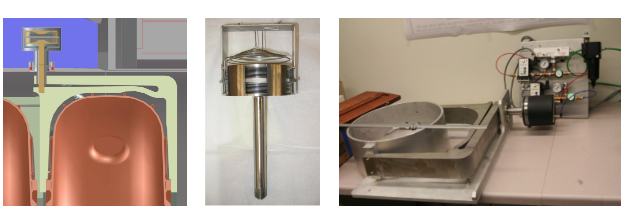

Figure 3: Tuner model (left), actuator prototype (center) and test setup (right).

Mechanical Setup

The initial hardware configuration is shown in Fig. 4. Due to limited height in the clean room during assembly and in the hallway leading to the MTA experimental hall during transport, a shorter stand was built and the vacuum vessel moved onto this temporary stand. A portable gantry crane was cleaned and placed in the clean room to lift the cavity which weighed in at 227 kg and should be about 400 kg with the tuners installed. Initial measurement of cavity parameters was performed with the cavity mounted on a vertical measurement stand. A rotation fixture was built to hold the cavity locked in a horizontal orientation for tuning fork installation as well as rotate it to a vertical orientation for handling by the crane. The cavity will be mounted in the vacuum vessel using struts forming a six-axis (Stewart) platform. An attachment was designed for use with a portable lift to insert the cavity into the vacuum vessel and hold it while the struts are connected.

Tuner System

In order for the tuning system to work correctly, all the forks should be in a plane parallel to the cavity plane of symmetry and the actuator shafts aligned with vessel ports. Extra material was included on the contact pads in the drawings for the flexure tuning forks. The ports on the vacuum vessel, the stiffener rings on the cavity body (which the forks are attached to) and the forks were surveyed with a laser tracker. Tuner fork contact pads were machined to match the largest gap between stiffener ring surfaces on the cavity and shims were prepared to take up the gaps as needed. The forks have been installed as shown in Fig. 5. A simple alignment tool was designed consisting of a rod with an outside thread on one end so it could be screwed into the tuner fork and a flat surface with a hole at the other end to accept a laser tracker target. These were mounted on

Figure 4: Clean room interior with the cavity (back) mounted on the vertical measurement stand under the portable crane, the vacuum vessel (left) with transparent cover plates on the temporary stand and part of the rotation fixture (front).

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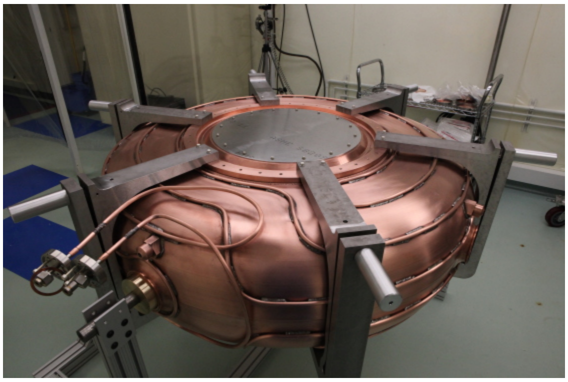

Figure 5: Cavity on rotation fixture with the tuner forks and alignment tools installed. Note the temporary aluminum cover instead of the Be window.

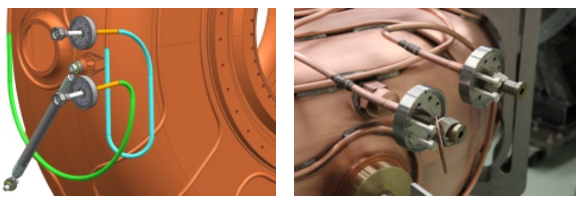

Figure 6: Cooling tube feed-throughs: model (left), installed on cavity (right).

the forks to be used for alignment of the forks on the cavity and alignment of the cavity within the vacuum vessel.

Water Connection

No water fittings are allowed inside vacuum volumes in MICE. The copper cooling water tube on the cavity body goes through a pair of stainless steel two-piece feed-through assemblies on the vacuum vessel (Fig. 6). A section of stainless steel tubing was vacuum brazed to a section of copper tubing. The stainless steel tube was then welded to the feed-through flange and a stainless steel fitting for the water connection on the air side. The copper tubing end was silfos brazed to the copper tube from the cavity body to complete the connection on the vacuum side. The feed-through assemblies were water pressure tested and vacuum leak checked before and after installation.

Diagnostics

The following instrumentation is in preparation for monitoring various aspects of cavity operation:

- On the cavity, couplers and vacuum vessel
  - Two pickup loops inside cavity to monitor the RF field
  - Vacuum gauges for the cavity, vessel and couplers
  - Thermocouples on cavity body
  - Infrared sensors pointed at the thin Be windows for temperature measurement
  - Fiber light guides viewing the cavity interior to detect sparking
  - Piezoelectric sensors on cavity body to detect and localize breakdown through acoustic signals
  - Electron pickups near the coupler ceramic vacuum windows to monitor coupler conditioning
  - Viewports near the vacuum windows to detect light in couplers due to breakdown
- In the experimental hall
  - Water pressure and flow. Note that there are five cooling tubes in the system: one for the cavity body and one for each of the coupler loops and RF windows
  - Gas pressure for tuner actuators
  - Radiation detectors
    - ionization chambers for overall dose rate
    - scintillator+PMT counters for X-ray rates
    - NaI crystal+PMT counter for X-ray spectra
  - Forward and reflected power waveforms from directional couplers near the cavity

Remaining Steps

The cavity will be installed in the vacuum vessel and the transfer function for the tuning system measured shortly. The vessel will be moved to the MTA hall after tuners and instrumentation are fully tested and assembly will be finished in the MTA clean room. The vessel will be initially placed in the fringe field of the MTA solenoid and moved next to the coupling coil prototype for testing in the full magnetic field configuration when that magnet is available. RF power station controls have been upgraded and commissioned with a test load and frequency tuning will be incorporated into the conditioning control software [7].

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