AN OVERVIEW OF THE CRYOMODULE FOR THE CORNELL ERL INJECTOR

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Abstract

The first stage of the Cornell ERL project will be a 100 MeV, 100 mA (CW) prototype machine to study the energy recovery concept with high current, low emittance beams. In the injector, a bunched 100 mA, 500 keV beam of a DC gun will be compressed in a normal-conducting copper cavity and subsequently accelerated by five superconducting 2-cell cavities to an energy of 5.5 MeV. We present an overview of the cryomodule design along with the status of the 2-cell HOM-free cavity, the twin-input coupler and the ferrite HOM dampers.

1 INTRODUCTION

The Laboratory of Elementary-Particle Physics, Cornell University, in collaboration with Jefferson Lab is exploring the potential of a Synchrotron Radiation User Facility based on a multi-GeV, low emittance, Energy-Recovery Linac (ERL) with a 100 mA CW beam[1]. The first stage will be a 100 MeV, 100 mA (CW) prototype machine to study the energy recovery concept with high current, low emittance beams[2]. A key element of this machine is a high brightness injector with every bunch filled , i.e. 77 pC/bunch at 1300 MHz [3].

The injector system needs to deliver 500 kW to the beam through input coupling devices, typically antennae that protrude into the beam pipe. . Beam energy is not recovered in the injector. More than a hundred watts per cavity of beam induced power must be removed through HOM couplers. Both power delivery and extraction must be accomplished without introducing emittance-diluting asymmetries. Fig 1 gives an overview of the cavity string of the injector cryomodule.

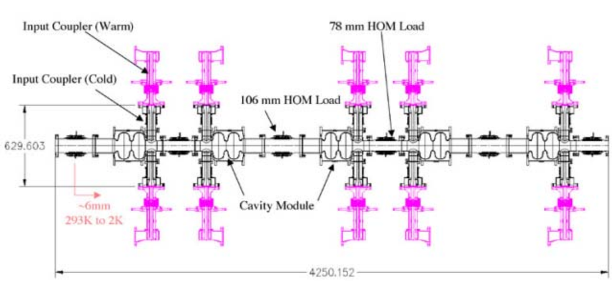

Fig. 1 The cavity string consists of five 2-cell cavities, dual input couplers and beam pipe HOM loads.

2 INJECTOR CAVITIES

Fig.2 shows the basic cavity design and Table 1 lists the properties of the superconducting 2-cell niobium structures [4]. Most parts of the cavity assembly are complete and await electron beam welding. A copper model is also underway for HOM mode and damping evaluations.

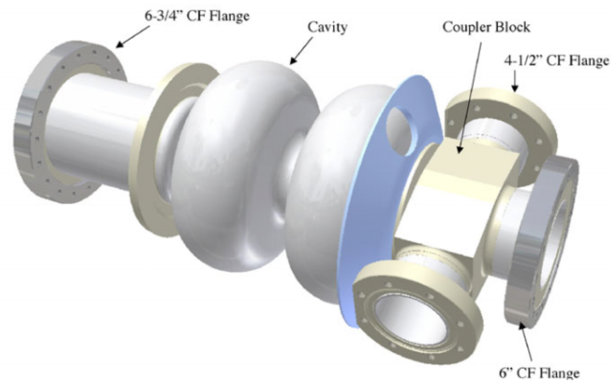

Fig.2: 2-cell injector cavity, input coupler ports and helium vessel disk.

Table 1: RF properties of 2-cell superconducting cavities

Frequency	1300 MHz
Number of cells	2
R/Q	218 Ohm
E_{pk}/E_{acc}	1.94
H_{pk}/E_{acc}	42.8 Oe/(MV/m)
Coupling cell to cell	0.7 %
Q_0 *at 2 K*	$> 5\times10^9$
Twin-Input coupler Q_{ext}	4.6×10^4 / 4.1×10^5
Accelerating voltage	1 MV / 3 MV
Max. power transferred to beam	100 kW

Despite the presence of a large beam pipe to propagate out HOMs, the main cavity parameters are similar to those of the TESLA cavity. This was accomplished through the additional freedom of the cell length. The injector cavity has a thicker iris than for the TESLA cavity. The resulting cell-to-cell coupling is weaker (0.7 %), but still sufficient for two-cells.

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3 INPUT COUPLER

Each cavity has two coaxial couplers (Fig.3 and Fig. 4), to minimize the coupler kick and keep the power delivered per coupler at a conservative 50 kW CW[5]. The couplers are variable, allowing the external Q to be changed through the range from 4.6×10^4 to 4.1×10^5. This feature permits operation at higher injector energy and reduced average current, subject only to the limitation imposed by the 500 kW of installed injector RF power. We will explore injector performance over an energy range of 5 to 15 MeV. The outer diameter of the coaxial line is 60 mm and impedance the 60-Ohm to minimize heating of the inner conductor. The geometry of the antenna tip is optimized to minimize penetration into the beam pipe. For a one mm offset between the two antenna locations, the kick is a factor of 100 lower than for the kick produced by a single coupler. In many aspects the coupler is similar to the TTF-III coupler. However, there will be forced gas cooling of the inner conductor, and the outer conductor bellows design is different.

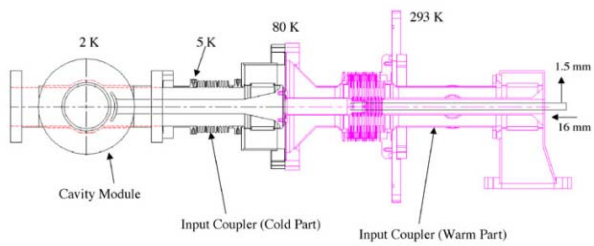

Fig. 3. Geometry of the input coupler.

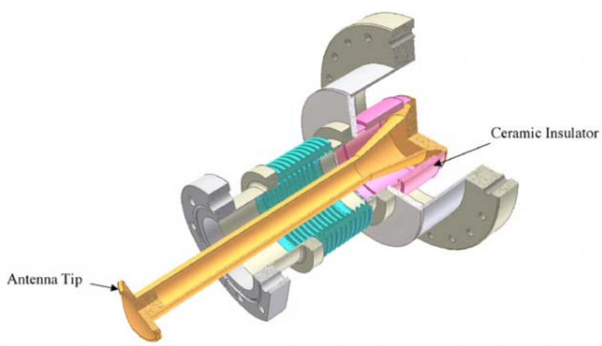

Fig. 4: Cold part of the input coupler

4 HIGHER MODE COUPLERS

One source of the emittance dilution is through interaction of the beam with high Q transverse higher-order modes (HOMs). Especially dangerous are the lowest frequency dipole modes with frequencies below the cut-off frequency of the beam pipes. With the cavity shape proposed, all HOMs propagate into the beam pipe where they are adequately damped by ferrite absorbers lining the beam pipe. The frequencies of all dipole and monopole modes are at least 10 MHz higher than the appropriate cut-off frequency of the beam pipe.

Strong damping of the HOMs is also essential for beam stability and to reduce the HOM losses to a few hundred watts per meter. To achieve this demanding goal we plan to place RF absorbing material in the beam tubes between the cavities in the linac (Fig. 5). This will require operating the HOM absorbers at 80K to simplify the thermal transition to the cavities at 2 K with low static losses to 2 K[6]. An inter-cavity bellows has been incorporated into the HOM absorber design. (Fig 5). Additional ferrite tiles have been placed to damp any modes excited in the bellows region.

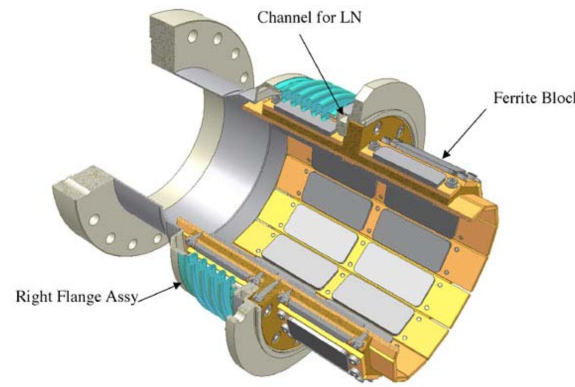

Fig. 5: Beam pipe HOM damper integrated with inter-cavity bellows.

Several absorber materials are under investigation including a variety of ferrites,. Fig .6 compares the magnetic absorption properties at 300 K and 80 K from 1 – 18 GHz. Measurements are being extended to 40 GHz.

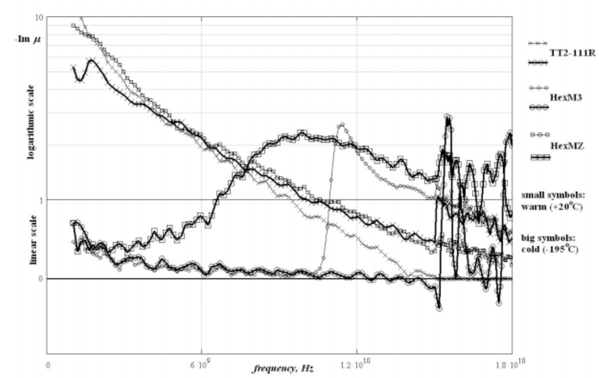

Fig.6: Imaginary part of μ for various ferrites at room temperature and at 80 K.

5 CRYOMODULE

For the injector cryomodule, our design closely follows concepts developed for the TESLA cryomodule, with the following exceptions. There will be two input couplers along with their associated penetrations, and additional guides for the input coupler alignment. Larger pipe sizes will be used for the two-phase line and the chimney connection to the cold return gas line to allow for CW operation. Liquid nitrogen will be used for the 80 K shield as well as for the heat intercepts of the input and HOM couplers. Fig. 7 shows the layout of helium vessel and its connections to the helium distribution in the cryomodule. We plan to use the blade tuner design integrated with the helium vessel as developed for the TESLA superstructure Fig 8 shows the location of some of 5 K shields in the module.

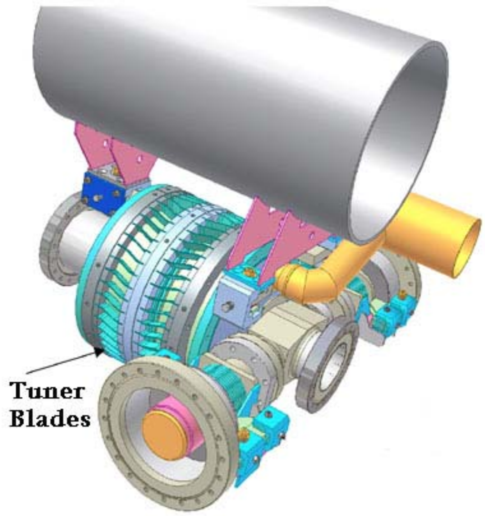

Fig. 7: One cavity assembly showing helium vessel, blade tuner, input couplers and connections to the helium input and output lines.

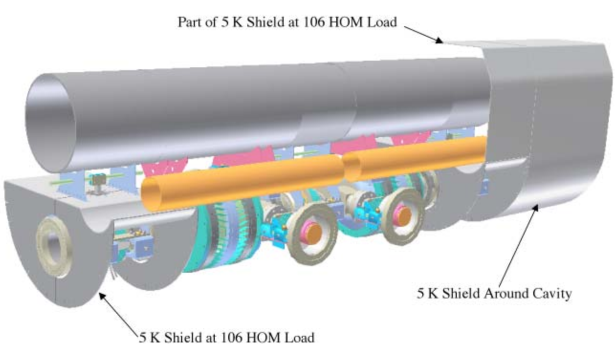

Fig. 8: Location of heat shields in the injector cryomodule.

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