STATUS OF HOM LOAD FOR THE CORNELL ERL INJECTOR*

V. Shemelin, P. Barnes, B. Gillett†, M. Liepe, V. Medjidzade, H. Padamsee, R. Roy, J. Sears
Laboratory for Elementary-Particle Physics, Cornell University, Ithaca, NY 14853

Abstract

The HOM load for the injector of the Energy Recovery Linac at Cornell University is proposed to work at a temperature of 80 K. The anticipated absorbed power of the load is up to 200 W. Versions with inner diameter of 78 and 106 mm are under development. Two different kinds of ferrites and a lossy ceramic are chosen as RF absorbers for the load to cover a wide frequency range. Measurements of electromagnetic properties of absorbing materials have been performed in a range from 1 to 40 GHz. The engineering design of the load is ready and technological issues of brazing the absorbing tiles and cooling have been solved. Brazing quality is controlled by IR thermograms. First warm measurements of a prototype load are expected this summer.

INTRODUCTION

Cornell University is studying a Synchrotron Radiation User facility based on a multi-GeV, 100 mA average beam current Energy Recovery Linac. The first stage of this project is a 5.5 to 15.5 MeV, 100 mA injector [1] to study the production of a high current, low emittance beam. Realization of this concept requires usage of superconducting cavities with strong HOM damping operating at a temperature about 2 K.

The five injector cavities are 2-cell niobium structures. They provide a total of 500 kW of RF power to the beam. Consequently, the beam energy gain after the injector is 5 MeV at 100 mA or can be 15 MeV if the current will be lowered to 33 mA. Since the beam has a relatively low energy in the injector part of the accelerator, it is especially important to exclude any action of extraneous fields on the accelerated bunches. However, the electron beam consist of very short bunches (0.6 mm) and power deposited into Higher Order Modes can be significant.

In the case of ERL, linac and injector, the HOM loads are parts of a beam pipe covered with absorbing material.

RF DESIGN

The RF design of the ERL HOM load was adopted from CESR HOM load [2], Fig. 1. However, major changes were implemented because of two main reasons:

First, to minimize the packing fraction, the absorbers are operated at a temperature about 80 K. A higher temperature will complicate the thermal transition to the cavities at 2 K, whereas a lower temperature would significantly reduce the efficiency of the power interception.

Second, shorter bunches, high current, and necessity of low emittance require damping HOMs over a large frequency range.

This is why 3 different absorber materials are used, so that dangerous modes of any frequency face high absorption at least in one of these materials. Loss angle tangents for magnetic and electric losses are presented in Fig. 2. More detailed data with real and imaginary values of ε and μ are presented in [3]. RF absorption in some materials depends on temperature. We performed measurements of several materials at 80 K in the frequency range up to 40 GHz to choose materials for our load.

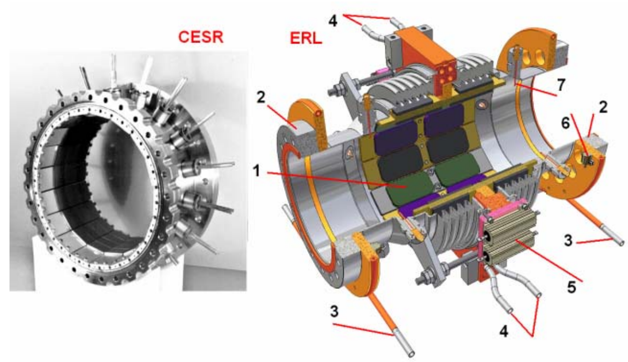

Figure 1: CESR and ERL HOM loads. 1 – absorber plates, 2 – flange to cavity, 3 – 5 K He cooling loop, 4 – 80 K cooling loop, 5 – 80 K heater, 6 – 5 K heaters, 7 – HOM pickup.

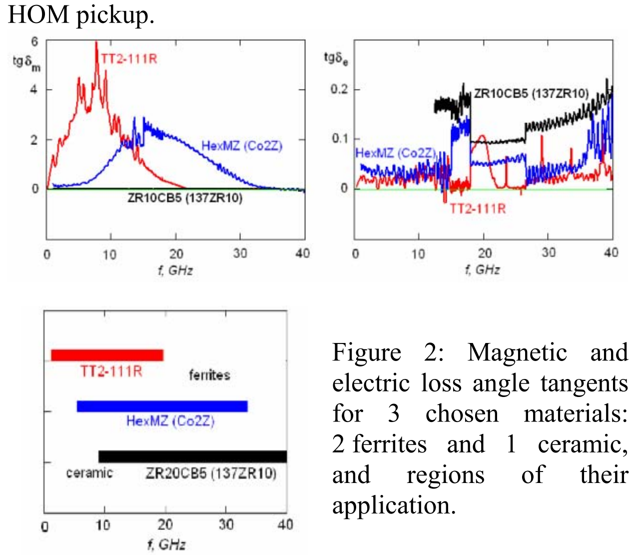

Figure 2: Magnetic and electric loss angle tangents for 3 chosen materials: 2 ferrites and 1 ceramic, and regions of their application.

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There are 12 absorber plates, each having 4 tiles, with 3 absorbing materials changing from plate to plate. Combination of ferrites and ceramic makes possible to absorb the modes having both high magnetic and high electric fields at the absorber location place.

Initially chosen ferrite HexMZ was later substituted by Co2Z, new brand of the same structure. Lossy ceramics ZR20CB5 and ZR10CB5 were initially evaluated and ZR10CB5 (now Ceralloy® 137ZR10 - experimental material grade manufactured by Ceradyne, Inc.) was selected due to its lower dielectric permittivity ε. This should have better absorption because of smaller reflection. On the initial stage of measurements, it appeared that different batches of this ceramic have an order of magnitude scatter of its loss tangent. R&D on reproducibility of parameters was performed together with Ceradyne, Inc. before the conditions of production an acceptable material were found.

The ERL 2-cell injector cavities have beam pipes of different diameter at their ends. This gives a possibility to have high coupling with the RF coupler on the smaller diameter and to propagate the most dangerous dipole modes from the cavity into the larger pipe [4]. According to this difference, we designed versions of the HOM loads with ID 78 mm and 106 mm.

MECHANICAL DESIGN

To facilitate assembling a string of cavities with HOM loads, the loads have bellows. Stainless steel bellows are copper plated from inside so that power losses of HOM occur at a defined cooled place, in absorber tiles. In addition, losses of the fundamental mode will be too high if the steel is not coated. On the other hand, we need to minimize heat transfer from the inner nitrogen gas cooled heat sink to the 5 K flanges. This is why the thickness of copper plating on the inner surface of bellows and stainless steel parts is chosen to be 10 micrometers.

End flanges have 5 K helium gas cooling loops to intercept the heat transfer to the cavity. The inner “copper base” is cooled by gaseous helium to bring out the heat absorbed by the tiles. There are 2 cooling channels in the copper base to bring out 200 W of heat.

Table 1: Properties of chosen materials

Material	TC, W/m·K	CTE, (@20 °C), ppm/°C
Elkonite® 10W3 [5]	220	8.5
TT2-111R [2]	(5)[*]	9
Co2Z	(5)[*]	No data
Tungsten 18 [6]	131	4.43
Ceralloy® 137ZR10 [7]	~100	4.5

[*]General data for ferrites, no data exists for these specific materials.

Tiles of TT2-111R and Co2Z ferrites (Trans-Tech) are soldered to the plates made of Elkonite® 10W3 (75 % W, 25 % Cu). Tiles of Ceralloy® 137ZR10 (Ceradyne, Inc.) are brazed to the tungsten 18 alloy plates (95 % W, 3.5 % Ni, 1.5 % Cu). Ferrites are soldered by 90 % Sn – 10 % Ag alloy in Ar atmosphere, ceramic is brazed by TiCuSil foil (4.5 % Ti, 26.7 % Cu, 68.8 % Ag) in vacuum. Thermal conductivity and coefficients of thermal expansion of these materials are presented in Table 1.

Quality of bonding between the tiles and metal plates was checked by thermography. The bonded tile was pressed against a heat plate with temperature about 100 °C for 5 -7 seconds, and then the picture of the tile was taken by IR camera. One can process the image so that only area within several degrees is seen. If this area was smaller than 2 °C, the tile was accepted as well bonded. One could also consider the histogram of temperature distribution across the tile surface. Usually its width at half height was also less than 2 °C.

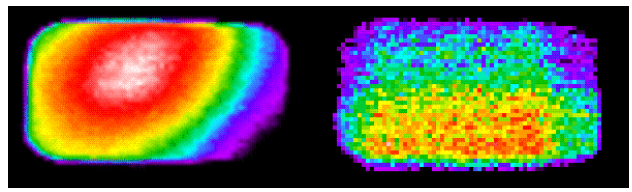

Figure 3: Infrared images of two tiles brazed to metal panels. Left: bad brazing, temperature difference across the tile is >10°; right: the difference is 2 °C.

FABRICATION OF PROTOTYPES

Production of two prototype, full-sized, loads is in progress. All the parts are produced. Cooling loops are formed and brazed to heat sinks. Ferrite and ceramic parts are bonded to the tungsten alloy plates, IR images checked, and absorber assembly is put together. Two outer halves consisting of welded 0.2 mm thick bellows units, tubes, 5 K cooling plates, and conflat flanges will finally be electron beam welded to the stainless steel rings on copper base.

Some parts in the intermediate stage of readiness are shown in Fig. 4.

Figure 4: Parts of the HOM loads ready for assembling.

Copper plating and final assembling are expected to be done by the end of June. HOM damping tests are planned in August. 6 more HOM loads will be ordered from industry for delivery by the end of 2006.

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