Broadband HOM Absorber for the Cornell ERL

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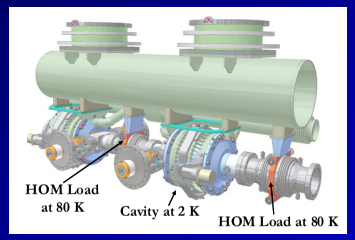
Abstract:
The damping of higher-order-modes (HOMs) in the Cornell ERL injector cryomodule is demanding: The high current beam (100 mA) with short bunch length will deposit significant HOM power at high RF frequencies up to tens of GHz. In addition emittance preservation is of outmost importance, and requires axial symmetry of the HOM absorber. Based on the successful HOM ring absorber in the CESR RF system, we have designed an RF absorber, which will be placed in the beam pipe between adjacent cavities in the ERL injector cryomodule. This absorber will be operated at 80 K to simplify thermal transitions to the cavities at 2 K. Several potential absorber materials have been studied in detail, and a combination of three materials has been chosen to guarantee efficient RF absorption over a wide frequency range. Prototyping of the absorber has been started. In this paper we present the design of the broadband absorber, show results of RF studies on the absorbing materials, and give an update on the prototyping work.

Introduction



Average HOM loss /cavity	26 W
Max. power per absorber	200 W
HOM frequency range	1.4 to > 50 GHz
Operating temperature	80 K
Coolant	GHe
Absorber type	TT2-111R, HexMZ, ZRC10CB5

- Absorbers are placed in beam line between cavities.
- Quality factors between some 100 and a few 1000 are required.
- Operated at 80 K to simplify thermal transitions to cavities at 2 K.
- Combination of three RF absorbing materials for effective damping from 1.4 GHz to > 50 GHz.

In *average* the total HOM losses per cavity are given by the single bunch losses (2cell ERL cavity, 77 pC bunch charge, 1.3 GHz bunch repetition rate, $\sigma_z = 600$ µm):

$$P_{||} = k_{||} Q_{bunch} I_{beam} = 3.4\text{V/pC} \cdot 77\text{pC} \cdot 0.1\,\text{A} = 26\,\text{W}$$

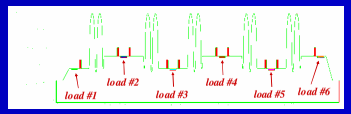
But: If a monopole mode is excited on resonance, the loss for this mode can be much higher:

$$P = 2\left(\frac{R}{Q}\right) Q I_{beam}^2$$ Need strong HOM damping!

⇒ Example: To stay below ***200 W*** (I=100 mA):
- achieve (R/Q)Q < 10^4 Ω,
- or avoid resonant excitation of the mode.

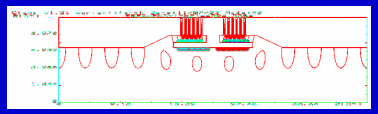
RF Design

CLANS Model



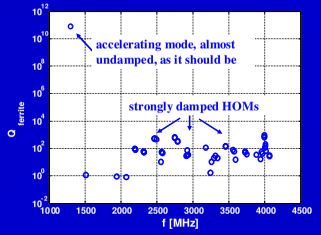
- Simulated whole injector module (5 cavities, 6 HOM loads) with CLANS.
- Results show very strong damping.

Bellow Mode

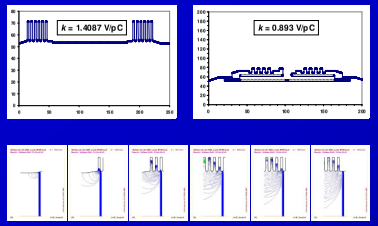


- Integrated bellows are shielded by the absorber ring (reduced loss-factor).
- Absorbing-tiles damp bellow modes.

Calculated Monopole Q-Factors

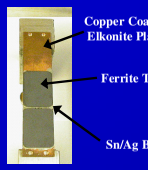


Loss-Factor Calculation



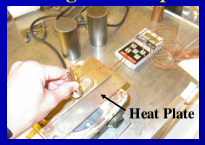
Brazing Tests

Plate with Two Ferrite Tiles



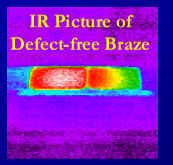
- Started brazing program to develop procedures for the brazing of the three different RF absorbing materials.
- Need to match thermal expansion of absorbing-tiles to expansion of metal plate.
- Test absorbing plates on heat plate to find voids in the braze.
- Cold-shocked plates several times to test thermal cycling of plates.

Brazing Test: Step 1



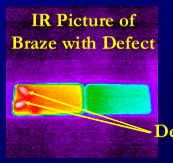
Brazing Test: Step 2

IR Picture of Defect-free Braze



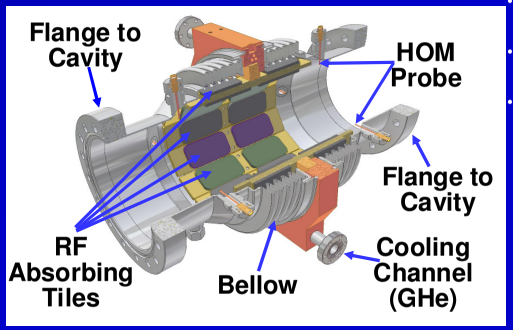
- Developed simple and fast test to evaluate quality of braze connection.
- Step 1: Put absorbing tiles on heat plate for several seconds.
- Step 2: Watch cool down of same tiles with IR camera.

IR Picture of Braze with Defect

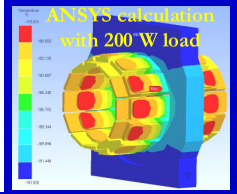


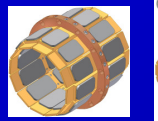
Tile came off during cold-shock

Mechanical Design



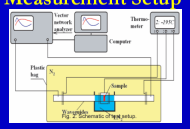
- Absorbing-tiles are brazed to metal plates.
- Indirect cooling via copper slab.
- Thermal behavior has been studied in detail.





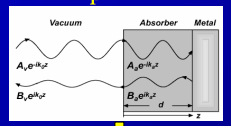
RF Absorber Studies

Measurement Setup

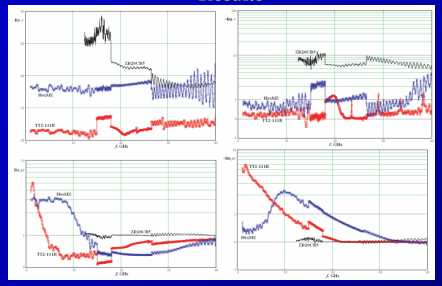


- Permeability and permittivity of RF absorbing materials have been measured between 1 GHz and 40 GHz at 300 K and 80 K.
- Three materials have been selected to guarantee efficient RF absorption over a wide frequency range.

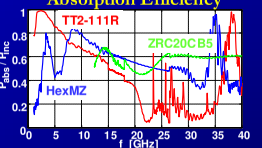
Simple Model



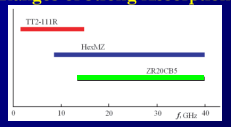
Results



Absorption Efficiency



Ranges of Strong Absorption



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