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R-square impedance of ERL ferrite HOM absorber ☆

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Abstract

An R&D facility for an energy recovery linac (ERL) intended as part of an electron-cooling project for RHIC is being constructed at this laboratory. The center piece of the facility is a five-cell 703.75 MHz superconducting RF linac. Successful operation will depend on effective HOM damping. It is planned to achieve HOM damping exclusively with ferrite absorbers. The performance of a prototype absorber was measured by transforming it into a resonant cavity and alternatively by a conventional wire method. The results expressed as a surface or *R*-square impedance are presented in this paper.

Keywords: Higher order modes; Ferrite absorber; Ferrite surface impedance; ERL

1. Introduction

A superconducting (SC) cavity for an energy recovery linac (ERL) is being constructed at this laboratory [1]. The performance of the SC cavity can be severely impacted by the presence of higher order modes (HOM). A carefully chosen design minimizes their presence and remaining HOMs must be damped by HOM couplers attached to the cavity located in the liquid helium [2] or by ferrite absorbers at room temperature [3]. The ERL cavity will rely completely on ferrite absorbers.

Ferrite absorbers have proven successful in damping higher order mode (HOMs) in single cell cavities (CESR [4], KEKB [5]). The Cornell ferrite design is being adopted here for the ERL five-cell linac cavity.

The production ERL HOM absorber is obtained from ACCEL, using the nickel–zinc ferrite C-48 produced by Countis Industries. The ferrite blocks are cooled by water flowing through the copper tubes brazed onto the surface of the heat sink of the ferrite. The ERL test porcupine used for the HOM measurements in the copper cavity is shown in Fig. 1. The unit has 18 sections in the 25 cm diameter spool, each assembled of two tiles with $2 \times 1.5 \times 0.125$ in. dimensions. A smaller 20 cm diameter unit with eight tiles was also available for the *R*-square measurements.

The dipole modes were measured in the ERL copper prototype cavity both with and without the ferrite absorber. The measured data are compared with the Mafia predictions in Fig. 2. The dominant dipole modes are found around ~900 MHz so that the absorber properties need to be measured primarily in the frequency range around this strong dipole mode. The dipole mode strength in the SC cavity will be equal to those shown in Fig. 2 with the ferrite absorber in place.

The RF properties of the ferrite absorber have typically been determined by measurements of the material permeability and permittivity in a waveguide or transmission line arrangement and subsequent theoretical calculation of the coupling impedance [6].

The measurement of RF properties of the ERL absorber are presented in this report in the convenient form of a *R*-square impedance (which is equivalent to the surface impedance of a metal) and provides the power loss per unit area by the relation

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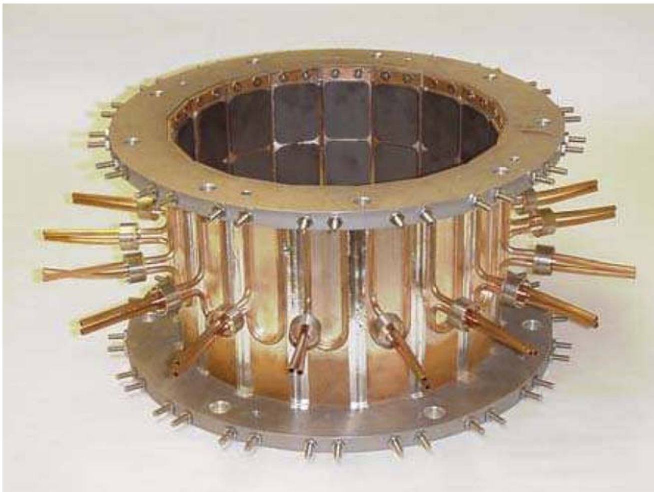

Fig. 1. HOM ferrite absorber test porcupine.

$$P = R_{SQ}H^2 \quad (1)$$

This approach seems justified by the small radial dimensions of the ferrite and the assumption that the losses are primarily magnetic field induced. The advantage of this interpretation stems from the applicability of standard expressions for losses, impedances, attenuation length and similar quantities.

The *R*-square value is obtained here by independent measurements. In the first, the absorber is transformed into a resonant cavity by attaching end plates with loop couplers in preparation for a comparison with a metal spool of the same dimensions. The cavity measurements give results only for a few identifiable resonances. In a further measurement the ferrite absorber is placed into a transmission line setup and the change of the forward scattering coefficient due to the absorber versus the spool as reference is interpreted as impedance by the network analyzer.

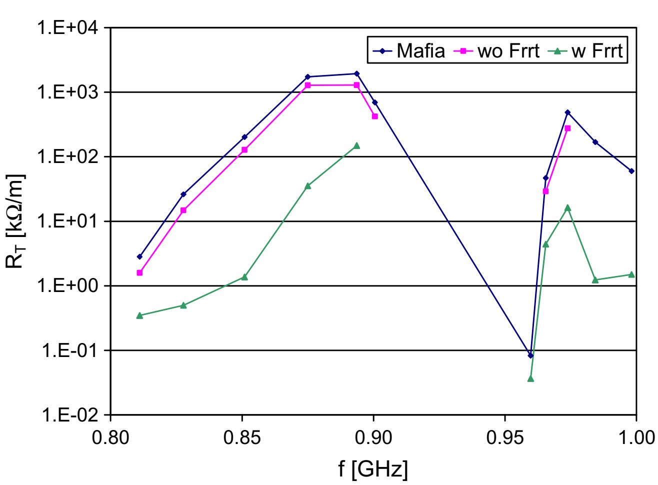

Fig. 2. Dipole HOMs in ERL copper model.

2. Resonant cavity

The ferrite absorber is transformed into a resonant cavity by attaching shorting end plates, and then is compared with a reference cavity of the same dimension. The reference cavity has an inner radius of $a = 12.5$ cm and a length of $d = 18.6$ cm. The end plates have stubs, 15 cm long with 4.8 cm i.d., to allow bead pulling for use in other experiments. The ferrite is treated as a thin layer on the same inner radius but covering axially only $d_{Fe} = 10$ cm (4 in.) of the cylinder.

The cavity was analyzed with SUPERFISH (SF) to compare it with a pill box cavity. The SF frequencies of the TM010 and TM011 resonances of the model cavity are 937.3 and 1252 MHz versus 917.8 and 1222 MHz of a pill box with the same inner dimensions. The SF geometry constants are 280 and 264 Ω versus the pillbox values of 271 Ω. In view of considerable measurement errors and for the sake of simplicity, the interpretation of the measurements will be based on a pillbox geometry.

The cavity is excited by two equal loops located in the shorting plates at the upper most radial position. The primary measurement of frequency and quality factor of a resonance is by means of the transmission coefficient S21 with a network analyzer. The S21 for the reference and the ferrite absorber cavity are shown in Fig. 3. The *R*-square impedance of the ferrite absorber will be determined for these two resonances.

In principle, the S21 measurement yields the loaded *Q* but the measuring loops are here only weakly coupled. Thus, the unloaded quality factors of the reference cavity are obtained directly. The absorber cavity was measured with two sizes of the coupling loop. The loop area was reduced from ∼45 to 25 mm^2 to move a stray resonance away from the TM011 resonance.

2.1. The ferrite absorber at the resonance frequencies, 955 MHz

The interpretation of the *Q* measurement in the absorber cavity is based on the fact that the losses are for all

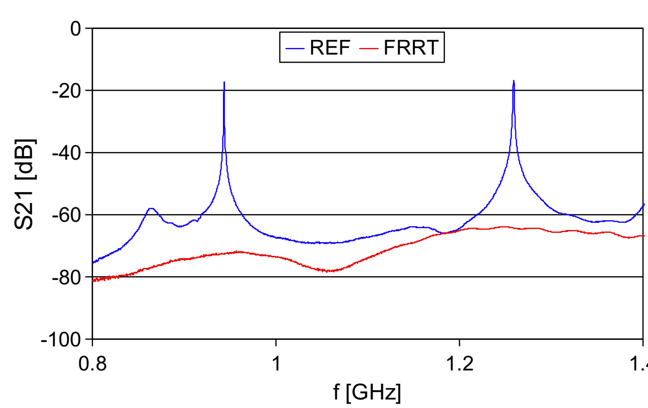

Fig. 3. S21 in reference and absorber cavity.