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HOMs of the SRF electron gun cavity in the BNL ERL

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Abstract

The Brookhaven Energy Recovery Linac (ERL) is operated as an R&D test bed for high-current, low emittance electron beams. It comprises a superconducting five-cell cavity and a half-cell superconducting RF photo-injector electron gun. The ERL is undergoing commissioning with focus on the performance of the electron gun, not the least on the cavity Higher Order Modes (HOM). Among the various alternative solutions, a beam tube damper based on a layer of ferrite tiles was adopted for the five-cell accelerator cavity. For the gun, a ceramic-ferrite damper consisting of a lossless ceramic cylinder surrounded by damping ferrite tiles has been investigated. This design is innovative in its damper approach and combines a variety of goals including broadband HOM damping and protection of the superconducting cavity vacuum from potential damage by the separately cooled absorber. In this paper the empirical performance of an installed ceramic-ferrite damper is described by the Q reduction of a few selected gun cavity resonances. The theoretical coupling impedance presented to a traversing beam is numerically analyzed in terms of radial waveguide modes in the damper section. Strong damping of the gun cavity HOMs by the fundamental power coupler (FPC) is found and discussed. Finally, the measured Q-values of the operational gun cavity without the ceramic-ferrite damper at superconducting temperatures are presented

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Keywords: Energy recovery linac; Superconducting electron gun cavity; Higher order modes; Ceramic-ferrite absorber; Radial waveguide modes.

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1. Introduction

An Ampere-class 20 MeV superconducting Energy Recovery Linac (ERL) was created to test various concepts relevant to the envisioned future projects at BNL [1, 2]. The primary goal for the ERL of high-current, high-charge electron beams together with low emittance from the high voltage superconducting cavities, make HOM mode damping an implicit necessity. The ERL consists of a superconducting (SC) five-cell ~704 MHz accelerator cavity plus a photo injector in the form of a SC half-cell RF cavity [3]. The ERL accelerating cavity can be operated in a pulsed "quasi-CW" mode up to 20 MV/m, and at 12 MV/m in CW mode. [4] The gun is designed to operate in two alternate modes, delivering high current of 300 mA with ~0.7 nC per bunches at a rate of 704 MHz or delivering high charge per bunch of 5 nC at a 10 MHz rate in the 50 mA current [5]. The facility is presently undergoing commissioning and once accomplished, its ERL components will find use for further accelerator improvement projects.

In addition to voltage and current goals, the ERL provides for the investigation of transverse and longitudinal instabilities caused by HOMs in the superconducting cavities. The HOM damping in the accelerator cavity had first been demonstrated in the copper cavity model at room temperature and then was also confirmed in the SC ERL cavity [6]. The HOMs in the accelerator cavity are absorbed with a beam line ferrite damper at room temperature [7]. Its design followed the techniques developed at Cornell [8] and KEKB [9] for ferrite absorbers and the absorbers were fabricated by industry according to Cornell-print [10].

The placement of the HOM damper for the electron gun is shown in Fig 1. The search for alternate dampers, influenced by the concern about Q-reduction from particulates and in part by the availability of surplus ferrite tiles, led to the concept of a ceramic break surrounded by a ferrite absorber, hereafter the Ceramic-Ferrite (CF) damper. The insertion of an aluminum oxide break provides separation of the ferrite tiles from the gun vacuum ensuring its high vacuum and the absence of particulates reaching the niobium surface. Initial studies of this configuration justified its adoption and led to experimental investigations for the SC ERL gun [11, 12]. The gun cryostat was finished first and the CF damper was added at the exit of the electron gun, in the injection beam line, but isolated from the e-gun vacuum when the e-gun exit gate valve is closed, thus determining the HOM measurements. The operational need of replacing the HTS with a normal conducting (NC) solenoid forced the removal of the CF damper and replacement by a NC solenoid

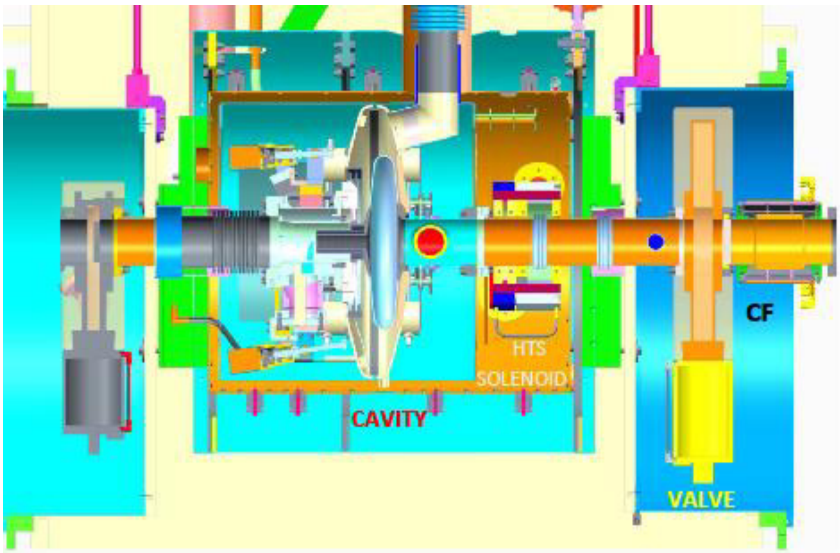

Fig. 1. SC RF electron gun cavity assembled in the gun cryostat. The HOM measured results depend on the status of the vacuum gate. For operation, the CF damper is replaced by a NC solenoid.