Electronic Activity at CEBAF Cold RF Window Induced by Cavity Operation*

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Abstract

The performance of RF windows in the input couplers of accelerating cavities is frequently limited by electronic activity at the window producing surface flashover and in some cases window failure. Such electronic activity is frequently caused by multipacting and also other factors in the window environment such as scattered electrons striking the window through beam scraping or field emission from cavity surfaces or photo-emission from window surfaces induced by X-rays from the cavity. This work examines the environmental component of this activity for the CEBAF cold RF window in the presence of field emission in the cavity and in the absence of beam. The currents collected on an electrically insulated RF window and an electrically insulated waveguide next to the window were found to be correlated to the level of field emission in the cavity.

1. INTRODUCTION

The Continuous Electron Beam Accelerator Facility in Newport News, Virginia contains 338 superconducting RF cavities in a five pass recirculating linac configuration to accelerate a continuous beam of electrons to an energy of 4 GeV. Each cavity is independently fed by a separate klystron through a waveguide coupler containing a cold window at the cavity end operating at 2K, and a warm window just outside the cryostat at 300K. An arc detector and infrared detector mounted near the warm window monitor the cold window and the intervening evacuated waveguide between windows for abnormal heating or electrical discharge and are connected to appropriate interlocks.

During the initial operation of completed portions of the linac, frequent interlock trips were seen by the window arc detector under certain operating conditions. These trips appeared to be correlated with the presence of field emission in the cavities. An accumulation of electric charge on the window and consequent surface flashover produced by radiation from cavities operated with field emission was first suggested by Sundelin[1] and shown to be possible through trajectory calculation at various operating gradients by Yunn and Sundelin.[2] A variety of detailed studies followed which supported this suggestion.[3,4,]

In this work the net electron flux on the window assembly was studied. One motivation was to demonstrate that the suggested electron flux exists and also examine its link to field emission and dependence on window location and orientation. Similar studies linking arcing rate at the window with cavity field emission for differing coupler geometries strongly suggest a charge accumulation on window surfaces.[5]

In addition to the charging of the ceramic window by electrons emitted from the cavity directly striking the window, charging can also occur by electrons and X-rays penetrating the walls of the cavity and then being intercepted by the window. Their flux is reduced in intensity by the quantity of intervening material but any X-ray source within the cavity can contribute.

2. EXPERIMENTAL

To further explore these possibilities, a series of RF tests were performed on a specially instrumented cavity to which an electrically isolated RF window was attached (Figure 1).

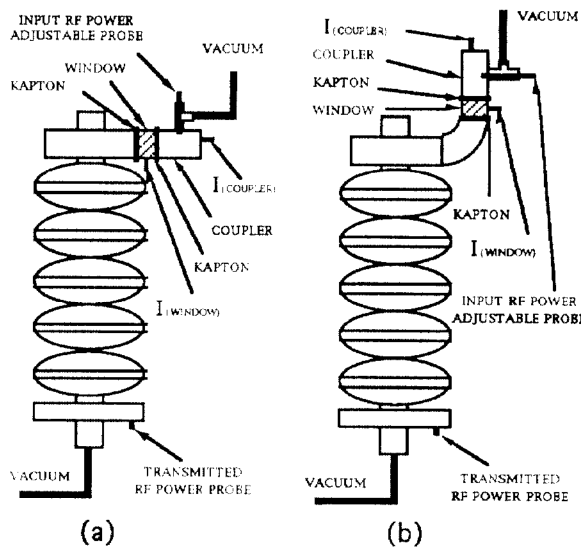

Figure 1. (a) Window directly attached to cavity. (b) Window attached to cavity through a 90° waveguide elbow.

The cavity used was a standard CEBAF production cavity. The waveguide coupler was replaced with a variable coaxial to waveguide transition which was also electrically isolated. Each of the isolated components was connected to ground through an electrometer and both window and coupler currents were recorded during operation of the cavity. Electrical isolation was achieved by bolting the niobium waveguide flanges of each component together using a thin kapton gasket sandwiched between two partially preflattened indium gaskets instead of the conventional indium seal. The bolts were covered with kapton tape and G-10 insulating washers were used. Some RF leakage through the kapton gaskets (0.13 mm thick) occurred and was responsible for a lowered Q_0 for this configuration, since the window and coupler are tightly coupled to the cavity through a port which has an external Q of 6×10^6.

For the arrangement shown in Fig. 1a, which is the normal location of the window in the CEBAF linac, it is known that trajectories are possible by which electrons may leave certain cavity surfaces, either by backscattering or by field emission, and strike the window.[2] In order to compare this configuration to one in which such trajectories ending on the window do not exist, a second configuration shown in Fig. 1b was tested in the same manner. The window and coupler are also insulated and monitored but are separated from the cavity by a 90° elbow.

A third configuration was also tested in which window and coupler currents were recorded without RF power in the cavity to which they were attached. An isolated single cell cavity, nearby but completely separated from the main cavity/window/coupler assembly, was driven well into its field emission regime to provide an external source of radiation.

3. RESULTS AND DISCUSSION

The window and coupler currents with the window directly attached to the cavity (Fig. 1a) are given in Figure 2.

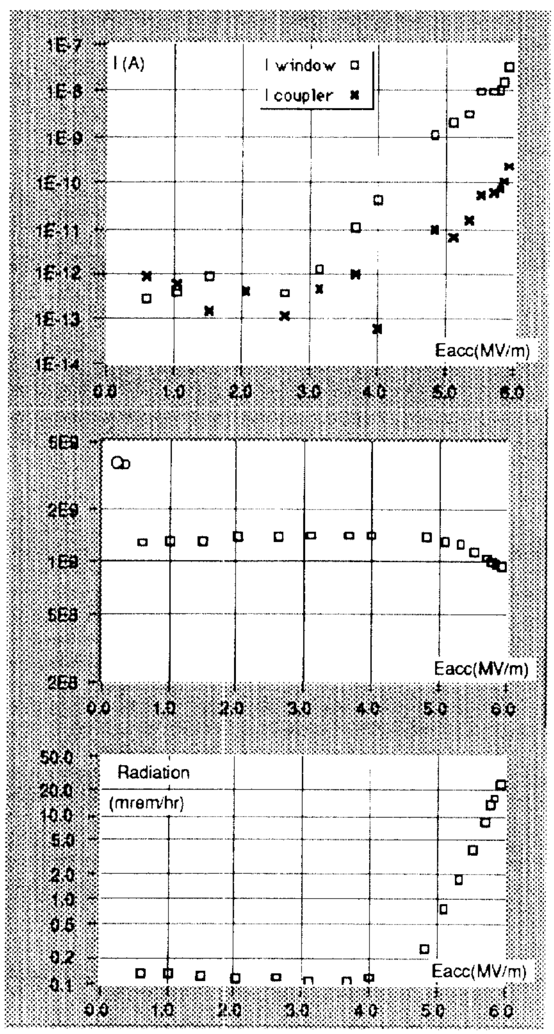

Figure 2. Dependence of window and coupler currents on field emission in the configuration of Fig. 1a.

At cavity fields levels below the onset of field emission, both window and coupler currents are within the instrument noise. The onset of significant field emission, as indicated by the appearance of radiation measured outside the cryostat and a decrease in cavity Q, can be seen to coincide with an increase in window and coupler currents. Both currents track the increase in the radiation detector output reasonably well. Each increases about three orders of magnitude over the same range of gradient.

The window current is a factor of about 10^2 higher than the coupler current. This measurement clearly demonstrates the existence of a charging mechanism but does not separate the contribution due to electrons from the cavity striking the window directly through the coupler waveguide from the contribution induced by radiation passing directly through the cavity walls, if any. Electron energies predicted by Yunn and Sundelin[2] are sufficient to penetrate the 1 mm ceramic window and reach the coupler beyond.

The same measurements were repeated with the window and coupler separated from the cavity by a 90° waveguide elbow as shown in Figure 1b.

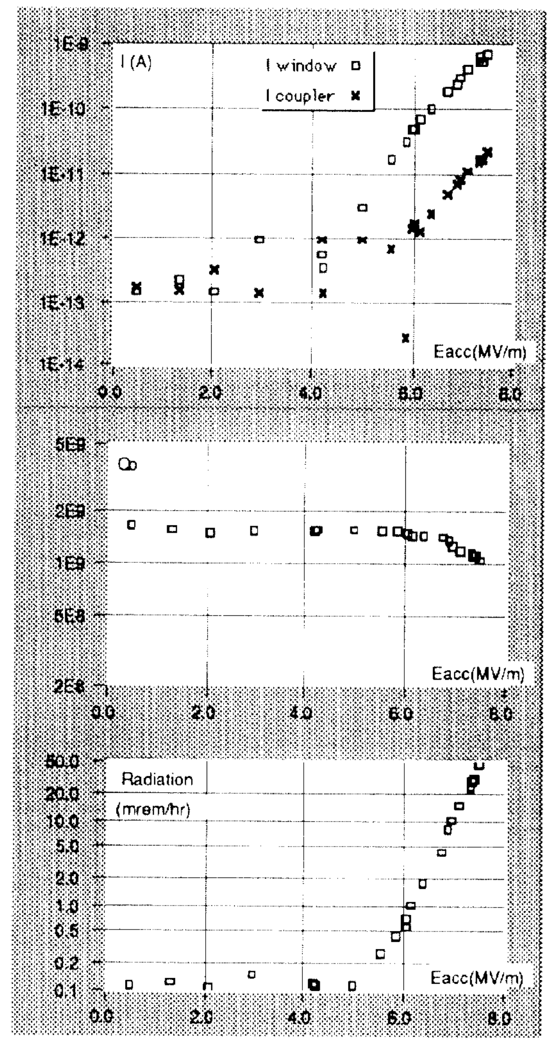

Figure 3. Dependence of window and coupler currents on field emission in the configuration of Fig. 1b

The window and coupler currents in this case (Fig. 3) show the same behavior but are smaller in magnitude. The ratio of window to coupler current is also reduced somewhat.

To examine further a geometry in which even scattered electrons from the coupler port are eliminated, the cavity to which the window and coupler are attached was turned off and a separate single cell cavity in the same cryostat was excited. In this arrangement there was no connection between the cavities, the only link being physical proximity. Again the same behavior was observed, but in this case the window and coupler currents are about equal (Fig. 4) and must be induced entirely from radiation in the adjacent cavity.

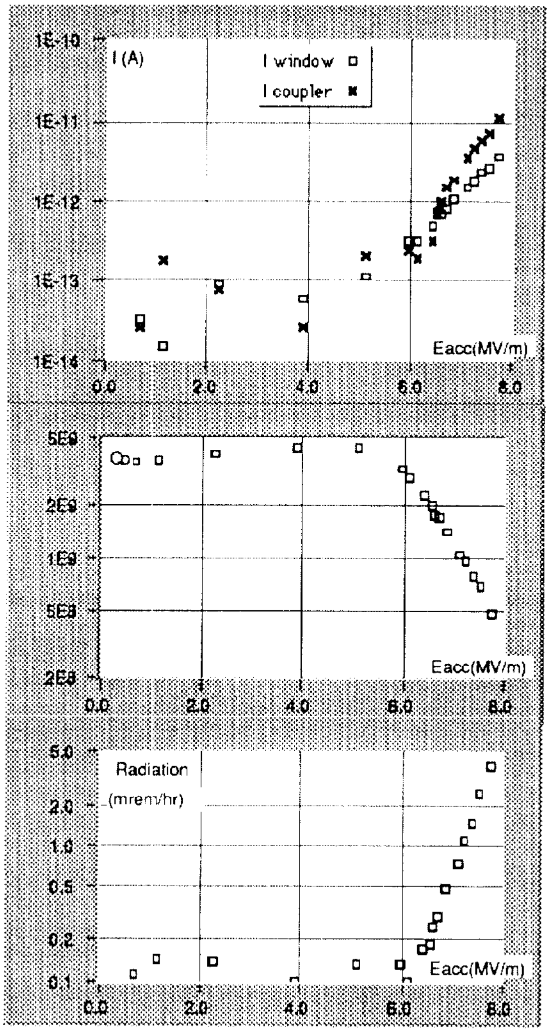

Figure 4. Dependence of window and coupler currents on the field emission of a separate cavity.

None of the measurements described here shed much light on the electron flux emanating directly from the cavity, but do show that even if the direct components were eliminated through geometry modifications, a substantial contribution still exists from the fog of radiation permeating the cavity environment, and external shielding must be used to further reduce its magnitude.

In this study, neither the location of the bremsstrahlung within the 5 cell cavity nor the energy spectrum of the radiation was measured. It is interesting that the polarity of the current was negative, that is, a net electron flow to the window and through the electrometer to ground was observed. In one test a bias of ± 100 V was applied to the window, and had showing no influence on the electrometer current within the resolution of the instrument.

These results are consistent with the coupler and window assemblies being showered by a flux of Compton scattered electrons or photoelectrons ejected from the outer surface of the cavity by X-rays passing through the 3 mm niobium walls. As is also the case with field-emitted or back scattered electrons directly striking the window assembly from within the cavity envelope, the secondary electron coefficient for high energy electrons will be less than one producing a negative electrometer current.

4. CONCLUSIONS

The charging of window assembly surfaces is shown by direct measuring to be correlated with the presence of field emission in the cavity. The measurements also show that some charging occurs by direct radiation through the walls of the cavity.

It is clear that the choice of window location and shielding can be used to reduce window charging if cavity operation in the presence of field emission is necessary. In the absence of field emission, charging is not seen.

5. ACKNOWLEDGMENTS

The authors are grateful for many useful discussions with their SRF colleagues, especially R. Sundelin, B. Yunn , L. Doolittle and P. Kneisel. The valuable participation of J. Mammosser, J. Pauley and P. Kushnick is thankfully acknowledged.

*This work was supported by the U.S. Department of Energy under contract DE-AC05-84ER40150.

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