MULTIPACTOR STUDIES IN RECTANGULAR WAVEGUIDES

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Abstract

Experimental and numerical studies of multipactor in rectangular waveguide geometries are discussed in this paper. A new section of rectangular waveguide similar to the input coupler of the CESR-type SRF cavities has been designed to experimentally verify various multipacting suppression methods. It will also show the effects on multipactor of cryogenic cooling, as well as the effects of surface coatings and roughness, through the use of changeable sample plates.

In parallel, the MAGIC PIC code has been used to simulate multipactor in rectangular waveguide geometries. Early results will be discussed.

INTRODUCTION

Multipactor is a parasitic resonant electron avalanche process that occurs in evacuated RF structures, and has caused frequent trips during the operation of the CESR-type waveguide input couplers. Studies aimed at understanding multipactor have already been carried out at Cornell University using two specially built waveguides [1, 2]. These experiments were successful in identifying multipacting and allowed us to verify several multipactor suppression methods. They however left unanswered questions such as the effects of cryogenically adsorbed gases on multipactor development, or the effect the slight waveguide deformations had on the width of the multipacting bands. A new waveguide is therefore useful to answer these questions as well as allow the evaluation of coatings as multipactor suppressors in waveguides. The new waveguide experiments will take place at Cornell University over the next few months.

EXPERIMENTAL WAVEGUIDE

Waveguide design

We propose an experimental waveguide section designed to accommodate a large sample plate (this increases the likelihood that electrons picked up on the electron probes come from the plate), for which any metal or surface finish may be chosen depending on the experimental requirements. The sample plate will be positioned on a broad wall, as the main electron trajectories of the two-point multipacting occurring in the waveguide are in the mid-plane of the waveguide between the broad walls.

The waveguide cross-section will be 18” by 4”, similar to the cross-section of the CESR SRF input coupler and the experimental waveguides used previously. It is fitted with a greater number of ports on the sidewall, which will be used for a view-port, an electron energy analyser (EEA) and a residual gas analyser (RGA). The broad wall opposite the sample plate is fitted with eight electron probes and a port for an EEA. Two thermocouples will monitor the temperature of the sample plate.

The sample plate is fixed onto a cooled plate, which is designed so that liquid nitrogen can run through channels cut within the plate. It is expected that with this system, the sample plate can be brought down to temperatures approaching 77K. The plate is stood off of the waveguide with a minimal number of contact points so as to limit heat conduction. Spring fingers resting on the edge of the sample plate should ensure RF contact with the rest of the waveguide.

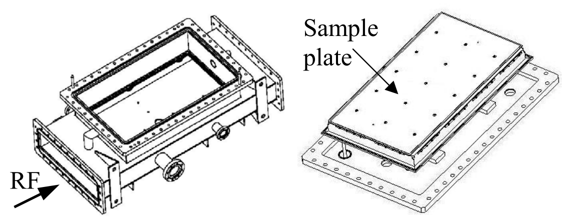

Figure 1: Schematic of the waveguide and of the sample plate mounted on the flange.

Vacuum will be ensured through the use of Mylar windows at either end of the waveguide section. They have been successfully used in the previous series of experiments. The use of such windows led to vacuum levels in the 10^{-5} – 10^{-6} Torr range.

Planned experiments

Experimental studies will test various types of sample plate materials and coatings. The materials tested will be stainless steel, copper and aluminium. The copper plate will be used for tests that will attempt to reproduce results from the previous series of experiments in addition to cryogenically cooled tests. The aluminium plate will be re-used after grooves have been cut into it, in order to test the effectiveness of multiple slots.

The stainless steel plate will have a smaller insert cut into it, allowing smaller scale experiments, most notably on surface coatings. We plan to test a TiN coated plate (coating provided by Dr. J. Lorkiewicz, DESY) to evaluate the effectiveness of such coatings in multipactor suppression.

MAGIC SIMULATIONS

In addition to the experimental aspects of the project, the MAGIC PIC code has been used to model multipactor in simple rectangular waveguide geometries. The MAGIC Tool Suite is a finite difference PIC code designed by Mission Research Corporation in Washington DC. The flexibility in the definitions of surface properties will allow a realistic study of multipactor, particularly in waveguide geometries where the limitations of a finite difference code, in particular surface fields, will not be too apparent.

The simulations are carried out in a rectangular volume bounded on either end with a port, one of which is an input port for an RF signal. Electrons emitted from a wall (modelled as beam emission) (Fig. 3a) seed the volume when the RF field has stabilised. The electrons are emitted for a duration of one RF period, then left to drift as the model dictates. The code then monitors the evolution of the electrons, which begin to exhibit multipacting behaviour, if favourable conditions are met (Fig 3b and 3c).

$$\delta(E_{impact},\theta,t)=1 \qquad E_{impact}<5\text{eV}$$

$$\delta(E_{impact},\theta,t)=(2.72)^2\,\delta_{\max}\,\frac{E_{impact}}{E_{peak}\cos(\theta)}\,e^{-\sqrt{\frac{2E_{impact}}{E_{peak}}}} \qquad E_{impact}>5\text{eV}$$

The secondary electron yield used for the simulations is based on the default yield given for MAGIC [3]. The step function at low electron energies is an attempt to simulate the important role played by backscattered low energy electrons. The height of the step function has been set to one (100% reflection) at present; it is not certain whether it should remain so. Several runs have been made with lower step function values: the effect is a reduction of the rate of electron build-up (negating multipacting in some cases). The reason for this is that electrons from retarding phases are absorbed by the surface, narrowing the phase acceptance band. A more realistic value for the yield of low energy electrons should probably come from an electron yield measurement that does not separate true secondary electrons from the backscattered primaries.

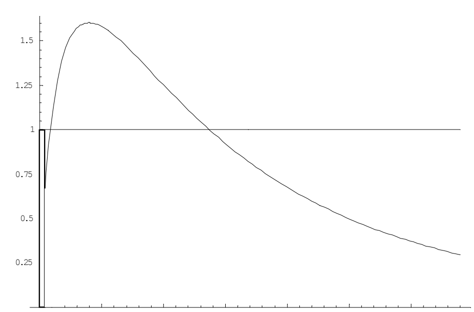

Figure 2: Secondary electron yield curve used for the simulations.

Simulations have been performed to assess the effectiveness of grooves for suppressing multipactor. The grooves were cut out of a waveguide broad wall, to a width and depth of 1cm. To improve the description of the fields in the vicinity of the grooves, the mesh density was increased so that the groove width was covered by a minimum of five cells.

It is apparent during the simulation that the grooves trap electrons in a low field region, where they stay until they are absorbed by the walls or leave the groove. The effectiveness of this multipacting suppression method appears to depend on the number of grooves cut into the walls as well as their size.

It appears that a ridge of the same dimensions as the groove has a similar effect, it would be interesting to verify this, as ridges should be easier to manufacture than grooves in a waveguide. Should time permit, their effectiveness will be studied experimentally.

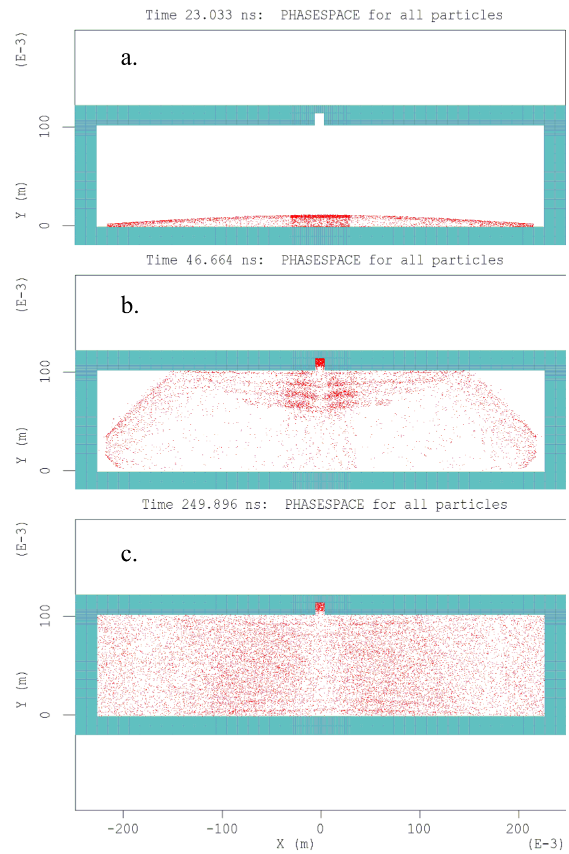

Figure 3: Evolution of a simulation with a single groove. a) Seeding the waveguide with electrons; b) First secondary electrons are created; c) After a long simulation time, the electrons are spread out independently of the starting conditions.

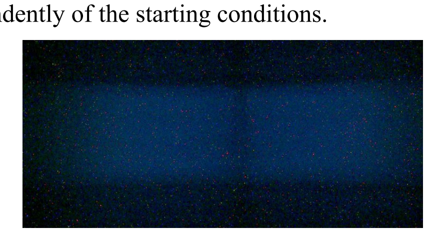

Figure 4: Picture of multipactor breakdown taken on a test waveguide, with a groove, showing the same pattern as Fig. 3c.

The simulations have also been used to examine a number of conclusions of the previous experiments, such as the effect of bias magnetic fields. It was verified that the code's results agreed with experimental observations.

Additional functions of the MAGIC code that could be studied include the possibility of studying ionisation of desorbed gases.

CONCLUSIONS

Studies into methods of electron multipacting suppression continue both experimentally and through modelling. An example of such suppression is the use of grooved surfaces, verified experimentally but also seen using the code. The forthcoming experiments should provide a good baseline to which any further simulations can be compared. It is expected that the MAGIC code will prove to be a useful tool to model electron multipactor.

ACKNOWLEDGEMENTS

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REFERENCES

[1] R.L. Geng, S. Belomestnykh, H. Padamsee, J. Reilly, P. Goudket, D.M. Dykes, R.G. Carter, "Experimental Studies of Electron Multipacting in CESR Type Rectangular Waveguide Couplers", EPAC'2002, Paris, June 2002, p.2238

[2] R.L. Geng, H. Padamsee, S. Belomestnykh, P. Goudket, D.M. Dykes, R.G. Carter, "Suppression of Multipacting in Rectangular Coupler Waveguides", Nucl. Instr. Meth. A 508 (2003) pp.227-238

[3] E.W. Thomas, "Data Compendium for Plasma-Surface Interactions", IAEA, Vienna, 1984, p. 94

[4] R. Cimino, I. Collins, "A Surface Science Approach to the Study of Electron Cloud Phenomena", presentation given at the Damping Ring Workshop 2003, Daresbury Laboratory, Jan. 2003