STUDIES OF ELECTRON MULTIPACTING IN CESR TYPE RECTANGULAR WAVEGUIDE COUPLERS*

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Abstract

The latest results from an experimental waveguide section, as well as simulations from a model of electron multipacting using the MAGIC PIC code, are discussed. Tests were carried out on a new waveguide section that included enhanced diagnostics and the possibility of changing surface materials and temperature. Those tests evaluated grooves, ridges and surface coatings, including a TiN coating and a TiZrV NEG coating, as methods of multipactor suppression. The conclusion after those tests remains that the most effective method to achieve complete multipactor suppression remains the application of a static magnetic bias, parallel to the wave propagation direction, of approximately 10G.

INTRODUCTION

Multipactor is a parasitic resonant electron avalanche process that occurs in RF structures under vacuum, 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]. While the results from those experiments were very useful, it was felt that additional investigations should be performed, including more variations on the slotted waveguide concept as well as an investigation into the effectiveness of coatings.

EXPERIMENTAL APPARATUS

A waveguide (Figure 1) was constructed at Daresbury with a large opening in the broad wall opposite the diagnostics [3]. This allowed the insertion of a large sample plate, mounted on a holding plate fitted with cooling channels and a heater tape. The temperature of the sample plate could thus be lowered to 147K (by running liquid nitrogen through the cooling channel) or raised in excess of 470K (through the combined use of the heater tape and hot air blown through the cooling channel) for extended periods of time, helping to clean the surfaces as well as allowing the study of low temperature performance. Vacuum integrity was however still ensured by Mylar windows, limiting the vacuum quality to about 10^{-5}Torr at room temperature in a well-processed waveguide. While these vacuum levels do not interfere with multipactor behaviour, they are expected to limit the effectiveness of coatings due to gas deposition on the coated surface.

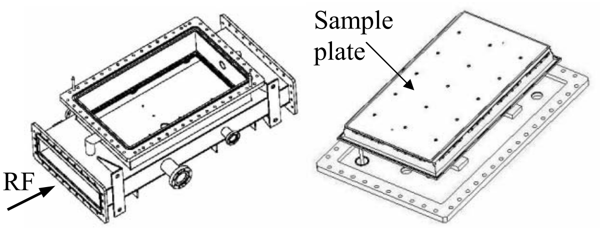

Figure 1: Schematic of the waveguide and of the sample plate mounted on the flange.

The waveguide diagnostics included eight electron probes and two energy analysers (Faraday cups with a retarding potential). Of the electron probes, four were off-axis, giving a better spatial resolution of the multipactor. Figure 2 shows the location of the electron probes on the waveguide.

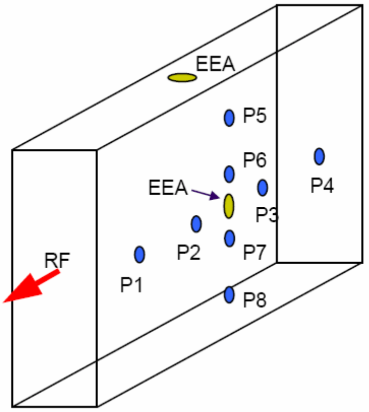

Figure 2: Location of the electron probes (Pn) and energy analysers (EEA) on the waveguide.

MULTIPACTOR SUPPRESSION

Alterations to the waveguide geometry

Multipactor suppression can be achieved by preventing multipactor trajectories from forming. Early simulations carried out be R.L. Geng [4] hinted at the possibility of using a groove cut into the centreline of the waveguide to capture what were initially thought to be the only viable multipactor trajectories.

However, the initial series of experiments, as well as subsequent explorations of multipactor behaviour using the MAGIC PIC code [5], showed that multipactor could develop despite the presence of the groove. In order to

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widen the catchment area of the electrons, the possibility of using more than one groove was studied. MAGIC simulations also tended to indicate that additional grooves should be successful at capturing electrons across a broader area of the waveguide centre (however, in order to keep simulation time to a reasonable level, the mesh in those simulations was still relatively crude in the vicinity of the grooves).

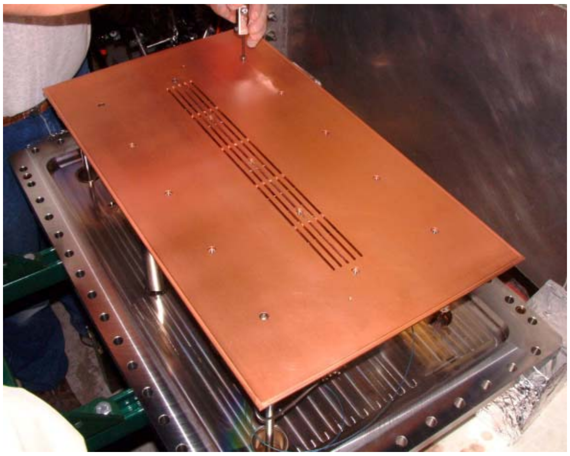

Figure 3: Sample plate with five grooves.

A copper plate was used for the experiments. It was initially tested as a plain un-grooved plate, then tested with one, five and thirteen grooves, each 3mm wide and cut through the 4mm thick plate. The grooves were separated by 10mm.

Results from a single groove were qualitatively comparable to what was previously achieved with the previous waveguides. Additional grooves, however, proved slightly more problematic as rather than improving the situation, the resulting multipacting current was often measured, as can be seen in Figure 4, to be greater than the groove-less case. It is likely that the causes for this were the tangential electric fields generated by the off-centre grooves as they intercept wall currents in the waveguide.

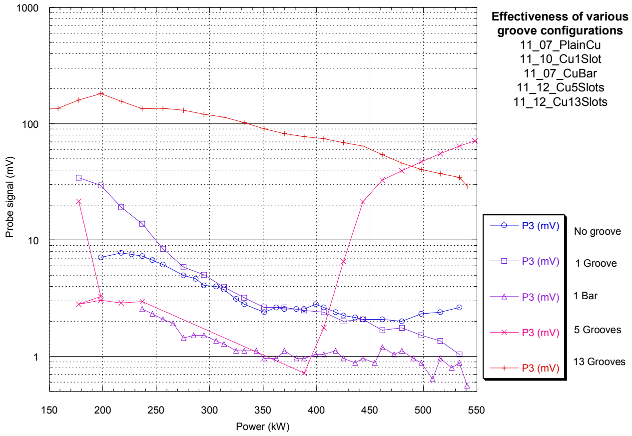

Figure 4: Collated results from probe P3 in the various groove/ridge situations.

An interesting observation was that a ridge placed along the centreline of the waveguide had much the same effect as a groove, reducing the multipactor current in the centre of the waveguide, but having a limited effect away from the central plane. The ridge has the advantage of being easier to manufacture and could be added to waveguides with minimal impact on their performance.

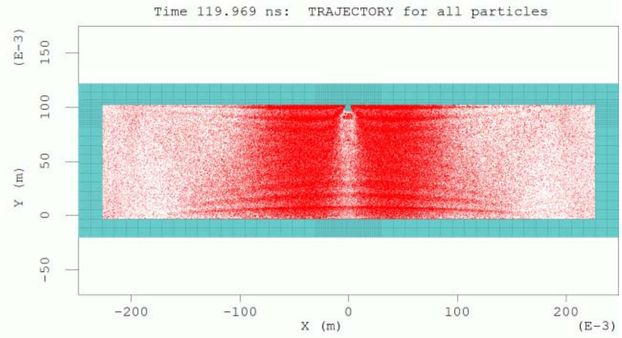

Figure 5: Status of a MAGIC simulation of a ridged waveguide after 120ns of simulated run-time.

MAGIC simulations also showed that while the multipactor build-up in a grooved or ridged waveguide was inhibited in the centre of the waveguide; the build-up in the other regions was similar to that of a normal waveguide. The benefit of using a groove mainly resides in raising the onset power at which multipactor occurs by hindering its appearance in the highest field region of the waveguide.

Surface coatings

Two surface coatings were tested. Due to the limited size of the deposition chambers available, it was unfortunately only possible to coat a small 15cm diameter sample plate insert rather than the entire sample plate.

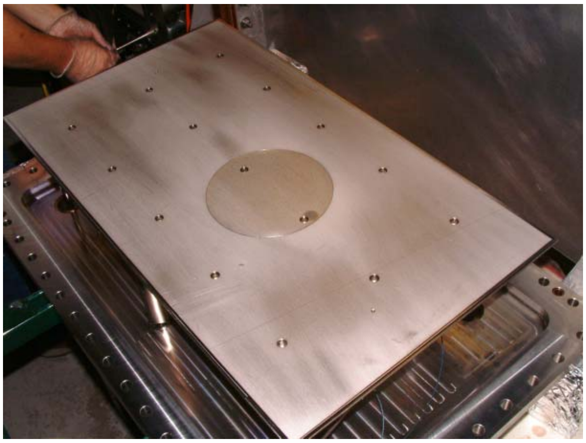

Figure 6: View of a TiN coated sample plate insert on the steel sample plate.

The first insert tested was a TiN coated disk (prepared by Dr. J. Lorkiewicz (DESY)). It was heated in excess of 200°C for six hours at 250°C. While the results were not decisive due to the contamination of the sample plate by gas from the rest of the waveguide surfaces, they do show a difference in current measured between a probe opposite the coated sample plate insert and one opposite the stainless steel sample plate holder. No notable difference was measured between the electron energies measured with and without a coated sample plate.

Likewise, a TiZrV NEG coated sample plate insert (prepared by Dr. Yulin Li (LEPP, Cornell University)) was also tested before and after activation (5h, 210°C).

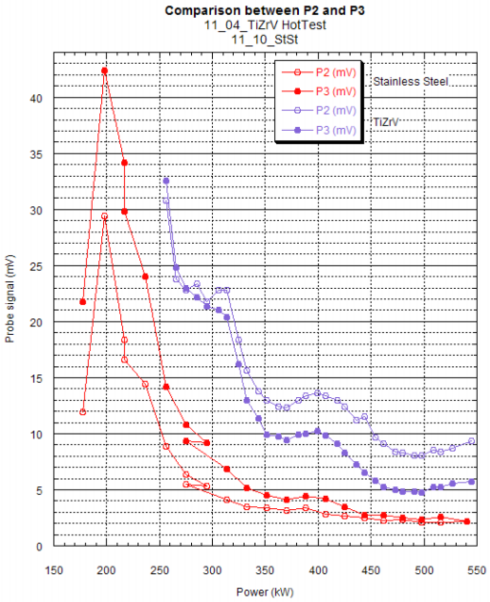

Figure 7: Comparison between P2 and P3 signals on a TiZrV sample plate and a plain Stainless Steel plate (the TiZrV plate was opposite P3).

As Figure 7 shows, the effect of the TiZrV coating was most notable at the higher power ranges. This result is quite encouraging given the small area covered by the coating and should encourage further investigations into the feasibility of applying a getter coating in an input coupler such as the one used in CESR cavities.

Anodised niobium was also found to have a lower secondary electron yield than untreated niobium. This was verified during tests that showed reduced current and delayed onset levels depending on the thickness of the coating.

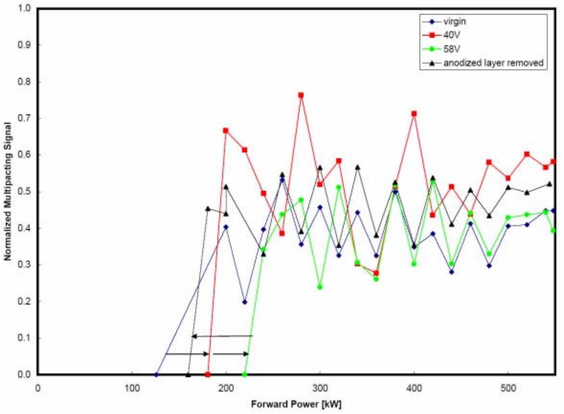

Figure 8: Measurement of the current on P3 for an anodised niobium sample plate (40V corresponds to an 80nm oxide layer, 58V to 120nm). The signals have been normalised to P2.

Alterations to electron trajectories

The previous series of experiments verified that the application of a magnetic field bias of approximately 10G was sufficient to prevent any occurrence of multipactor in a rectangular waveguide. This method has the advantage of being reliable in that the secondary electron yield properties of the surface do not affect its effectiveness.

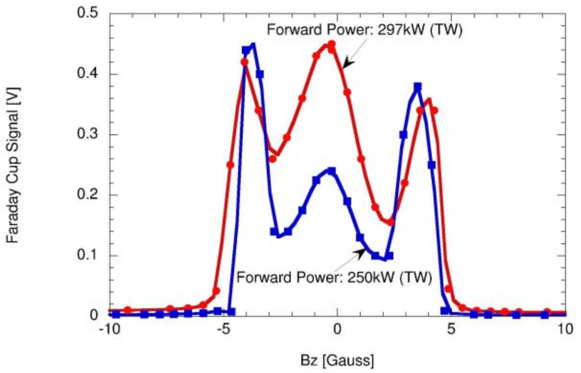

Figure 9: Multipactor suppression achieved with a longitudinal magnetic field

CONCLUSION

Despite several promising possibilities offered by the use of coatings and ridges, neither of these methods has been shown to suppress multipactor completely. Only the application of a magnetic field has been proven to completely extinguish multipactor in a rectangular waveguide. If, however, the risk of placing magnetic fields close to superconducting materials is too great, the appearance and severity of multipactor can be reduced using a groove or a bar on the waveguide centreline. Coatings should not be completely discounted and further investigations, using a fully coated waveguide section under better vacuum levels, could lead to more conclusive results.

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