REDUCTION OF MULTIPACTING IN AN ACCELERATOR CAVITY

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Abstract

The choice of a suitable geometry in designing a radio-frequency cavity for e^+e^- storage ring allows the reduction of multipacting (MP) discharges. We have studied the behaviour of resonant electron discharges in the RF cavity of the Adone storage ring in Frascati, that shows a broad MP barrier in the 35 to 70 kV range of the accelerating voltage. It can be explained by one point MP on the end-plates of the resonator. Our computer simulations of the trajectories of electrons in the RF fields of the cavity clearly show multipacting trajectories in that region of the cavity at about that field level. On the base of our experimental measurements and simulations, the design of a new RF cavity, multipactor free in the end-plates region, is presented.

Introduction

Resonant discharge phenomena plague the operation of high-vacuum resonators in particle accelerators. These phenomena have therefore been widely studied and there exists now a well founded theory and a large amount of experimental investigations[1,2,3]. There are now valid tools to localize possible discharges in structures having cylindrical symmetry, so it is advisable to take into account the possibility of reducing multipacting in the design of a cavity.

Our interest has been stimulated by the annoying behaviour of a 51 MHz, 200 kV Aluminum resonator that is installed on the storage ring Adone[4]. This resonator shows a hard multipacting barrier from 35 to 70 kV, limiting the operating voltage range and requiring high peak power with steep rise time from the feeding amplifier to overcome the barrier.

The possibility of resonant trajectories depends both on surface properties (secondary emission) and geometry. As to the latter, two kinds of trajectories can be distinguished: "two points" trajectories where the transit time is an integer number of half cycles and "one point" ones, where transit time is a whole number of cycles. Secondary emission can be acted upon by suitable surface treatments, but often they do not suppress completely the phenomena or they are not compatible with ultra-high vacuum.

By acting on the geometrical shape, instead, one often succeeds in eliminating resonant trajectories whatever be the surface secondary emission coefficient[5]. We therefore decided to build a scaled model of the cavity in order to study the effect of the shape variations and to gain confidence in computer codes we use.

The model

The model is an Aluminum cavity resonating at 100 MHz, whose dimensions are given in fig. 1 together with the electric field lines traced with the aid of a modified version of the LALA code[6].

Besides the feeding and pick-up loops there is a small antenna by which we detected the electron current associated with the discharges. The cavity is evacuated by means of a 60 lt/sec ion pump.

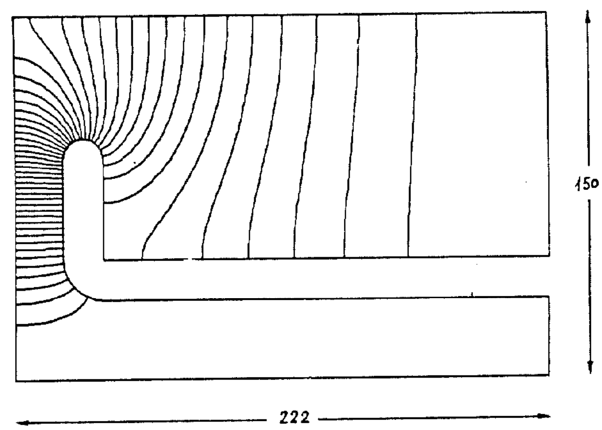

FIG. 1 - Section of one quadrant of the cavity model showing the electric field flux lines (dimensions in mm).

The parameters of the cavity are:
Characteristic impedance R/Q=60 Ohm, Q=6500.
With a 300 W generator we were able to obtain up to 15 kV peak at the gap. Before evacuating, the cavity surface was cleaned very simply with abrasive powder and water, without organic solvents. Vacuum tightness is ensured by Viton gaskets. Moderate baking was made. In fig. 2 is shown a picture of the model. Base pressure was about 3×10^{-8} mbar.

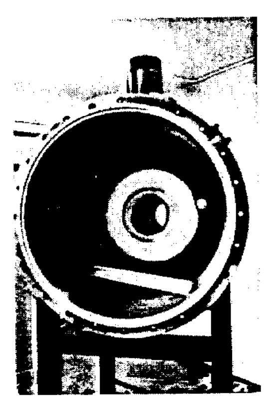

FIG. 2 - Picture of the cavity model before evacuation.

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Numerical simulation

The numerical code at our disposal is the TRAJECT code, which is a modified version of a code obtained from Dr. Halbritter of Karlsruhe Labs. It uses the fields obtained by the LALA code to compute the trajectory of an electron of given initial conditions.

The simulation makes use of the fields whose values are known at the crossing points of a square mesh. An electron, starting from any position inside the cavity with given initial energy, direction, RF phase and gap voltage, is followed, by solving the motion equations, until it impacts with the walls of the resonator. The process of re-emission from the surface can be a back-scattering of the impinging particle or emission of secondary electrons, whose motion in the RF field is followed until a new impact. At each impact the electron multiplication efficiency is registered and the process is stopped if the efficiency becomes too low or after a given number of RF cycles.

In fig. 3 is shown a resonant trajectory corresponding to 2.5 kV gap voltage. The computation shows a set of such discharge levels between 2.5 kV and 5 kV.

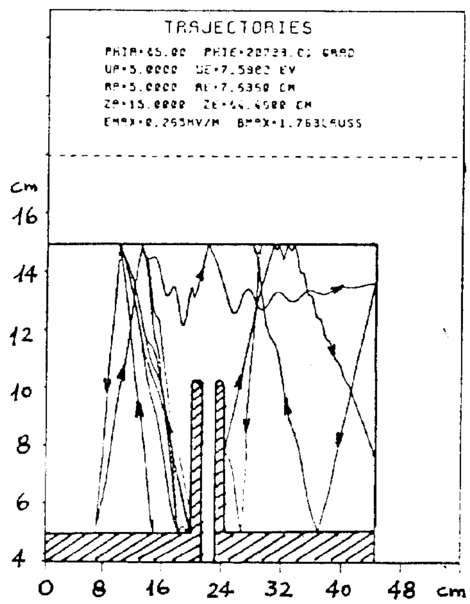

FIG. 3 - Resonant trajectories for the cavity model and 2.5 kV gap voltage.

Experiments

To detect multipacting discharges we looked at the decay of an RF pulse sampled through a pick-up loop.

Multipacting electrons subtract energy from the cavity and therefore cause a sudden change in the slope of the envelope of the RF waveform. In addition, multipacting electrons drift towards the short circuiting plates of the resonator. A small antenna situated on those plates detects the electron current associated with the discharges. In fig. 4 is shown a photo of the decay of an RF pulse in coincidence with the integrated current from the antenna. A multipacting band between 2 kV and 5 kV is evidenced. The computer simulation indicates that these discharges take place between the inner electrodes and the outer envelope of the cavity.

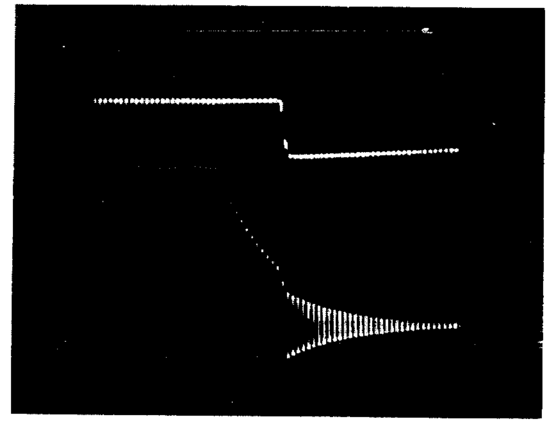

FIG. 4 - Decay of an RF pulse evidencing a multipacting barrier between 2 kV and 5 kV. V = 2.5kV/cm.

In order to locate experimentally the discharges we have painted with graphyte black a zone corresponding to the highest probability of discharge. The result on the RF waveform is shown in fig. 5.

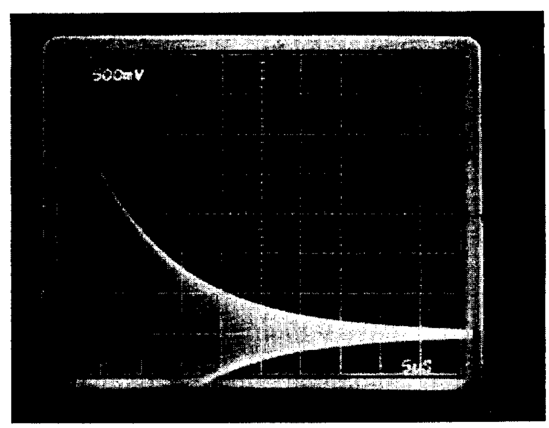

FIG. 5 - RF decay after painting with graphite black. V = 2 kV/cm.

The decay fits well with an exponential and no current is detected by the antenna. There is no more evidence of multipacting levels in the previous voltage range and this supports our localization of the discharges.

Conclusions

Having gained confidence in our computer codes we have spotted probable multipacting trajectories in Adone's 51.4 MHz cavity on the end short circuiting plates. A typical trajectory is shown in fig. 6.

We have then tested the effect of changing the shape of these plates into a toroidal form. This shape introduces an electric field perpendicular to the plate surface, that inverts its direction when crossing the mid point of the arc.

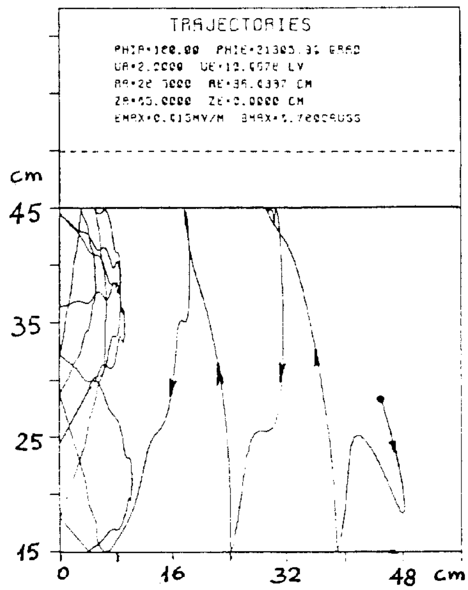

FIG. 6 - Trajectories on end plate flat shape (not to scale).
$V_{RF} = 30\ kV_p$.

Therefore a secondary electron emitted from the surface is pushed towards that mid point and there it stops due to the change of direction of the electric field. A trajectory relative to toroidal end plates is shown in fig. 7.

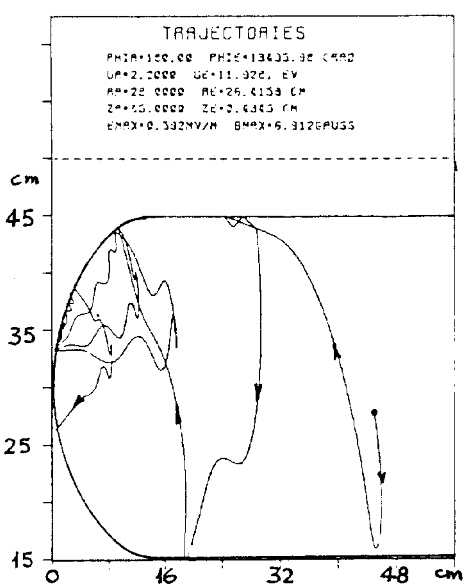

FIG. 7 - Trajectories on end plate toroidal shape (not to scale).
$V_{RF} = 44\ kV_p$.

Following these results we have made the design of a new resonator for Adone, a sketch of which is shown in fig. 8.

The toroidal shape, together with a slightly smaller dimensions, should allow us to render multipacting much less troublesome.

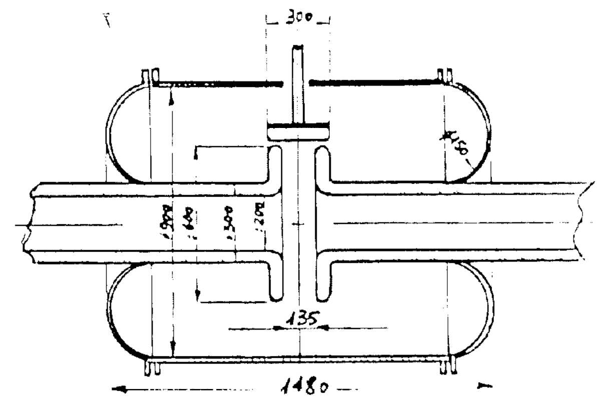

FIG. 8 - Sketch of the new cavity resonator for Adone storage ring.

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