THE OPTIMIZATION OF THE BUNCHER AT 145.2 MHZ TO REDUCE MULTIPACTOR EFFECT

M.A. Gusarova, I.I. Petrushina, S.M. Polozov, National Research Nuclear University «MEPhI», Moscow, Russia
A.S. Plastun, T.V. Kulevoy, FSBI «SSC RF ITEP», Moscow, Russia

Abstract

The results of the 145.2 MHz single gap buncher cavity in order to reduce multipacting discharge influence are presented in this paper. Resonant voltages, impact energies and corresponding particle trajectories are obtained. The ways of cavity design modifications to reduce multipacting discharge effects are considered.

INTRODUCTION

The proposed cavity is a single gap buncher of medium energy beam transport system (MEBT) for linear injector of Nuclotron-NICA project (JINR) [1-2]. The cavity shape is a modified E_{010} pillbox. The modifications are performed in order to decrease the cavity size and to place MEBT quadrupoles near the cavity, according to the general layout. 3D model of the buncher cavity before the optimization is presented in Figure 1.

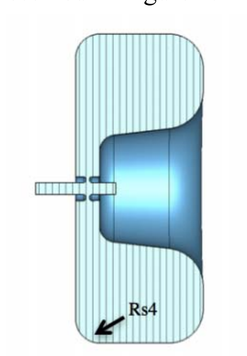

Figure 1: Side-view of the buncher cavity.

Computer simulations of the multipacting dischegre were performed using MultP-M [3] and CST PS [4] software. The possibility of multipacting discharge was concluded from the percentage growth rate of secondary electrons number inside the cavity, the shapes of resonant electron trajectories and the energy of impact with the cavity surface. Secondary emission coefficients for copper surface that were used in simulation are taken from [5].

MULTIPACTING DISCHARGE SIMULATIONS OF THE NON-OPTIMIZED CAVITY

Electric field and voltage values presented in this paper are normalized to 1 J of energy stored in the cavity. Initial computer simulation with MultP-M code was performed in order to identify the most dangerous levels of normalized voltage in the range U_N = 0 - 5, which can induce the progress of multipacting. The operating voltage of 150 kV corresponds to the normalized voltage of $U_N = 0.45$, and the operating voltage of 337 kV corresponds to $U_N = 1.0$. Figure 2 illustrates the number of particles percentage growth rate after 10 RF periods for U_N levels from 0 to 5.

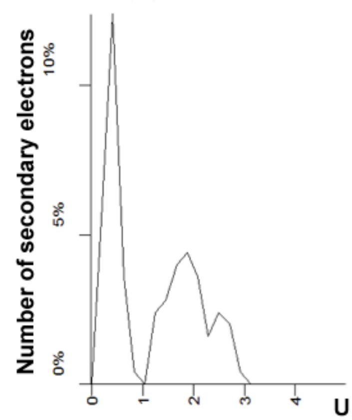

Figure 2: Number of particles percentage growth rate of after 10 RF periods for U_N levels from 0 to 5.

Figure 2 shows the possibility of multipacting at U_N voltage levels from 0 to 3 with two or three peaks, which correspond to several different multipacting spatial domains. The detailed analysis has detected these three spatial domains of multipacting discharge, which are presented in Figure 3 along with particle trajectories. In the range of $U_N = 0.001$ - 0.018 (Figure 3*a*), the number of particles growth rate peak is observed at $U_N = 0.015$. Multipacting discharge shifts outside from accelerating gap and totally attenuates after 40 RF periods.

The trajectories in the range of $U_N = 0.063$ - 0.461 is shown in Figure 3*b*. Secondary electrons return to the cavity surface every single RF period, so this discharge is of the 1st order. Simulation has shown stable electron trajectories in the whole range of $U_N = 0.063$ - 0.461 during 50 - 200 RF periods. The number of particles growth rate peak is observed at $U_N = 0.417$, which is close to the operating value. In this case, the discharge remains stable for more than 200 RF periods. The impact energy is 800 eV at $U_N = 0.14$, while at $U_N = 0.424$ it is 1400 eV. Analysis of secondary emission coefficient variation has shown that the surface quality and polishing are very important for discharge attenuation.

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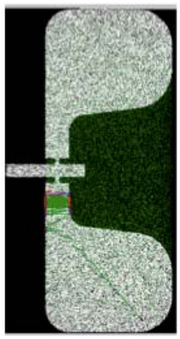
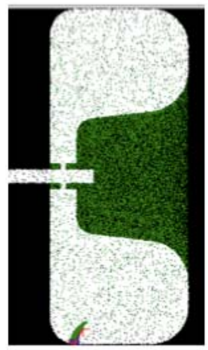


a: $U_N = 0.001 - 0.018$



b: $U_N = 0.063 - 0.461$

c: $U_N = 0.424 - 2.992$

Figure 3: Spatial domains of multipacting trajectories.

The multipacting discharge in the range of $U_N = 0.424 - 2.992$ is shown in Figure 3*c*. This range overlaps with the previous one shown in Figure 3*b*. Thus, multipacting can occur in both 3*b* and 3*c* spatial domains in the voltage range of $U_N = 0.424 - 0.461$.The most dangerous voltage level is $U_N = 2.5$. It provides a stable 1st order multipacting discharge with the impact energy of 1400 eV. Higher voltage levels are dangerous only for dirty copper surfaces. Fortunately, U_N level of 2.5 is significantly higher than the operating level.The first peak shown in Figure 2 corresponds to multipacting discharge in the domain shown in Figure 3b and, probably, Figure 3c. The Second and the third peaks correspond to multipacting discharge in the domain shown in Figure 3c.

Computer simulation of multipacting discharge in the cavity were also performed in CST Particle Studio. The results of these simulations are in agreements with the MultP-M code results. . Figure 4 illustrates the domain of discharge avalanche at $U_N = 0.45$ and the increase of particles number in time.

As mentioned above, the multipacting discharge can occur in the spatial domains, shown in Figures 3b and 3c, at operating voltage level of 150 kV or $U_N = 0.45$. Therefore, the cavity geometry optimization has been done to avoid multipacting discharge progress. Blending radius *Rs* (shown in Figure 1) was increased and the parallel surfaces near the accelerating gap were replaced with conical.

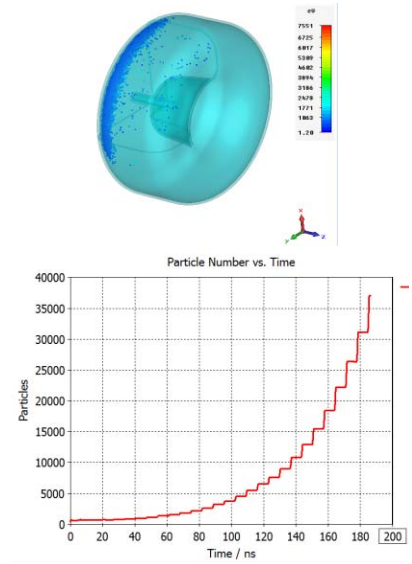
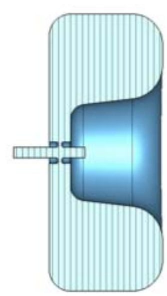


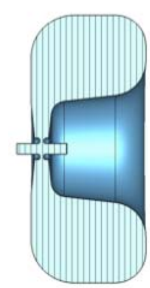
Figure 4: Multipacting discharge area and an increase of particle number in time.

MULTIPACTING DISCHARGE SIMULATION OF THE OPTIMIZED CAVITY

The side-view of the optimized cavity is presented in Figure 5*b*.



a



b

Figure 5: Geometry of the cavity (a) before and (b) after optimization.

Simulation show that the increase the blending radius *Rs* from 60 mm to 120 mm, allows us avoiding the resonant conditions at $U_N = 0.45$. But multipacting isn't totally suppressed – the trajectories remain stable during 5 to 15 RF periods.

Figure 6 presents the number of particles percentage growth rate of for 100 initial electrons in the voltage range of $U_N = 0 - 1$ at the step of 1/400 of RF period during 100 RF periods. The plot illustrates the contribution to this growth only from particles which had more than 25 hits with cavity surface.

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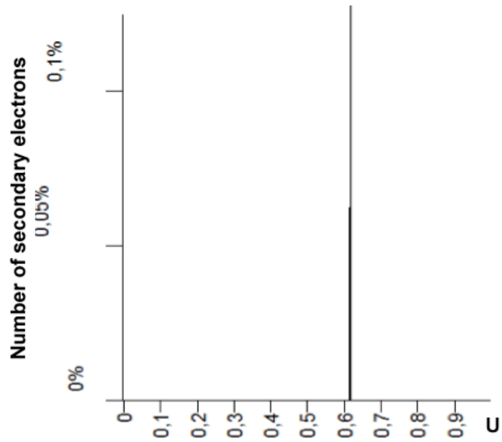
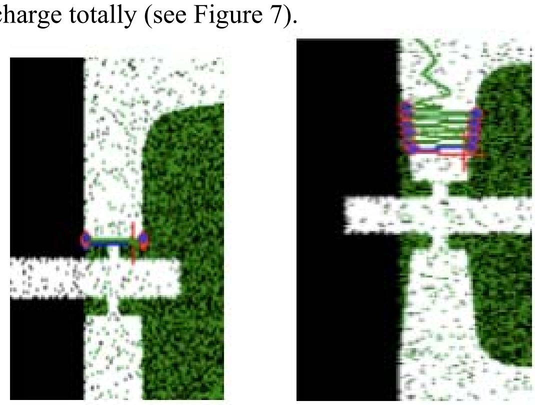


Figure 6: Percentage growth rate of number of particles in optimized cavity after 100 RF periods of simulation for U_N levels from 0 to 5.

Further increase of the blending radius Rs doesn't change the result - multipacting trajectories remain stable during 5 -10 RF periods.,The surface cleaning and the longtime RF conditioning of the cavity should be performed in order to avoid the progress of multipacting discharge.

Conical or V-shape surfaces near the accelerating gap provide multipacting suppression in spatial domain shown in Figure 3*a* at low voltages of U_N from 0.009 to 0.016. Strong resonant conditions don't remain active during multipacting discharge, but also don’t suppress the discharge totally (see Figure 7).



a *b*

Figure 7: Electrons trajectories for (a) parallel and (б) V-shape surfaces.

The results of the computer simulations of multipacting sicharge in domains, illustrated in Figure 7s, done in CST Particle Studio, are in agreement with the results achieved in MultP-M code. The optimized geometry is presented in Figure 8.

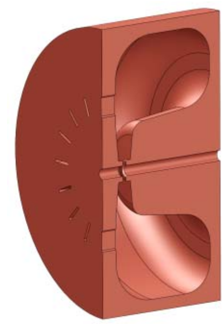


Figure 8: The optimized geometry of the single gap buncher cavity.

SUMMARY

In order to reduce the multipacting discharge effect, the , the 145.2 MHz single gap buncher cavity shape was optimized. . The threshold values of the accelerating gradient when the discharge may occur in these structures have been calculated. Several ways of the cavity design that help to reduce multipacting discharge effect were considered.

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