THE NEW RF DEFLECTORS FOR THE CTF3 COMBINER RING

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Abstract

To suppress the vertical beam instability in the CTF3 Combiner Ring caused by vertical trapped modes in the RF deflectors, two new devices have been designed and constructed. In these new structures the frequency separation between the vertical and horizontal deflecting modes has been increased and special antennas have been inserted to absorb the power released by the beam to the modes. The deflectors have been made in aluminium to reduce the costs and delivery time and have been successfully tested and installed in the ring. In the paper we illustrate the design, the realization procedures, the RF tests results and the multipactig analysis.

INTRODUCTION

The second stage of the bunch train compression in CTF3 [1] is realized in the 84 m circumference Combiner Ring (CR). This is achieved by means of two travelling wave (TW) RF deflectors (RFDs) working at fRF=2.99855 GHz already built and successfully tested in the CTF3 Preliminary Phase [2]. In the run of November 2007 a vertical beam instability has been observed during operation [3]. A detailed analysis [4] has identified in the RFDs vertical trapped modes the source of such instability. The analysis showed that the instability could be completely cancelled with a strong reduction of the quality factors of the trapped modes and with a strong frequency shift of such modes with respect to the horizontal deflecting polarity (working mode). For these reasons new RFDs have been designed and constructed. The electromagnetic (e.m.) design criteria are illustrated in the second paragraph of the paper while the realization procedure and the RF tests are illustrated in the third paragraph. The fourth paragraph is dedicated to illustrate the results of the multipacting analysis.

NEW RFD DESIGN

The RFDs installed in the CR are TW devices that deflect the beam in the horizontal plane. The main parameters of the structures are reported in Table 1. In the original design [2], two metallic rods (Fig. 1a) have been inserted into each cell to separate in frequency the deflecting mode with vertical polarity. The dimension and position of the rods have been chosen to fix the polarity of the horizontal mode, avoiding the tilt of the working polarity through the deflector and avoiding the excitation of the vertical mode by the beam power spectrum line at 2.99855 GHz. The frequency shifts of the vertical modes were about 48 MHz, as shown in the dispersion curve plots of Fig. 2. According to the beam dynamic simulations, the new RFDs have been designed to increase the frequency shift of vertical modes by more than 300 MHz (at least for the 2π/3 one that has the largest impedance) and to strongly reduce their quality factors (the whole design has been done by HFSS [5]). The first goal has been achieved by moving the rods in each cell towards the center of the structure as shown in Fig. 1b while the second goal has been reached by modifying one of the two rods (except those of the input and output couplers) into a damping antenna connected to an external load (Fig. 1c). The dispersion curves are reported in Fig. 2 while the quality factors of the vertical modes are so low that they cannot be well calculated.

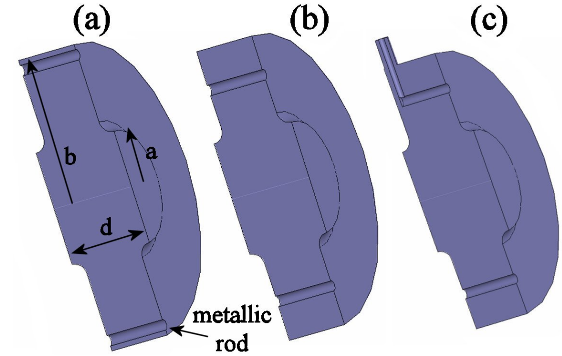

Figure 1: Single cell geometry: (a) old; (b) rod modified; (c) rod modified and damping antenna.

Table 1: main RFD parameters and dimensions

RFD frequency	2.99855 GHz		
TW mode of operation	$2\pi/3$		
Total number of cells	12		
Filling time	~47 [ns]		
Nom./Max Transv. voltage	~0.9/~2 [MV]		
Nom./Max input power	~2 /~10 [MW]		
E_{surf} @ P_{in}=10 MW	~21 [MV/m]		
H_{surf} @ P_{in}=10 MW	~65 [kA/m]		
RF operating pulse length	~1.5 [µs]		
Dimensions [mm]	a≅21	b≅56	d≅33

REALIZATION AND RF TEST

To reduce the cost and delivery time we built the new RFDs in aluminium. The cells have been machined, put into a stack, clamped and soldered together (*). Figs. 3 and 4 show the assembled cells and the final RFD under test. RF measurements have been done in all phases of the constructions to control the machining and the assembly process. The final measured reflection coefficient at the input port is reported in Fig. 5 and, at the working frequency, it is about -25dB. The transmission coefficient between two antennas is reported in Fig. 6 in two cases:

* The construction has been done at COMEB Comp. (www.comeb.it).

all antennas connected to the loads and only two antennas (those used for measurements) connected to the loads. In the first case all modes have quality factors practically not measurable while in the second case some modes appear but the damping is still strong since the modes are multi-cell modes and the loads connected to the two antennas are sufficient to give a strong damping.

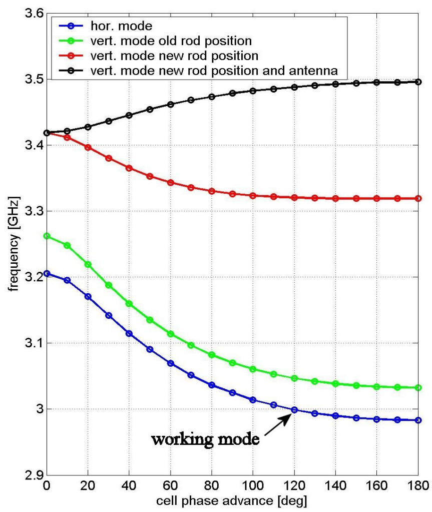

Figure 2: Dispersion curves of the deflecting modes.

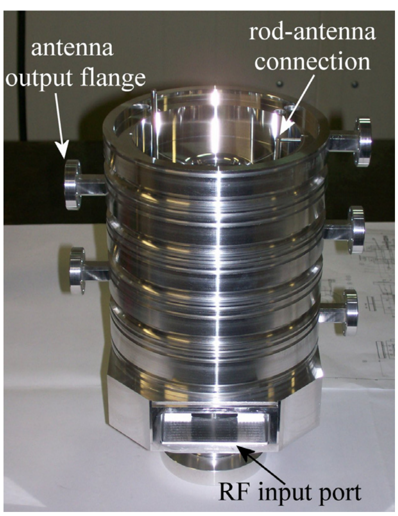

Figure 3: Assembled RFD cells.

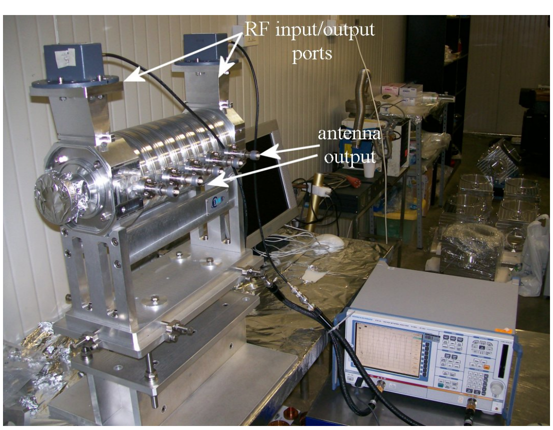

Figure 4: RFD under test

Finally the transmission coefficient between the RF input port and the antennas have been measured. Typical results were below -60 dB and guaranteed that the RF power does not couple with the antenna loads causing reduction of the deflector efficiency and possible damages of the loads themselves.

The cavities have been installed in the CR and RF power conditioning needed less than 1 hour. Each cavity has been fed with more than 10 MW and no multi-pacting effects have been observed. Beam recombination in the CR has been achieved very soon without evidence of vertical instabilities [6].

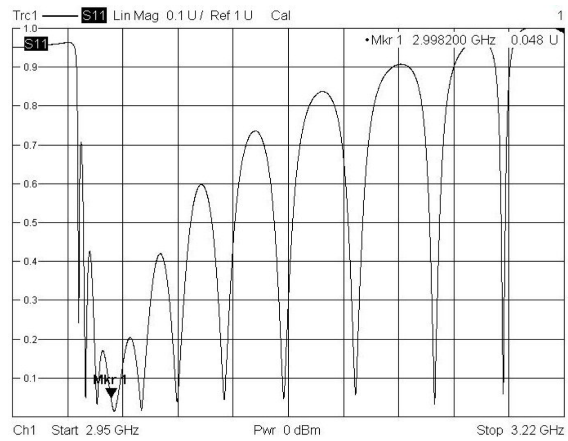

Figure 5: Measured reflection coefficient ate the input port

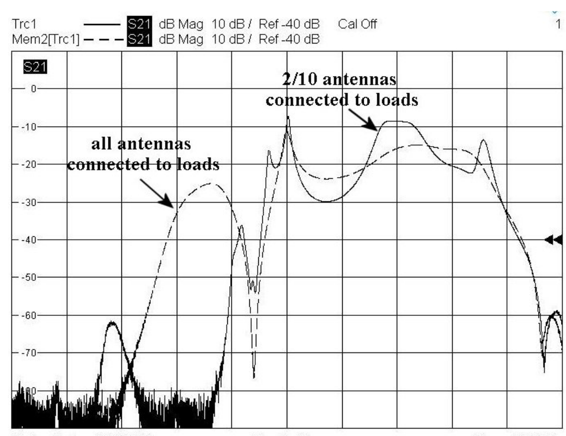

Figure 6: Transmission coefficient between two antennas

MULTIPACTING ANALYSIS

Even if, from the multipacting (MP) point of view, the aluminium is worse with respect to the copper because of its higher secondary electron yield (SEY), the choice of the aluminium has been still maintained. The risks have been evaluated even if, at the beginning, no MP simulations were available. In particular we were encouraged from the following reasons. First of all no evidence of MP (even small) has been observed in the previously installed copper deflectors at any input power. Second, the dynamics of the secondary emitted electrons in deflecting structures is completely different with respect to the dynamics in accelerating structures and, in the region where we have maximum electric field, it is strongly perturbed by the high magnetic field. Third, in case of strong MP a backup solution could be to provide a Ti-coating of the internal surfaces of the structure to reduce the SEY.

All this intuitive arguments have been confirmed by the very good performances of the deflectors and by MP simulations that we have done “a posteriori” by the code Analyst [7]. The code simulate the SEY by emitting particles from all faces of one cell (one particle per mesh element face) at regular intervals during the first RF period, then tracks these particles until they either hit a "dark" wall (no re-emission), or they accumulate at total of n impacts, where n is usually 20 to 40. Yield for each impact is tallied to determine total particle counts associated with each resonant orbit, and the set of resonant orbits are used to determine MP statistics. The code generates a single secondary with a user-specified normal velocity (usually corresponding to 2eV) following an impact (unless the E-field phase is such that it won't be lifted off the wall). The code keeps track of the SEY associated with each impact, and terminates the particle if either the aggregate yield falls below a specified threshold, or the total number of impacts for the particle reaches a specified value (at which point the particle orbit is considered "resonant"). Statistics such as counter functions are then computed by looking at all of the resonant orbits (the code track the particles for about 30-50 RF periods).

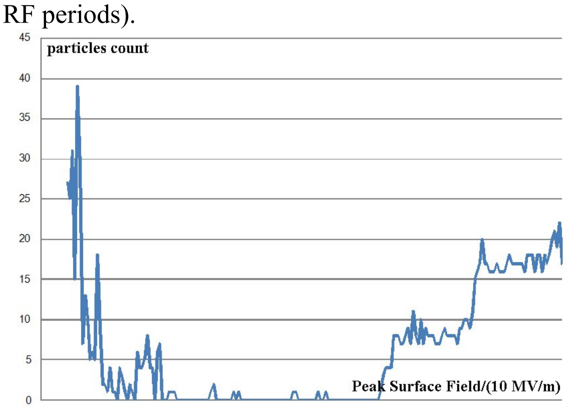

Figure 8: Number of “resonant” particles.

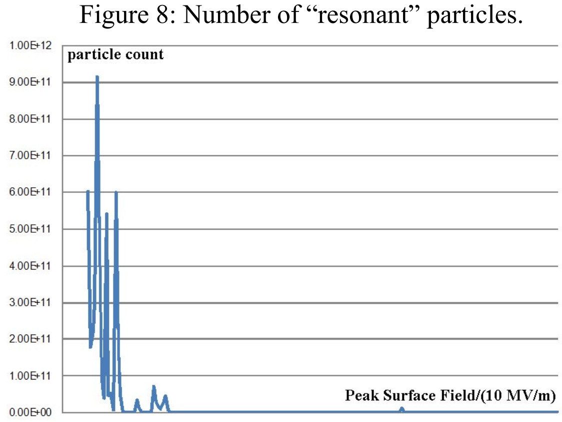

Figure 9: Total count of secondary electron yield.

The results of the simulations for the RFD are reported in Figs. 8-10. Figs. 8 and 9 show the number of “resonant” particles and the total count of secondary electron yield as a function of the maximum surface field (20 MV/m correspond to the 10 MW input power) while Fig. 10 reports the multipactors (MPs) trajectories at 1.3 MV/m peak surface field. From the plots it is possible to conclude that the bulk of the action is at low field strengths (peak field<3 MV/m). In any case there are a small number of MPs at any given field level with, typically, 2 RF periods per impact (some 3 periods). “Geometric resonances” (that have an impact yield generally less than 1 and therefore they do not generate MP effects) are found at higher field levels (peak field> 15 MV/m).

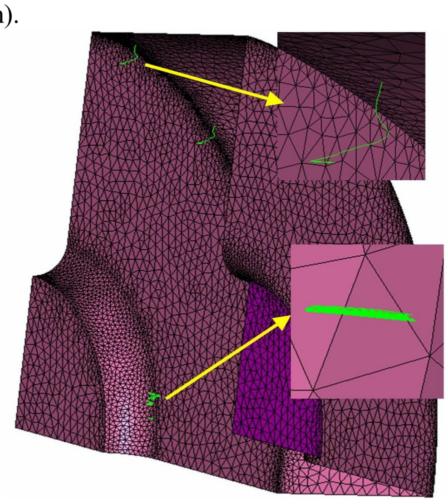

Figure 10: MPs trajectories at 1.3 MV/m peak surf. field.

CONCLUSIONS

New RF deflectors for the CTF3 Combiner Ring have been designed and constructed to suppress the vertical beam instability caused by vertical trapped modes in the previous structures. In these new devices the frequency separation between vertical and horizontal deflecting modes has been increased by modifying the rod position and special antennas have been inserted to absorb the power released by the beam to the modes. The deflectors have been made in aluminium to reduce the costs and delivery time. Low power RF tests have confirmed the expected results and the new structures have been successfully installed in the ring demonstrating the suppression of the instability itself. A multipacting analysis has also been done showing that, in this type of structures, there is a small numbers of multipactors at any given field level.

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