MODIFICATIONS TO THE PUMP OUT BOX TO LOWER THE Q_{EXT} OF DIAMOND SCRF CAVITIES

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Abstract

Diamond's CESR-B cavities are iris coupled and have fixed Q_{ext}. For reliability, the cavities are operated at 1.4 MV or less. This results in the optimum condition for beam loading being satisfied around 100 kW. For operation at 300 mA with two cavities, the RF power needed per system exceeds 200 kW. Consequently, the cavities need to be operated under-coupled. To lower the Q_{ext} and move the optimum operating point nearer to 200kW, 3 stub tuners are used in the waveguide feed line. The difference in the height of the coupling waveguide on the cavity and that of the vacuum side waveguide on the window assembly results in a step transition which affects the Q_{ext}. The present window/step location results in Q_{ext} higher than that without the window. The Q_{ext} can be lowered by re-locating the RF window or by shifting the step change in the waveguide cross-section from its present location. This needs modification to the Pump Out box. The pros and cons of the proposed modification to the pump out box in terms of standing waves and multipacting characteristics studied with CST Studio are discussed in this paper.

INTRODUCTION

The Diamond storage ring currently operates with two CESR-B type SCRF cavities. The RF voltage required for normal operation is 2.5 MV. For better reliability the cavities are operated at relatively low and unequal voltages, e.g. one of the cavities is operated at 1.1 MV and other at 1.4 MV [1]. The Q_{ext} of the cavities is much higher than that required for matched operation at lower voltage. Sometimes it has also been necessary to feed more power from the cavity operating at lower voltage during routine 300 mA run. This necessitates the lowering of the Q_{ext} and is achieved with the help of 3 stub tuners in the waveguide feed line [2].

QEXT VS STEP LOCATION

The Q_{ext} of CESR-B cavity increased from its design value of ≈ 2.0e+05 to about 2.5e+05 after connecting the RF window due to the step resulting from the difference in the height of the coupling waveguide on the cavity and that of the vacuum side waveguide on the window assembly. The Q_{ext} follows a sinusoidal pattern with period $\lambda_g/2$ following the SW pattern in the waveguide as the step location is varied [3, 4]. The points of highest Q_{ext} correspond to step locations at $n\lambda_g/2$ and the points of lowest Q_{ext} to the step locations at $(2n+1)\lambda_g/4$ from the cavity (coupling iris), where λ_g is the guide wavelength. Simulations with CST Studio [5] reveal that the minimum value of Q_{ext} that can be obtained with the window assembly is ~ 1.42e+05. Using this fact, the possibility of lowering the Q_{ext} is explored in case the cavities go for refurbishment [4].

The step location which gives lowest Q_{ext} lies quite close to the joint between the waveguide transition (where the coupling waveguide comes out of the cryostat) and the Pump Out Box (POB). To avoid practical difficulties, the step can be shifted away from the joint inside the POB without significant increase in Q_{ext}. At the location of the step, the waveguide cross-section changes from 433 x 102 mm to 457 x 140 mm symmetrically. Two geometries a) step and b) tapered transition are considered for the cross-section change. As this is exterior to the cryostat, no modification is required to the cavity or the cryostat.

SIMULATIONS WITH CST STUDIO

Table 1 lists the Q_{ext} and the power at match for original and modified POB geometries for cavity voltage V_c = 1MV. As the Q_{ext} is different in the original and the modified POB cases, the match occurs at considerably different power levels for the same cavity voltage. If the match at the same power is considered, the voltage across the cavity will be different. The penetrating Standing Wave (SW) field from the cavity into the coupling waveguide is proportional to the cavity voltage. Also, since the SW field in the rest of the waveguide and so the power dissipation in the walls and the MultiPacting (MP) characteristics will be dependent on the forward power, the cases with same Q_{ext} need to be considered. Therefore, for comparison, the case of original POB with Q_{ext} adjusted with 3 stub tuner to the same value as that of the modified POB Step is considered in place of original POB alone.

Table 1: Q_{ext} and Power for match at V_c = 1 MV

POB Geometry	Q_{ext}	P_F for match (kW)
Original	2.35e+05	47.2
Modified Step	1.44e+05	78.0
Modified Taper	1.48e+05	76.0
Original 3 Stub	1.44e+05	78.0

Results and Discussion

The cavity with the coupling waveguide, the RF window and the following waveguide WR1800 with 3 stub tuner is modelled in CST Studio FD solver [5] considering losses to calculate steady state fields at different operating conditions. During the normal 300 mA run the cavi-

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ties are operated under-coupled with some reflection with Q_{ext} adjusted with the help of 3 stub tuners. The cavity at lower voltage routinely operates with reflection coefficient |S11| ~ 0.3. To compare the two scenarios with the original and the modified POB geometries, simulations were performed for matched (S11 ~ 0) and under-coupled (S11 ~ 0.3) cases. The CST model for the modified POB Step is shown in Fig. 1.

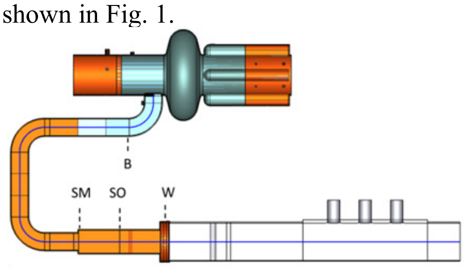

Figure 1: CST Model of the cavity with modified POB Step, the window assembly and the 3 stub tuner.

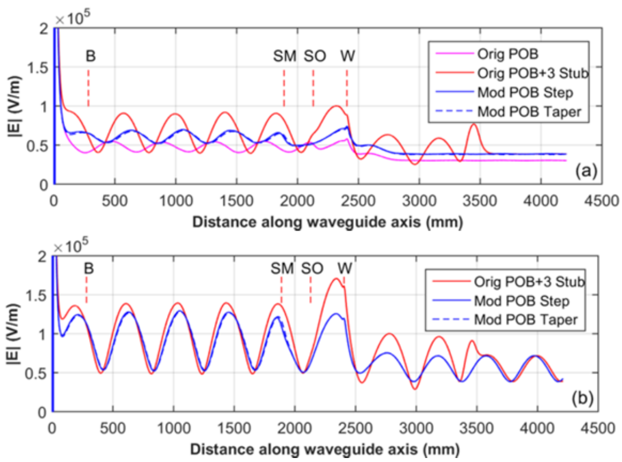

Figure 2: Electric field amplitude along the centreline of the waveguide scaled for Vc = 1 MV for different POB geometries for (a) matched condition (b) S11 = 0.3 under-coupled. See text.

Table 2: Forward and Reflected Power for Under-Coupled Operation at V_c = 1 MV and |S11| = 0.3

POB Geometry	P_{FOR} (kW)	P_{REF} (kW)
Original	97.76	8.87
Modified Step	158.95	14.3
Modified Taper	155.72	14.2
Original 3 Stub	159.20	14.3

The amplitude of electric field along the centreline (shown as blue line in Fig. 1) of the waveguide for different POB geometries is shown in Fig. 2(a) for matched and Fig. 2(b) for under-coupled |S11| = 0.3 conditions respectively. The field values are scaled for V_c = 1 MV across the cavity. The vertical dotted lines and the letters B, SM, SO and W indicate the locations of the Niobium bend, Step in the Modified POB, Step in the Original POB and the Window respectively on the curve (see Fig 1).

Matched Operation It can be observed from Fig. 2(a), that there is no SW after the window towards the generator end (right) for matched cases of original and modified POB indicating good match. A SW exists between the window (step) and the cavity for all the cases irrespective of how perfectly the cavity is matched. A higher SW in case of modified POB geometries as compared to the original POB is due to the fact that the match occurs at higher power (see Table 1). In case of the 'original POB + 3 Stub tuner', a much stronger SW exists all along the waveguide with the same amount of forward power. In particular the field in the coupling region (to the left of the dotted line B in Fig. 2) and in the window assembly (between dotted lines SO and W) is much stronger.

Under-Coupled Operation Figure 2(b) shows the SW for under-coupled operation with |S11| = 0.3. It can be noted that the SW field in case of 'original POB + 3 Stub tuner' is stronger than that of the modified POB cases for the same Q_{ext}. The field in the coupling region and in the window assembly is relatively high as compared to that of the modified POB geometries. The forward and reflected power values for different POB geometries are listed in Table 2 for V_c = 1 MV and operated with reflection coefficient |S11| = 0.3.

Multipacting Simulations MP studies are carried out to compare the modified and the original POB geometries for cavity voltage V_c ranging from 0.8 to 1.4 MV and for matched and under-coupled |S11| = 0.3 conditions. The SW fields differ in the two cases along whole of the reduced height waveguide including the window assembly. Since the major difference in the SW fields occurs in the coupling region and in the window assembly, these are considered for MP simulations for sake of comparison.

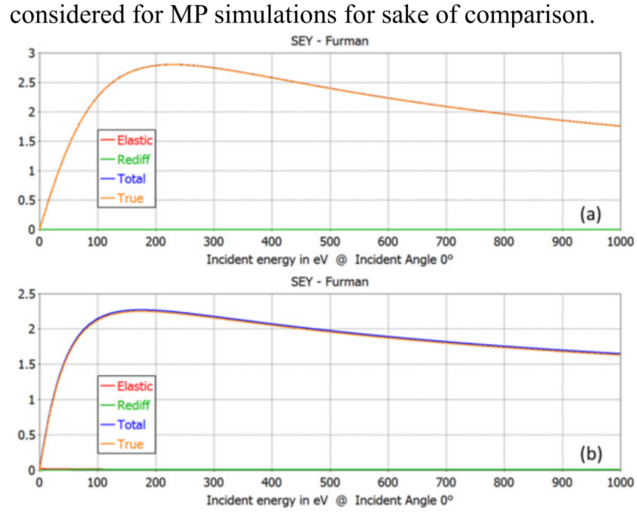

Figure 3: SEY for (a) Niobium Wet Treatment and (b) Copper for MP simulation in the coupler and in the window regions.

CST Studio PIC solver is used to simulate the MP. For computing the steady state fields, full model with complete waveguide, the window and the 3 stub tuner is used. For MP simulations in the coupling region, the built-in material in CST Studio 'SEE Niobium Wet Treatment' with Secondary Electron Yield (SEY) as shown in Fig. 3(a) is chosen. As the coupling waveguide is plated internally with copper, built in material 'SEE Copper ECSS' with SEY as shown in Fig. 3(b) is chosen for the window assembly.

Figure 4(a) shows the MP growth rate in the coupling region for (a) matched operation and (b) under-coupled |S11| = 0.3 case for V_c varied from 0.8 to 1.4 MV. The continuous lines show the growth rate for the modified POB geometry and the dashed lines for the original POB + 3 stub tuner for the same Q_{ext}. The pictures in the inset show the CST models used for PIC simulations. For matched case, the simulations were performed with space charge included. The space charge computation was switched off and a smaller model (Fig. 4(b)), without the RBT thermal transition, the fluted beam tube and the straight waveguide is considered for the under-coupled case to reduce the computation time. The number of primary electrons used was 360 and 720 in the matched and in the under-coupled case respectively. The green boxes just under the coupling iris in the pictures show the volume in which the primary electrons were released in all the cases.

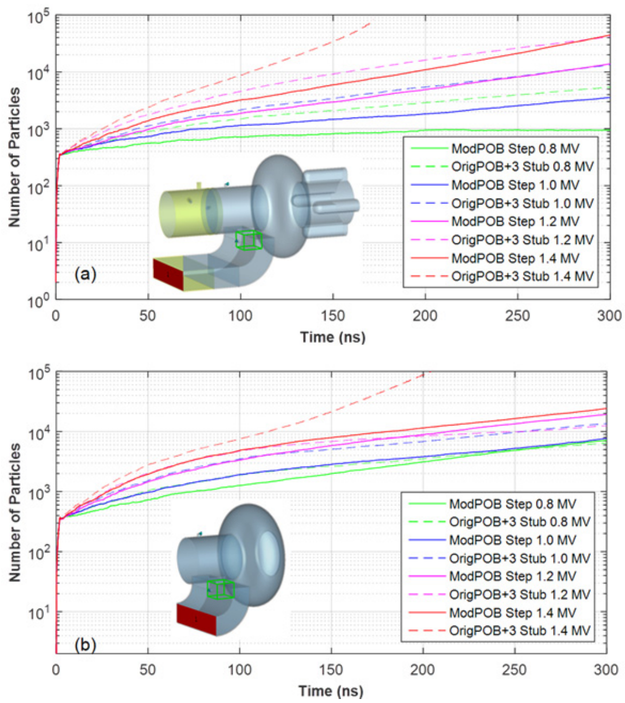

Figure 4: Number of particles vs time - the MP growth rate in the coupling region for Vc = 0.8 - 1.4 MV. Continuous lines – Modified POB Step, dotted lines Original POB + 3 Stub tuner. (a) for matched (b) under-coupled |S11| = 0.3 operation.

Figure 5 shows the MP growth rates in the window assembly for (a) the matched and (b) the under-coupled case. The continuous lines show the growth rates for the modified POB and the dashed lines for the original POB + 3 stub tuner. The picture in Fig. 5(a) shows the original and modified POB geometries.

It can be seen from Figs. 4 and 5 that the MP growth rates for the modified POB geometry are lower than those for the original POB + 3 stub tuner case commensurate with the SW fields in the respective regions.

SUMMARY

It is clear from Fig. 2 that the SW fields in case of the original POB + 3 stub tuner are much stronger all along the coupling waveguide than those in case of the modified POB for the same Q_{ext} and similar operating conditions. Especially the fields in the vicinity of the coupling iris and the RF window are relatively very high. As anticipated, the MP growth rates are higher for the original POB + 3 stub tuner case as compared to those for the modified POB.

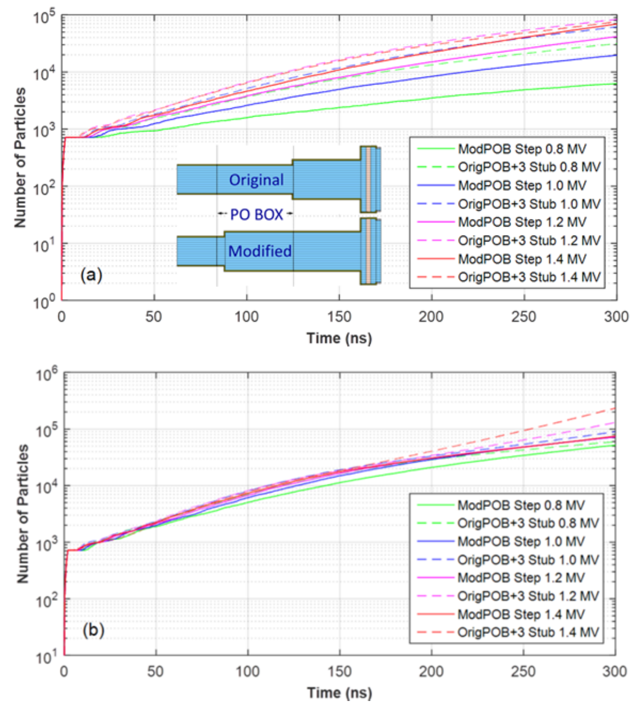

Figure 5: Number of particles vs time in the window assembly for Vc = 0.8 - 1.4 MV. Continuous lines – Modified POB Step, dotted lines Original POB + 3 Stub tuner. (a) for matched (b) under-coupled |S11| = 0.3 case.

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