ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI049

OPTIMISATION OF WINDOW POSITION ON DIAMOND SCRF CAVITIES*

S. A. Pande[1#], C. Christou, Diamond Light Source, Oxfordshire, UK
[1]Lancaster University, Lancaster, UK

Abstract

The Diamond storage ring uses CESR type superconducting cavities. These cavities have a fixed coupling resulting in fixed Q_{ext} which is considerably higher than the optimum. We use 3 stub tuners to match the cavities under these non-optimum conditions. Diamond Cavity-1 will soon be refurbished. This opportunity could be used to lower the Q_{ext} on the cavity. One of the options is to modify the coupling tongue geometry along with a matching section. This may require cutting off the beam tube with the coupler for rework or it may need to be newly fabricated. We investigated another option to lower the Q_{ext} of the cavity by optimising the location of the window with respect to the cavity, maintaining the same coupling tongue geometry. The height of the waveguide on the vacuum side of the window differs from that of the coupling waveguide on the cavity resulting in a step. The location of window with respect to the cavity makes a significant difference to the ultimate Q_{ext} obtained after putting the window in place. In this paper we present the results of our numerical simulations comparing the present and the proposed window position under different operating conditions.

INTRODUCTION

The Diamond storage ring operates with two SCRF cavities installed in the ring and one spare. The measured values of Q_{ext} for these cavities range from 2.30e+05 to 2.35e+05. For reliable operation, the cavities are operated at relatively low and unequal voltages, e.g. one of the cavities is operated at 1.2 MV and other at 1.4 MV. Sometimes it also becomes necessary to feed more power from the cavity operating at lower voltage which requires further lowering of Q_{ext}. The optimum condition for beam loading for reflection-less steady state operation changes with voltage [1]. For operation at 300 mA with the installed IDs, the power delivered to the beam by each system exceeds 200 kW which is far more than the optimum stated in ref. 1. This makes the Qext of the cavities much higher than that required for matched operation. In Figure 1, the beam power vs cavity voltage for matched operation with Q_{ext} = 2.35e+05 and required Q_{ext} vs voltage for matched operation at 300 mA are shown with blue and red lines respectively. The Q_{ext} required for voltage under 1.6 MV needs to be lower than 1.5e+05. With the help of 3 stub tuners, the Q_{ext} of individual cavities is lowered to reduce the reflected power for operation at 300 mA. Due to the limited range of 3 stub tuners, the two presently operating cavities (called Cavity-2 and Cavity-3) operate with some reflection.

Cavity-1 which was in operation since the beginning of operation in January 2007 has been taken out of service since November 2012. This cavity is scheduled for refurbishment soon. It is shown below that the Q_{ext} changes with window position relative to cavity and so we investigated the possibility of utilising this opportunity to lower the Q_{ext} without major rework on the cavity itself (e.g. enlarging the coupling iris) when it goes for refurbishment.

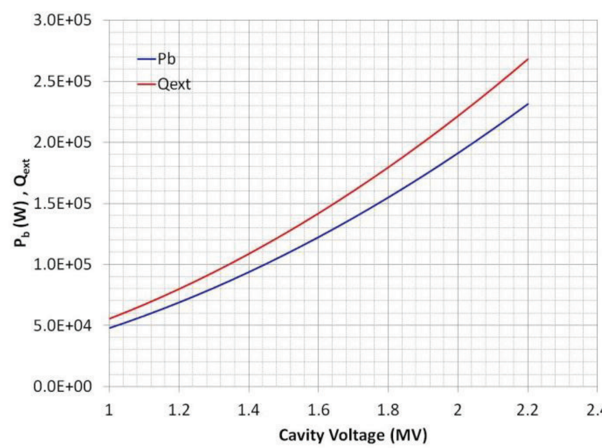

Figure 1: Beam power P_b for matched operation with Q_{ext} = 2.35e+05 (blue line) and Q_{ext} required for matched operation at 300 mA (red line) as a function of cavity voltage (assuming two cavities at the same voltage).

Q_{ext} ON CESR MODULES

The waveguide coupler of the CESR cavity was originally designed for Q_{ext} = 2.0e+05 [2]. The measured values of Q_{ext} for 7 cavities with smooth waveguides were found to vary from 1.75e+05 to 1.99e+05 rising to the range of 2.51e+05 to 2.67e+05 after connecting the waveguide. The Q_{ext} of the cavity varies with the location of the step or the window position. An equivalent circuit model was used in ref. 2 to analytically estimate the variation of Q_{ext} with the position of this step and compare the results with those obtained with MAFIA and CST Studio simulations and also using another technique.

Q_{ext} AND WINDOW POSITION

There are three major points to be considered while deciding the location of the window in the voltage Standing Wave (SW) pattern in the waveguide. These are,

#shivaji.pande@diamond.ac.uk

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI049

rf heating of the ceramic, voltage breakdown at the ceramic and multipacting near the window [3]. The variation of Q_{ext} with window position, its effect on the SW pattern and vice versa under different operating conditions has been studied with 3D Electromagnetic simulation code CST Studio [4].

Cascaded Transmission Line Model

We used a cascaded transmission line model [5] to study the variation of Q_{ext} with the position of the step. Two waveguides of different heights are represented by two transmission lines of different characteristic impedances and the junction represents the step as shown in the inset in Fig.2. The cavity of known Q_0 along with an arbitrary length of coupling waveguide is represented by impedance Z_c. The impedance transformed at the input end of TL-1 varies with the length of TL-2 which is used to calculate the reflection coefficient or Q_{ext} as shown by red curve in Fig.2.

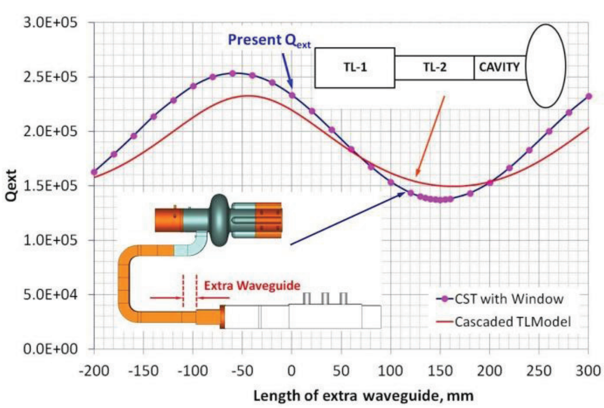

Figure 2: Variation of Q_{ext} with the extra length of short waveguide, red curve - cascaded transmission line model and blue curve - CST Studio.

CST STUDIO SIMULATIONS

Shift in Window Position

An extra length of short waveguide is introduced between the window and the short waveguide on the cavity to change the location of the window with respect to the cavity. The variation of Q_{ext} with the length of this extra waveguide as computed by CST Studio is shown in Fig. 2 by the blue curve with pink dots. Each dot represents a CST Frequency Domain solver run. It can be seen that the Q_{ext} follows a sinusoidal pattern with period $\lambda_g/2$ following the SW pattern in the waveguide. The maximum and minimum Q_{ext} values of 2.537e+05 and 1.372e+05 are obtained for extra waveguide length of -50 mm and +150 mm respectively. As our aim is to look for the window location which gives lowest Q_{ext}, the pros and cons of choosing this location are discussed below.

The two most relevant cases of operation of DLS cavities are during matched operation with beam and with full reflection during high power cavity conditioning. Figure 3 shows the electric field along the axis of the waveguide for two window locations, existing and shifted by 150 mm. The green and the purple curves represent 'Matched' (M) operation in case of the existing and shifted window location respectively. There is no SW that can be seen between the window and the waveguide on the input side but it exists between the window and the cavity due to the step in the window waveguide. The brown and the blue curves represent the 'Excessively Over-Coupled' (EOC) operation in case of existing and shifted window location respectively. This choice of window location leads to a voltage maximum near the window. This still looks acceptable as the fields during pulse processing at 3MV are well within acceptable limits (<300kV/m). From the rf heating point of view, it is acceptable to place the window anywhere in the SW pattern because the power dissipation in the window will be the same during matched operation at the design voltage and high power conditioning at twice this voltage.

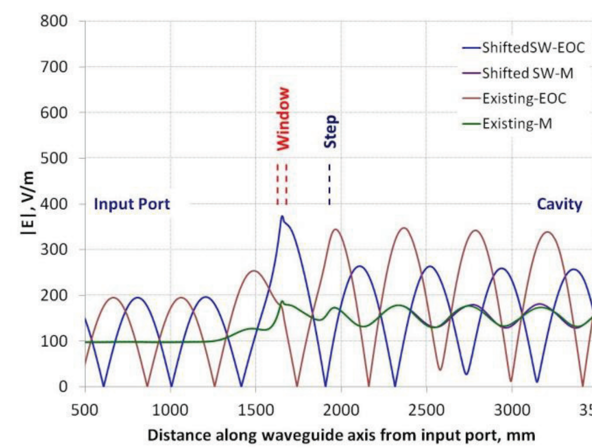

Figure 3: Electric field along the axis of the waveguide, green, purple - matched operation with existing and Shifted Short Waveguide (Shifted SW) locations respectively, brown and blue - full reflection or EOC cases. (NB: the curves are shifted to align at the window for comparison).

Shift in the Waveguide Step

The electric field along the axis of the smooth waveguide connected to an EOC and a slightly over-coupled cavity are shown by the blue and green curves respectively in Fig. 4. The location of the waveguide step (without window as shown in the inset) is varied in a few steps towards the cavity. The horizontal coordinates of the red dots denote the location of the step on the SW pattern and the corresponding Q_{ext} values are given by their vertical coordinates. The step location on an anti-node results in highest Q_{ext} and its location at a node gives the lowest Q_{ext}. Keeping the location of the window fixed at the existing position, the location of the waveguide step is varied (the length of short waveguide is decreased as the length of the window waveguide increases). If we place the step at the node in the SW pattern, it should result in lowest Q_{ext}. We can locate the window at ~$\lambda_g/2$ from the step so that the window falls at the next node in the SW

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI049

pattern. The presence of the matching posts forces the voltage minimum to be at a different location than mentioned above.

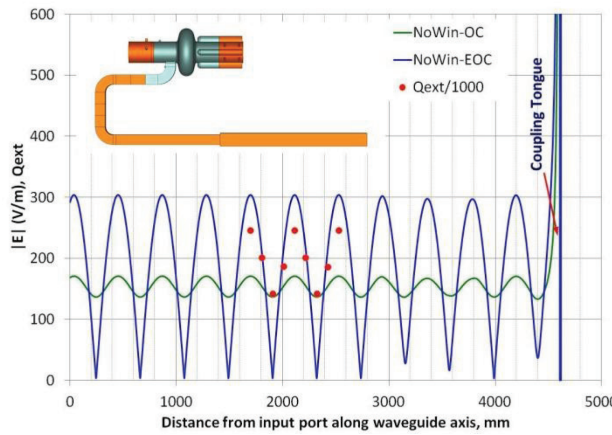

Figure 4: Voltage Standing Wave pattern of an EOC (blue) and slightly over-coupled cavity (green) connected to a smooth waveguide. The red dots denote the location of the waveguide step on horizontal axis and corresponding Q_{ext} values given by vertical axis.

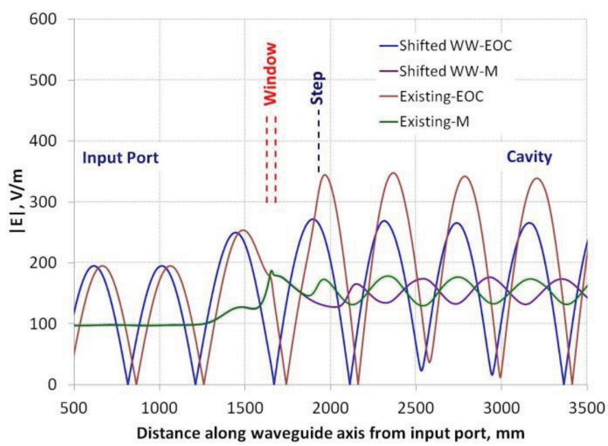

Figure 5: VSW pattern for an optimised window location.

The location of the window has been optimised to have the voltage minimum at the window. Figure 5 shows the electric field along the axis of the waveguide for matched and EOC cases by purple and blue curves respectively for this Shifted Window Waveguide (Shifted WW) case. The fields for the existing window configuration are included for comparison. Figure 6 shows sections through the window for 3 full reflection cases, existing, Shifted SW and Shifted WW cases. The table below lists the Q_{ext} values for the different cases studied compared with DLS cavities.

Table 1: Measured and Estimated Values of Q_{ext}

Measured	Existing	Shifted SW	Shifted WW
2.35e+05	2.335e+05	1.372e+05	1.458e+05

CONCLUSION

As described above, the window location on the cavity can be changed to lower the Q_{ext} for optimal operation in the Diamond storage ring. We compare only the full reflection condition as matched operation gives the same field at the window (will scale with actual power as match occurs at different power levels). Adding extra length to the short waveguide gives the lowest Q_{ext} ~ 1.372e+05. This choice leads to relatively higher electric field at the window. Even for conditioning at 3 MV, the field at the window is < 300 V/mm, which is much lower than the breakdown limit. The second choice is extending the vacuum side window waveguide towards the cavity replacing part of the short waveguide and re-locating the window at the voltage minimum. This choice is very attractive for power loss, breakdown and multipacting at the window during conditioning. But the window will see high power only during matched operation and so it will be difficult to process or condition the widow itself. Placing the window at the voltage minimum makes a voltage maximum at the matching posts which might be a favourable condition for multipacting at the matching posts. Detailed multipacting simulation needs to be performed for these geometries to look into the merits and demerits of each.

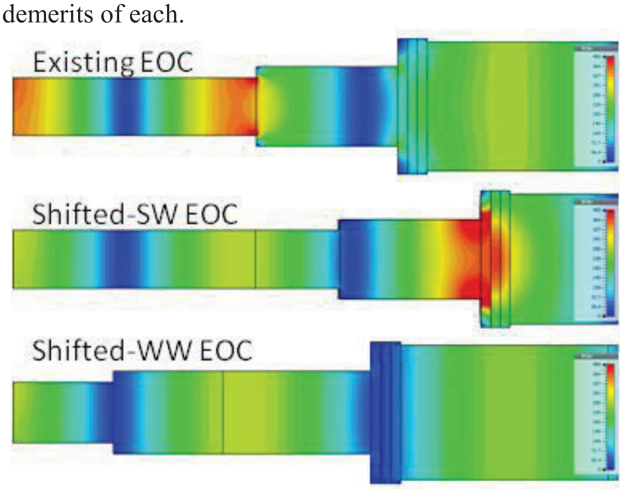

Figure 6: |E| near window for existing, the Shifted SW and Shifted WW cases under full reflection. The colour ramp maximum is 400 V/m in each case.

REFERENCES

[1] P. B. Wilson, SLAC-Pub-2884, Feb. 1982.
[2] V. Shemelin and S. Belomestnykh, Calculation of the B-cell cavity external Q with MAFIA and Microwave Studio, *Report SRF020620-03*, LNS, Cornell University, Ithaca, NY 14853.
[3] H. Padamsee, et. al., *RF Superconductivity for Accelerators*, John Wiley & Sons, Inc. New York, 1998), 411.
[4] CST Studio suite, CST AG, www.cst.com
[5] S. Ramo, J.R. Whinnery, T. Van Duzer, *Fields and Waves in Communication Electronics*, (John Wiley & Sons, Inc. New York, 1993), 244.