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DESIGN AND OPTIMISATION OF BUTTON BEAM POSITION MONITOR FOR SPS-II STORAGE RING*

MOPP29

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ABSTRACT

The Beam Position Monitors (BPMs) for the new Thailand synchrotron light source, Siam Photon Source II (SPS-II), has been designed utilizing as the essential tool for diagnosing the position of the beam in the storage ring. Its design with four-button type BPM has been optimized to obtain the high precision of position data in normal closed orbit and feedback mode as well as turn by turn information. We calculate feedthroughs capacitance, sensitivities, induced power on a 50Ω load, and intrinsic resolution by using Matlab GUI developed by ALBA, to find the appropriate position, thickness, and gap of the BPM button. Extensive simulation with the electromagnetic simulation tool CST Particle Studio was also performed to investigate the dependence of the induced BPM signal, wakefield, Time Domain Reflectometry (TDR), and power loss on different BPM geometry.

INTRODUCTION

Four-button pick up electrodes have designed for a stable and precise beam position monitor in the SPS-II storage ring. They are an essential part to provide information about the position of the beam in the vacuum chamber during machine commissioning, beam tuning and routine operation. The preliminary design of the button electrode is performed by using ALBA/DIAMOND Matlab tool [1]. The button diameter, thickness and the gap between button and chamber wall are necessary to optimize for archiving low power losses, high signal transmission, Time Domain Reflectometry (TDR), Thermal transferring and proper impedance matching. These simulations are performed by using simulation packages in CST Studio Suite. [2]. The model was used in the simulation shown in Fig. 1.

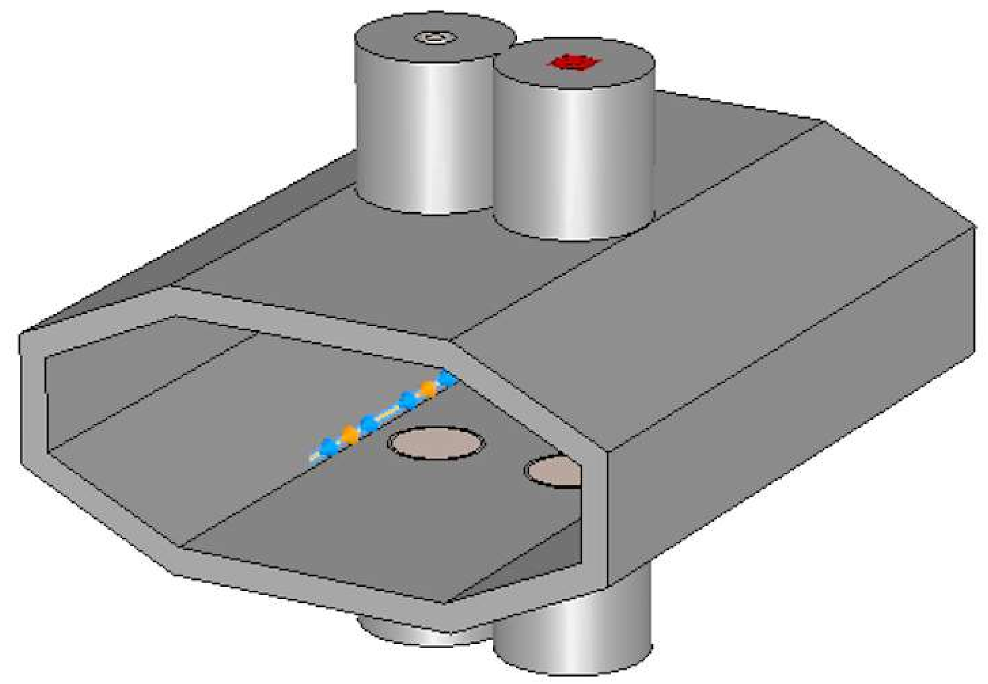

Figure 1: Simulation model of SPS-II storage ring BPM.

GENERAL CONSIDERATION OF BPM BUTTON

The BPM chamber have been modelled based on standard storage ring vacuum chamber which designed as an octagonal shape with a vertical inner aperture of 16 mm, a horizontal inner aperture of 40 mm and side of 6.6 mm. In order to achieve a sufficient induced power, sensi-tivity, and mechanical limitation of the storage ring vacuum chamber the BPM button diameter is considered to be 6 mm. The gap size between button electrode and housing should be smallest as possible as a mechanical limitation, to increase the button capacitance and shifts the high order modes (HOM) resonances to higher fre-quencies. The trapped HOMs can be caused beam instabilities and will leak inside the button when the button thickness is too thin. To avoid this issue, we con-sider increasing the button thickness to be 4 mm.

Optimization of BPM buttons separations and Impedance matching

We have calculated the sensitivity with different horizontal button separation from 10 mm to 12 mm to determine the proper horizontal button separation. The result is shown in Fig 2. The horizontal button separation of 10.5 mm is chosen that both sensitivity Sx and Sy are approximately the same at 0.134. Diameter of ceramic, pin and feedthrough are optimized by using Eq.1. The matching gives us the diameter of feedthrough, pin and ceramic diameter is 2.764 mm, 1.2 and 6.6 mm, respectively.

$$Z_0 = \frac{1}{2\pi\varepsilon_0 c}\cdot\sqrt{\frac{1}{\varepsilon_r}}\cdot\ln\left(\frac{D}{d}\right) \qquad (1)$$

where Z_0 is characteristic impedance in Ω, ε_0 is vacuum permittivity, ε_r is relative permittivity of the dielectric, c is the speed of light, D is inner diameter of the outer conductor and d is diameter of the inner conductor.

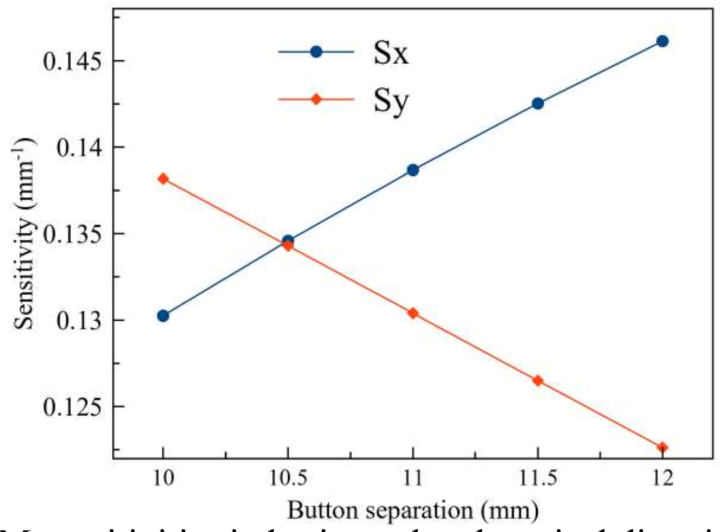

Figure 2: BPM sensitivities in horizontal and vertical direction as a function of horizontal button separation.

SIMULATION OF BPM BUTTON SIGNAL

The SPS-II button geometry as shown in Fig. 3 is based on button geometry implemented at ALBA [6]. The BPM housing and chamber are made of stainless steel 316L. The BPM button and central conductor are made of Molybdenum and form the central pin of a reverse-polarity female SMA connector. An insulator is located between the central conductor and the outer conductor for electric insulation and vacuum shielding and is made of aluminium oxide (Al_2O_3). There is an insert step button and an upper ceramic gap in the button structure which use to improve the time signal and shift HOM inside the button. To check the BPM performance, we have simulated RF characteristics on the BPM button pick up electrodes such as induced voltage signal, wake impedance, Time Domain Reflectometry and power loss by using CST CST Studio Suite with three simulation packages consists of Wakefield solver, Time domain solver, and Thermal and Mechanics. The BPM model as shown in Fig. 1 and Fig 3 are used in the CST simulation.

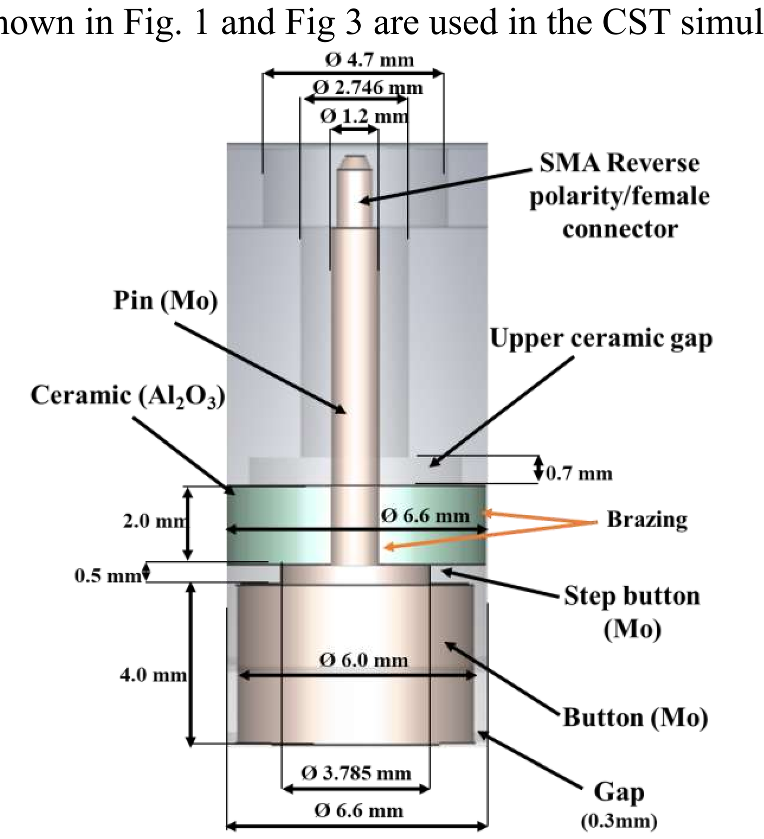

Figure 3: The designed BPM button electrode for the SPS-II storage ring.

Simulation results

An induced voltage signal for a single bunch electron beam obtained from Wakefield simulation package in the CST Particle Studio is shown in Fig. 4. A signal waveform with bunch length 4 mm and 7.48 mm are also plotted for comparison. For the 2 mm thickness ceramics, the first trapped mode arises at frequency 13.49 Hz, compared to the 1 and 1.5 mm thickness ceramics with arising at frequency 14.30 Hz and 13.87 Hz, respectively as shown in Fig. 5. This suggests that the small ceramic thickness should be chosen for shifting the first trapped mode to a higher frequency. TDR curve obtained by CST Time domain simulation is shown in Fig. 6. It can be seen a slightly mismatching in ceramic position at a time of 0.16 ns when the ceramic thickness is increased. While adjusting the thickness of upper ceramic gap does not affect the TDR curve.

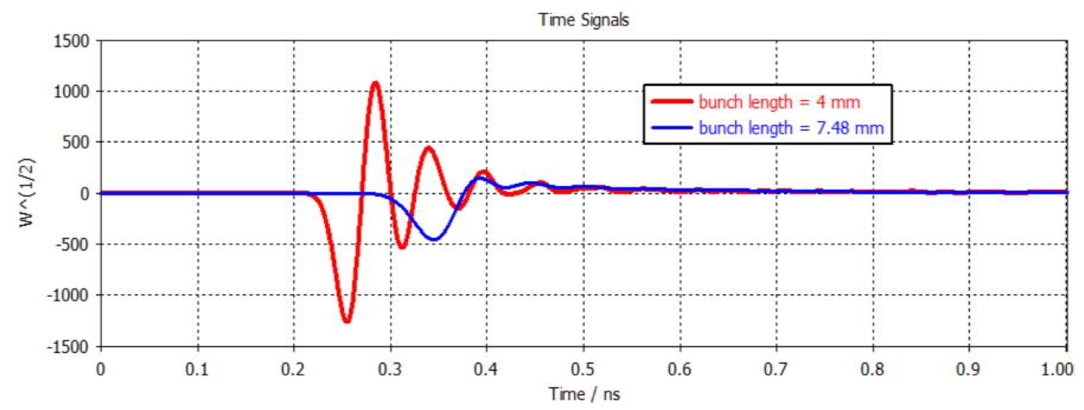

Figure 4: Simulation result of induced voltage signal of BPM button as a function of time with different bunch length.

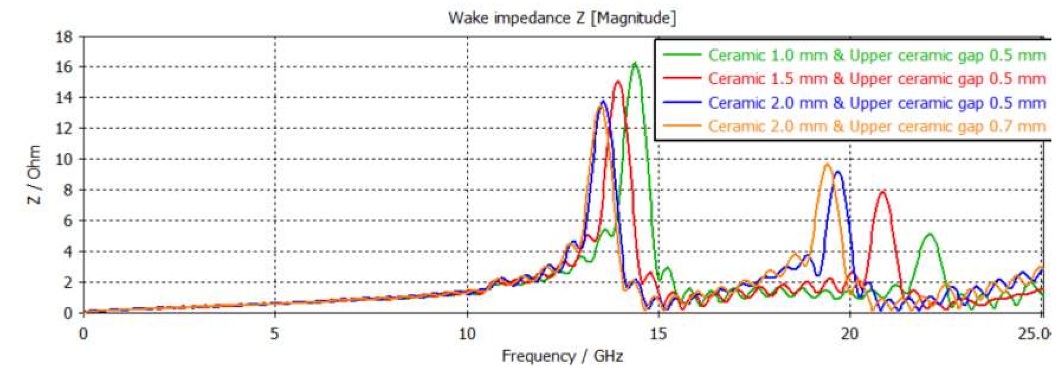

Figure 5: Simulation result of longitudinal wake impedance as a function of frequency with different ceramic thickness and upper ceramic gap thickness.

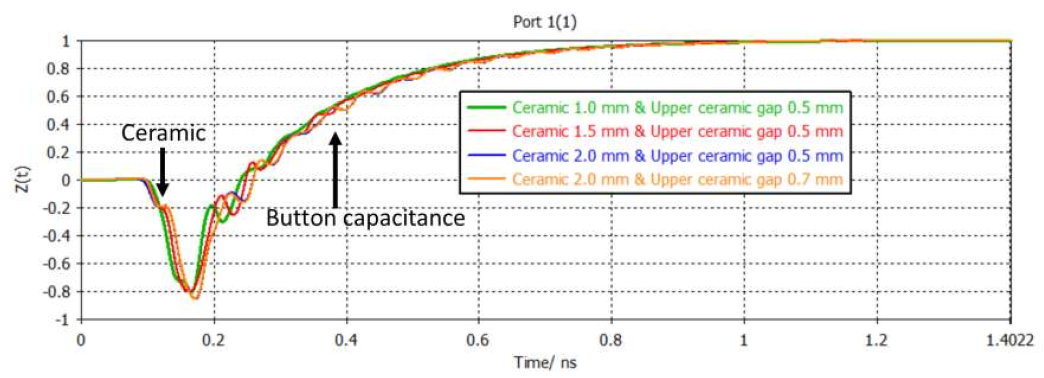

Figure 6: TDR simulation result.

Power loss

The calculation results for bunch length (σ) of 4 mm and 7.48 mm are also shown for comparison. The power loss is found at 1 to 7 Watt, for σ = 7.48 mm and 4 mm respectively, at I_{av} = 300 mA in M =140 bunches and 1.2 µs revolution period. Wake loss factor increases slightly when the thickness of the ceramic is increased. The power loss (P_{loss}) depends on the wake loss factor and bunch parameters, which can be defined as

$$P_{loss} = T_0\frac{I_{av}^2}{M}\kappa_{loss} \qquad (2)$$

where I_{av} is the total average current, T_0 is the revolution period, and M is the number of bunches.

THERMAL ANALYSIS OF BPM BUTTON

Thermal simulation of heat transfer for three different ceramic thicknesses was calculated by CST Thermal and Mechanics module. In the simulation, an ambient temperature of 30 °C and one watt heat source are applied to each button as a worst-case. The simulation results are shown in Fig. 7. It can be seen that increasing the ceramic thickness reduces the temperature difference between Button and Pin ($\Delta T = T_{button}-T_{pin}$). The greatest temperature difference (ΔT= 2.24 °C) is found on the BPM structure with 2.0 mm ceramic thickness. This is mainly due to the larger contact area between the button and ceramics.

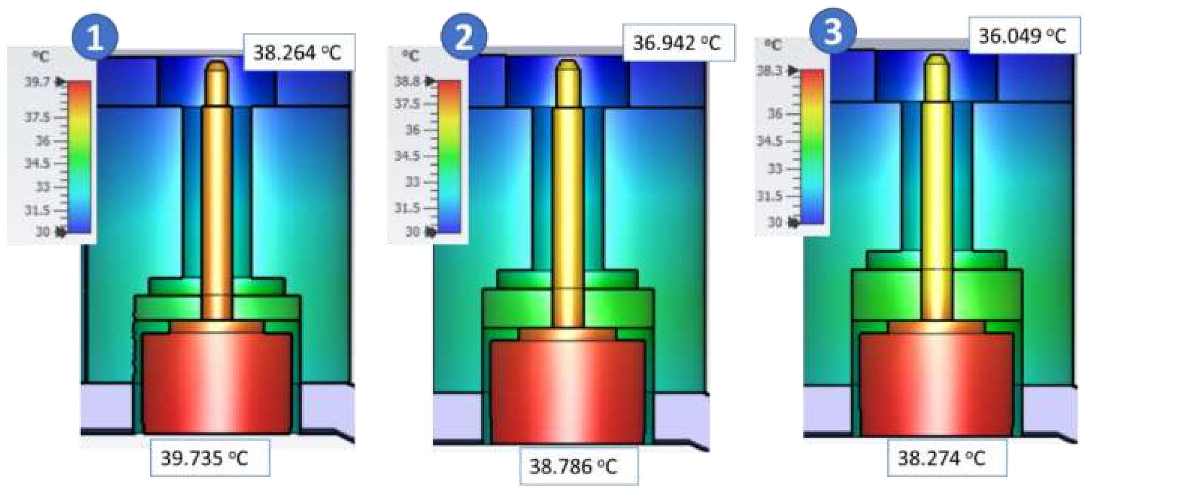

Figure 7: Thermostatic results for: 1) Ceramic thickness 1 mm 2) Ceramic thickness 1.5 mm 3) Ceramic thickness 2 mm.

CONCLUSION

The SPS-II BPM is composed of the four-button pick up electrodes and the 50-Ω-matched SMA-type feedthrough mouthed on the octagon chamber. The button diameter, the button gap, and the horizontal separations of the buttons are designed as 6 mm, 0.3 mm, and 10.5 mm, respectively. This BPM design is sufficient to obtain 100 nm position resolution at 100 mA and 2 kHz bandwidth. In order to verify the BPM performance, the RF characteristics together with the thermal analysis on the BPM button are also performed by using the simulation packages in CST Studio Suite. The BPM capacitance, sensitivities obtained from CST simulation is in good agreement with the value calculated by the Matlab tool. The effect of different bunch lengths and different BPM button geometry on the induced voltage signal, wake impedance, wake loss, TDR and heat transfer have been analyzed. It was found that these parameters need to be optimized together in order to determine the proper BPM geometry. Manufacturing of the SPS-II BPM button prototypes will be performed by choosing the BPM structure with the ceramic thickness of 1.5 mm and the upper gap thickness of 0.5 mm.

ACKNOWLEDGEMENTS

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REFERANCE

[1] A. Olmos, F. Pérez, and G. Rehm, "Matlab code for BPM button geometry computation", in InProc. 8th Eu-ropean Workshop on Beam Diagnostics and Instrumenta-tion for Particle Accelerators (DIPAC'07), Venice, Italy, May 2007, paper TUPC19, pp. 186-188, doi:10.1.1.611.4846
[2] CST, http://www.cst.com/.
[3] AL-BA, http://www.cells.es/Divisions/Accelerators/RF_Diagnostics/Diagnostics/OrbitPosition/BlocksAndButtons/SR/.

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