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DESIGN OF BUTTON BEAM POSITION MONITOR FOR THE ILSF BOOSTER

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Abstract

The Iranian Light Source Facility Booster is under design with a 504 m circumference and will accelerate the electron bunches from 150 MeV to 3 GeV. The 50 button-type beam position monitors (BPMs) are considered the non-destructive tools to measure the beam position in the ILSF booster. In this paper, the design of the BPM for the ILSF booster is studied. The BPM blocks have 4 buttons (electrodes) that are placed at 45 degrees to the beam axis. to choose the best geometry, The BPMs with different button diameters and gaps are simulated by the CST Microwave Studio and BpmLab.

INTRODUCTION

The button beam position monitors are non-destructive and are the main beam diagnostics tools used to define and measure the beam position in all synchrotrons. For the ILSF booster, fifty BPMs have been considered to monitor and determine the beam position. Each BPM blocks consist of four identical buttons (electrodes), positioned at 45 degrees relative to the beam axis inside the vacuum chamber. These four electrodes are isolated using ceramic material, specifically alumina, which also prevents vacuum leakage. This system is designed to match the 50 Ω impedance of the coaxial feed-through cables.

As the beam passes through the vacuum chamber, an image charge is induced on the electrodes. By measuring the induced voltage (U) on every electrode, one can obtain the beam position in the horizontal and vertical plane via the following formulas [1]:

$$x = \frac{1}{S_x}\frac{U_{right}-U_{left}}{U_{right}+U_{left}} = \frac{1}{S_x}\frac{\Delta U_x}{\sum U_x} \quad (1)$$

$$y = \frac{1}{S_y}\frac{U_{up}-U_{down}}{U_{up}+U_{down}} = \frac{1}{S_y}\frac{\Delta U_y}{\sum U_y}.$$

In this paper the BPMs with different electrode diameters and thicknesses, upper gaps and gap between the electrodes and housing (gap side) are simulated by the CST Microwave Studio and BpmLab to compare and choose the best design.

DESIGN

In this design, four electrodes are placed at 45, 135, 225, and 315 degrees in the housing that has the same diameter as the booster vacuum chamber (diameter=33 mm) (see Figs. 1 and 2).

At first, four different button diameters were considered for the electrodes [1]. The BPMlab software with delta over sum approach was used to calculate the position detection and BPM sensitivity (see Figs. 3 and 4) [2].

The button capacitance is given by:

$$C_b = \frac{2\pi\varepsilon_0 t}{\ln(\frac{d+g}{d})} \quad (2)$$

where d is electrode diameter, t is button thickness and g is the upper gap.

The monitor constant given by:

$$k_{x,y}(mm) = \frac{1}{S_{x,y}(0,0)} \quad (3)$$

where $S_{x,y}(0,0)$ is the proportional constant when the beam is in the center of the chamber (see Table 2).

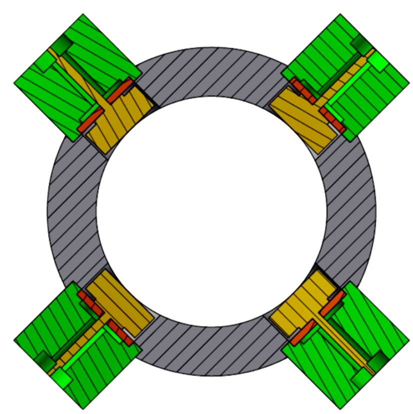

Figure 1: Overview of four button installed in the booster.

Table 1: Design of Button BPM for the ILSF Booster with Different Button Diameter

Geometry	Design			
	A	B	C	D
Button diameter(mm)	5	7	10	13
Button thickness (mm)	4	4	4	4
side gap (mm)	0.3	0.3	0.3	0.3
upper gap (mm)	0.5	0.5	0.5	0.5
button capacitance (pF)	1.963	2.707	3.823	4.934

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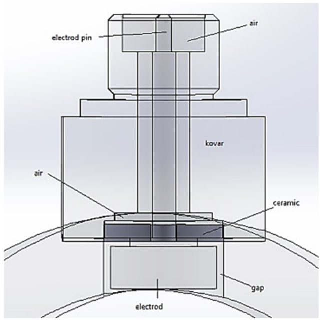

Figure 2: Overview of a button BPM.

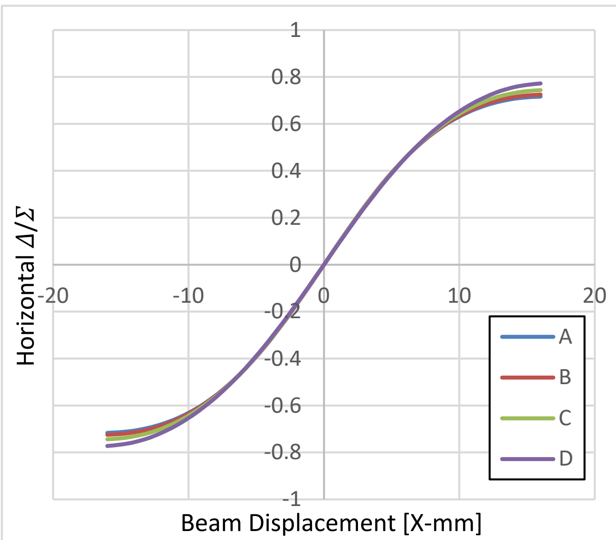

Figure 3: Position detection and BPM sensitivity by BPMlab.

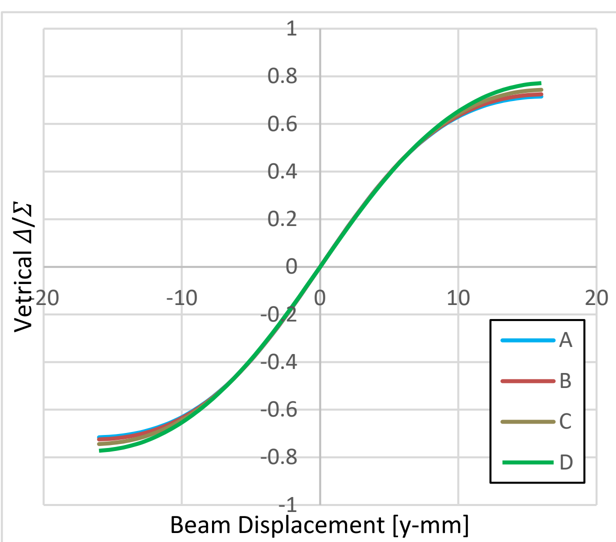

Figure 4: Position detection and BPM sensitivity by BPMlab.

Table 2: Design of Button BPM for the ILSF Booster with Different Proportional Constants

Design	A	B	C	D
$S_x(0{,}0)[\frac{1}{mm}]$	0.0842	0.0838	0.0832	0.0823
$S_y(0{,}0)[\frac{1}{mm}]$	0.0841	0.0838	0.0830	0.0822
$K_x(0{,}0)[mm]$	11.870	11.924	12.006	12.45
$K_y(0{,}0)[mm]$	11.880	11.919	12.014	12.456

Based on the results obtained from the Bpmlab software, it was observed that, due to the circular structure of the vacuum chamber and the symmetry of the electrodes, the spatial sensitivity in both horizontal and vertical directions for the mentioned designs is very close within the 4*4 beam range. All four designs exhibit a linear response, making it difficult to distinguish significant differences between them. Consequently, another method was employed for simulation and comparison – CST software was used to select the optimal geometry. Although the wakefield problem is not important in the booster, it helped in identifying the best design (see Fig. 5, Fig. 6, and Fig. 7) [3].

Since Design (A) has a small button diameter, it was disregarded. This is because a larger button diameter results in a greater sensitive area, leading to a better spatial response.

The chamber and electrode housing material are considered to be 316LN, the electrode material is molybdenum, and the ceramic is alumina.

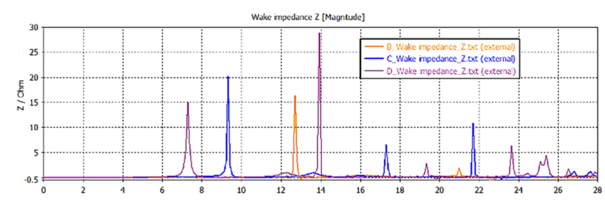

Figure 5: Longitudinal wake Impedance for button BPM with Table 1 parameters.

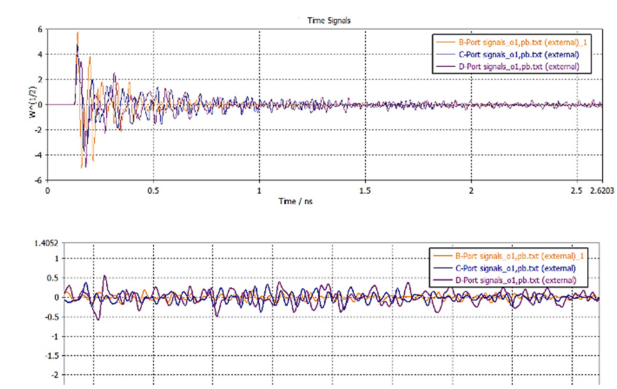

Figure 6: Port signal for button BPM with Table 1 parameters.

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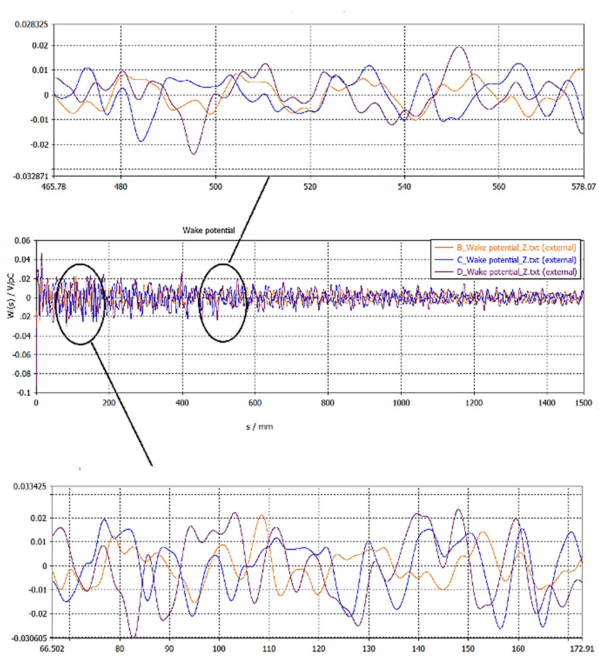

Figure 7: Wake potential for button BPM with Table 1 parameters.

Although the wakefield effect in the booster is not of primary importance, based on the results, it can be said that Design C is suitable due to its geometric parameters, such as button diameter, its capacitive value, and wakefield diagrams.

Three different button thicknesses were considered for the electrodes to evaluate the effect of thickness on the design (see Table 3).

Table 3: Design of Button BPM for the ILSF Booster with Different Button Thicknesses

Geometry	**Design**		
	C	**C2**	**C3**
Button diameter(mm)	10	10	10
Button thickness (mm)	4	3	5
side gap (mm)	0.3	0.3	0.3
upper gap (mm)	0.5	0.5	0.5
button capacitance (pF)	3.823	2.864	4.773

Additionally, four different side gaps were considered to examine their impact on the design (see Table 4).

Table 4: Design of Button BPM for the ILSF Booster with Different Side Gaps

Geometry	**Design**			
	C	**C4**	**C5**	**C6**
Button diameter(mm)	10	10	10	10
Button thickness (mm)	4	4	4	4
side gap (mm)	0.3	0.2	0.4	0.5
upper gap (mm)	0.5	0.5	0.5	0.5
button capacitance (pF)	3.823	5.673	2.891	2.334

CONCLUSION

The greater the thickness of the button, the higher the capacitance, and consequently, the lower the losses. The larger the radius, the higher the sensitivity. The smaller the gap, the lesser the effects related to HOM (higher capacitance and lower losses).

According to the mentioned points and the results of calculations and simulations, Design (C) is the chosen design for the ILSF booster (see Fig. 8).

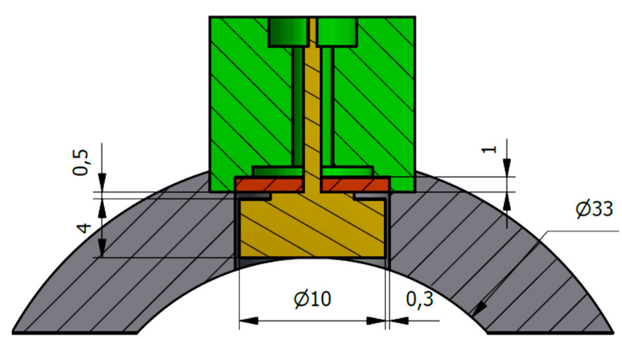

Figure 8: Button BPM for the ILSF booster.

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