Development of High-Precision Beam Position Monitor for the Korean 4GSR Project

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Abstract

The Korean 4GSR project is currently under construction in Ochang, South Korea, with the aim of achieving first beam commissioning in 2027. Designed to achieve an emittance approximately 100 times smaller than that of third-generation synchrotron radiation storage rings, the project requires the development of several high-precision beam diagnostic devices. In particular, the beam position monitor (BPM) is aimed at reducing longitudinal wake impedance to suppress heating and beam instability. This paper discusses the development of two types of 4GSR BPM pick-up antennas: one utilizing a SiO2 glass insula-tor and another designed in a cone shape using Al2O3. We will also describe the performance of these designs through beam tests. Additionally, this paper provides an overview of the current development status of the BPM system for the 4GSR project.

Development of 4GSR BPM pick-up

Two types of BPM pick-up antennas have been developed for the 4GSR project. The first type utilizes a SiO2 glass insulator, providing excellent thermal and mechanical stability, essential for minimizing noise and ensuring accurate beam position measurements. The second type is a cone-shaped design using Al2O3, which offers a higher mechanical strength and low wake impedance in BPM. These designs have been optimized through extensive simulations to ensure the highest possible resolution and accuracy in beam position monitoring. The SiO2 BPM is constructed with molybdenum pins and a SiO2 glass insulator with a dielectric constant of 4, housed in ASTM-F15 material. In contrast, the Al2O3 BPM features titanium pins and a ceramic disc with a dielectric constant of 9.9, enclosed in an SUS316 stainless steel housing.

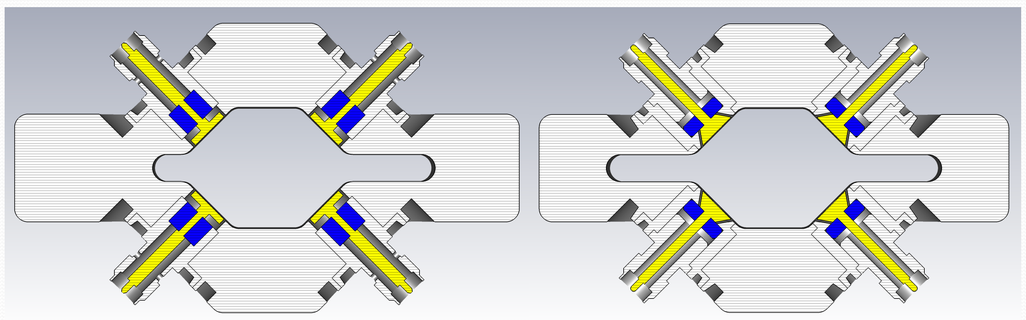


Fig. 1: Development strategy of 4GSR BPM pick-up antennas. SiO_2 glass BPM(left) & $Al2O_3$ BPM(right).

TDR measurement of 4GSR BPM pick-up

A prototype batch of 50 SiO2 antennas and 25 Al2O3 antennas for the 4GSR BPM has been produced, and TDR measurements were conducted on all prototypes (see Figure 2). The TDR measurements were performed using a Keysight N9951B and an Anritsu MS46122A. Figure 2 shows the simulation and measurement results of the TDR for both types of BPM pick-up antennas.

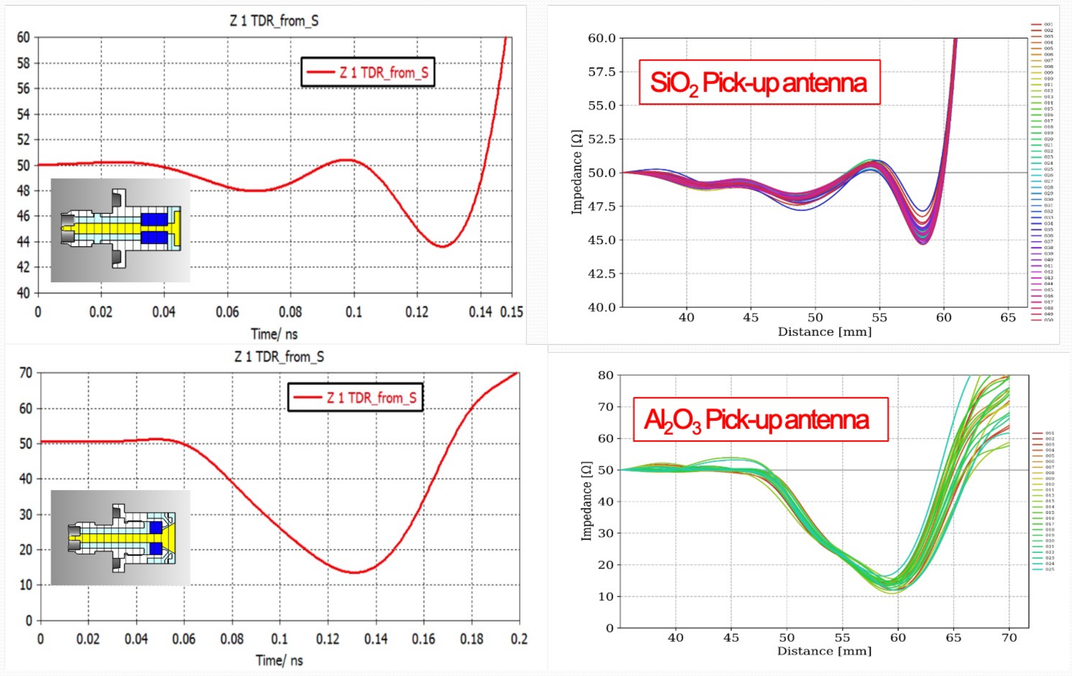
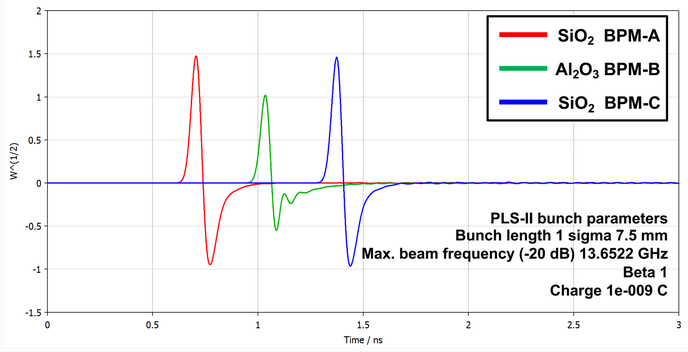


Fig. 2: A proto-type of 4GSR BPM pick-up time domain reflection measurements results.

Test BPM for beam test @ PLS-II storage ring

Table 1: Comparison of Beam Parameters of 3rd & 4th Generation Storage Ring

Parameters [unit]	3rd Gen. Storage ring	4th Gen. Storage ring
Energy [GeV]	3	4
Circumference [m]	281.82	799.297
Beam current [mA]	300 or 400	400
Harmonic number	470	1332
Nat. emittance [pm.rad]	5800	62.20
Bunch length rms [ps]	20	13.54/54.15
BPM vac. chamber [mm]	66/22 (H/V)	24/18 (H/V)
Number of BPM	96	280



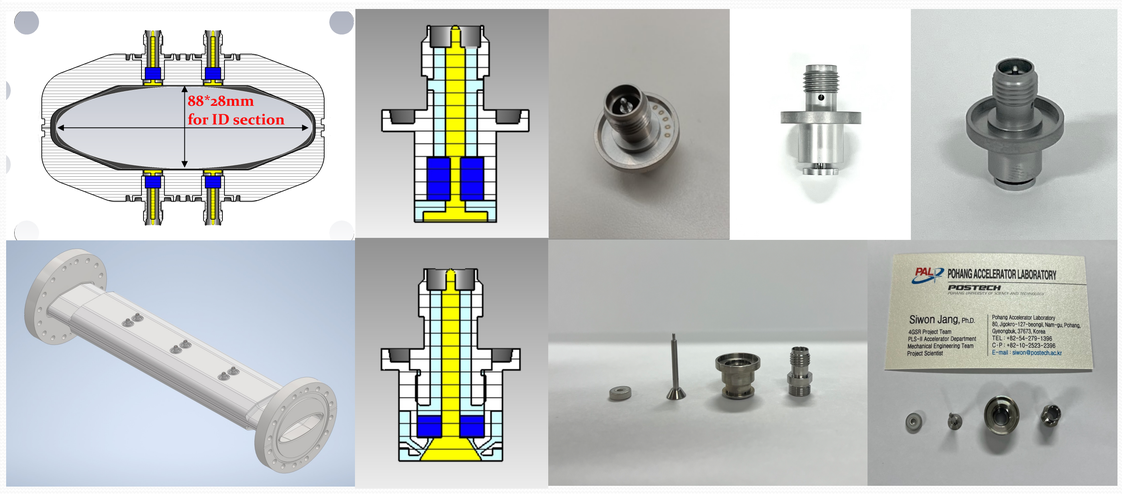


Fig. 3: 3D simulation and fabrication of Test BPM for the beam test at PLS-II storage ring.

Beam test results of Test BPM for 4GSR BPM

To evaluate the performance of the 4GSR BPM, test BPMs were installed in the ID straight section of Cell 7 in the PLS-II storage ring at the Pohang Accelerator Laboratory. A total of three BPM pick-ups were mounted on the test BPM, with SiO2 pick-ups placed on both sides and an Al2O3 BPM placed in the center. The output signals from the BPMs, with a 16 GHz bandwidth, were observed without loss using a high-performance oscilloscope with a 50 GS/s sampling rate. Turn-by-turn data for beam position resolution measurements were acquired using I-Tech's Libera Brilliance+ system.

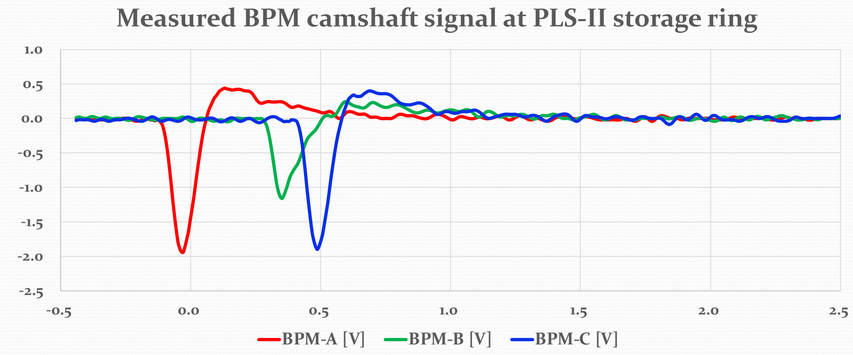


Fig. 4: A measured raw BPM signal with test BPM at the PLS-II storage ring.

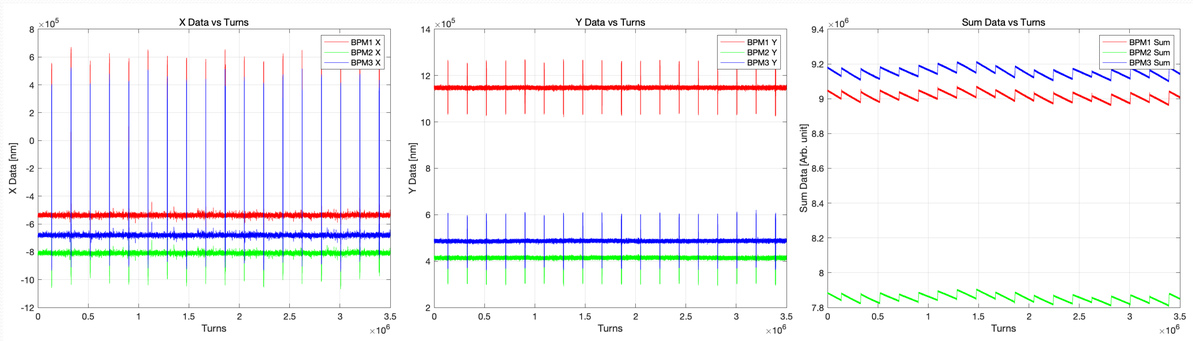


Fig. 5: A measured Turn by Turn BPM data with 3.5 million turns by using LB+.

- BPM-AX (predict) = α1·BPM-AY+α2·BPM-BX+α3·BPM BY+α4·BPM-CX+α5·BPM-CY +α6·BPM-A_SUM+α7· BPM-B_SUM +α8· BPM-C_SUM
- Residual = BPM-AX(meas.) - BPM-AX (predict.)
- BPM resolution = RMS of residual x Geo. factor

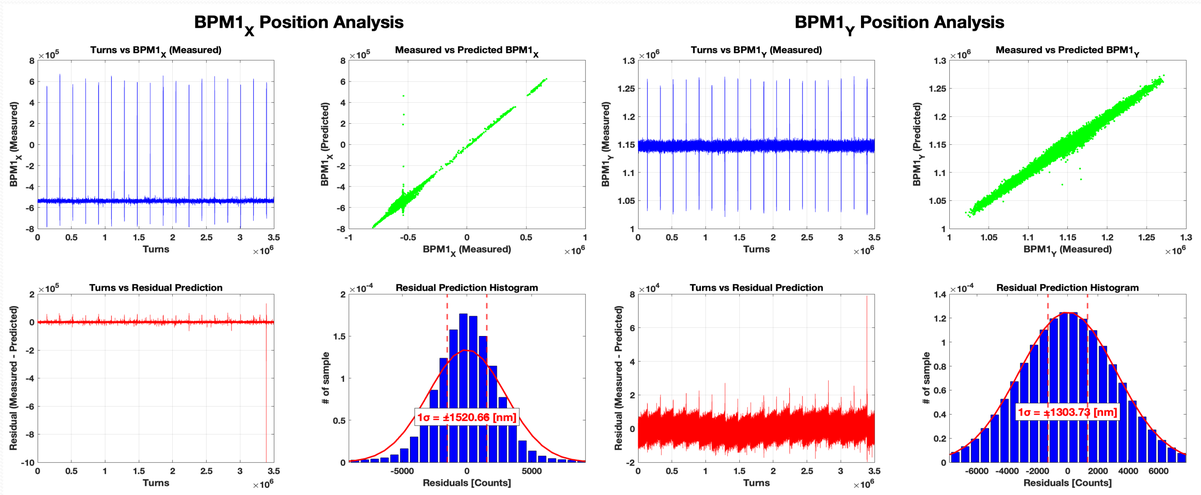


Fig. 6: A measured BPM-A resolution with 3.5 million TbT data by using LB+.

Table 2: A measured Three BPM resolution results.

TbT resol.	BPM-A	BPM-B	BPM-C
X-port	1.52 um	2.70 um	1.50 um
Y-port	1.30 um	2.16 um	1.08 um

CONCLUSION

The Korean 4GSR project in Ochang is currently under construction with the goal of completion by 2027. We developed a prototype of the pick-up antenna for the 4GSR BPM and performed TDR measurements and beam position resolution tests at the PLS-II storage ring using a test BPM chamber designed for this purpose. By utilizing turn-by-turn data, we measured beam position resolutions ranging from approximately 1 to 3 micrometers. Based on the results of the beam test, we will finalize the design of the 4GSR BPM's pick-up antenna and aim to start mass production, targeting completion by 2027.

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