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A TEST BENCH FOR 324 MHz RF DEFLECTORS USED IN BUNCH SHAPE MONITORS FOR CSNS-II LINAC UPGRADE*

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Abstract

Bunch shape monitors based on the transverse modulation of low energy secondary emission electrons, will be used in the measurement of longitudinal beam density distribution in the upgrade of CSNS-II linac. A test bench for commissioning the 324 MHz RF deflectors used in BSM has been built in the laboratory, which consists of a Kimball E-gun, a vacuum chamber for electron optics, an RF stimulator, a 324 MHz RF power source, HV power supplies, a bending magnet and a set of MCP+Screen+camera+DAQ. This paper gives the design consideration, some results of the test bench and the continuing CST design of a λ/2 RF deflector.

INTRODUCTION

China Spallation Neutron Source (CSNS) is the first pulsed neutron source built in China [1]. Now its upgrade project CSNS-II has been started this year. Two Feschenko-type bunch shape monitors (BSM) are planned to be installed at the 324 MHz and 648 MHz sections of superconducting cavities [2], due to the longitudinal bunch widths at the BSM installation point will be as small as 2.77° and 1.05° separately [3]. BSM can be used to explore longitudinal beam dynamics, evaluation of longitudinal emittance, estimation of longitudinal beam halo, longitudinal beam matching etc. Using of BSM at the exit of accelerator enables to estimate a beam quality for further use [4-7].

A prototype 325 MHz RF deflector has been fabricated for the longitudinal bunch shape measurement in C-ADS. As the installation space of C-ADS is so limited, the prototype is assumed to be tested at the CSNS campus. Before the new BSM is installed in the tunnel of CSNS linac, it also needs to be tested in the lab. Therefore, a test bench was built up for both the prototype RF deflector and the new designed one.

BSM TEST BENCH SETUP

A Kimball EMG-4212/EGPS-4212 source produces a pulsed 10keV electron beam to mimic the secondary emission electrons from the tungsten wire bombarded by H- ions. The electron beam travels through a collimating slit, a 324 MHz RF deflector and a 50 cm-long vacuum chamber, then hits a YAG:Ce screen. There is a camera installed vertically right above the view port of the screen. The 3D drawing of the test bench is shown in Fig. 1. The system timing is controlled by a digital delay generator DG645, providing a TTL triggering pulse, 2~5 µs, adjustable delay, about 1~2 ms in advance of the beam. An R&S SMA-100B generates a 324 MHz reference RF signal, also acts as the stimulator of a 1 kW RF amplifier. A voltage-controlled phase shifter is used to change the RF phase for the electron transverse modulation. Two power meters (Mini-Circuit PWR-8PW-RC) are used to monitor the power fed into and out of the RF deflector.

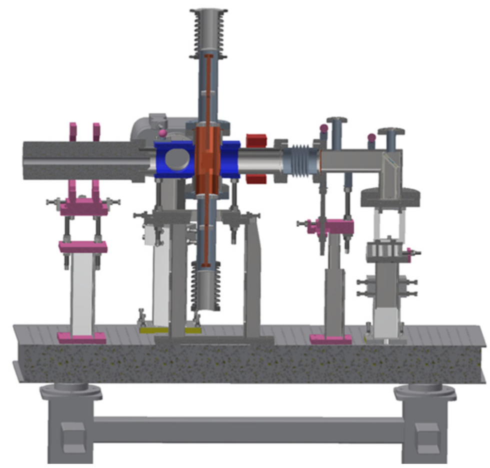

Figure 1: 3D drawing of the BSM test bench.

The test bench is built inside the D1 building at CSNS campus, with a 19” electronic rack with the depth 800 mm for BSM test bench electronics housing, as shown in Figs. 2 and 3. The camera will be shielded with a cylindrical baffle to improve SNR.

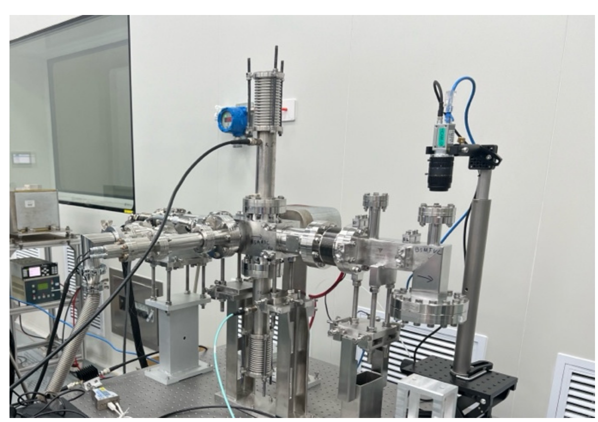

Figure 2: BSM test bench built in CSNS campus.

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Figure 3: A 19” electronic rack with the depth 800 mm for BSM test bench electronics housing.

According to the datasheet of the pulsed Kimball EMG4212 electron source, it can provide an adjustable beam current of 10 μA-20 μA with a pulse width of DC-2 μs, which is larger than that we need (1 ns). The pulse delay generator will be used to test the minimum width it could get with the electron gun, by controlling the TTL signal fed into the trigger port on the EGPS-4212 rear panel.

If there is an opportunity to test in the front-end experimental lab in CSNS, a Plan B of the BSM test bench is to install a bending magnet additionally for separation of the low energy secondary emission electrons and the stripped electrons from H- ions, with a set of MCP+screen+ camera+DAQ. The schematic diagram is shown in Fig. 4.

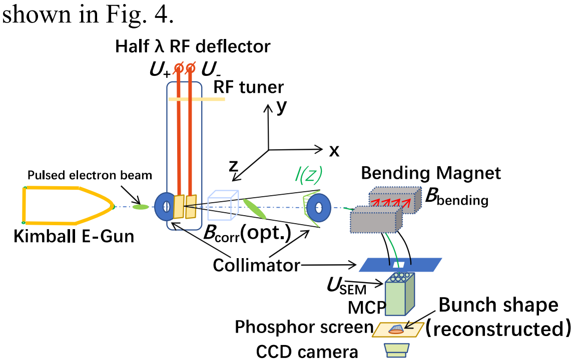

Figure 4: Plan B of BSM test bench in CSNS campus.

The second slit in BSM test bench is 130 mm upstream to the inlet of bending magnet. The outlet edge of the bending magnet is 50 mm above the MCP input. The rigid of 10 keV electron beam is $B\rho = 3.39\times10^{-4}$ T.m. The magnetic field along the electron orbit is design as Fig. 5, and the mechanical 3D drawing is shown in Fig. 6.

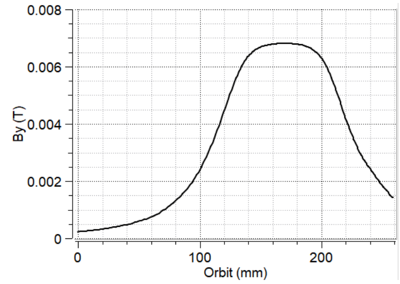

Figure 5: Magnetic field along the electron orbit in bending magnet.

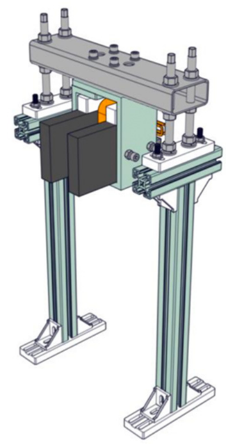

Figure 6: Design of the bending magnet for BSM test bench.

PARTICLE TRACKING OF PROTOTYPE RF DEFLECTOR

To evaluate the electrical field of the prototype RF deflector with proper configuration of the focusing voltage, the RF voltage and the steering voltage, preliminary particle tracking of a 10 keV electron circular beam was done with CST PIC module. As shown in Fig. 7, the electron beam travels towards -X direction. The charge of the electron beam is 1e-18C with $\sigma = 5$ ps. A focusing voltage of 5 kV is set on the two plates as static potential. Electron tracks with only V_{focus} on are shown in Fig. 8.

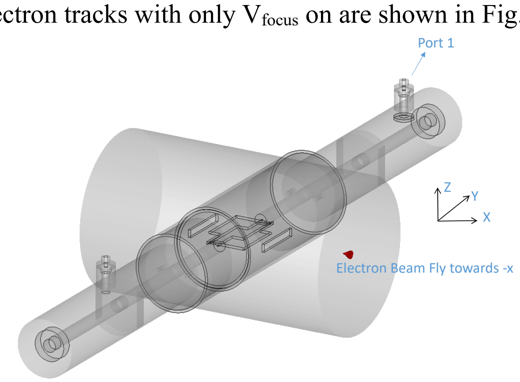

Figure 7: CST PIC simulation model of the prototype RF deflector.

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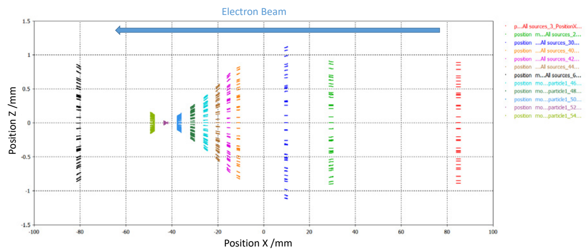

Figure 8: Electron tracks with V_{focus} = 5 kV in CST PIC simulation.

The port 1 of the RF deflector was fed in with a RF voltage of 150 sqrt(W), and a steer voltage of 50 V was set to make the static potential of the plate one as $V_{focus} - V_{steer}$ and the other as $V_{focus} + V_{steer}$. Electron tracks under this condition are shown in Fig. 9.

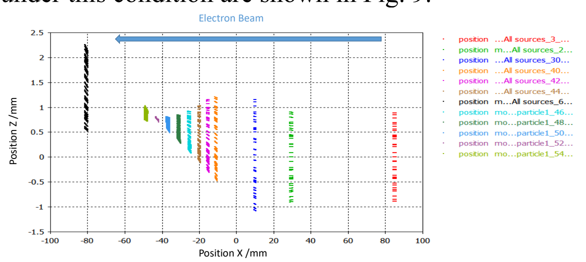

Figure 9: Electron tracks with V_{focus} (5 kV) + RF (150 V_{pp}) + V_{steer} (50 V) in CST PIC simulation.

All of the voltage configuration will be tried in the BSM test bench in the future, and we can choose an optimized one for a better phase resolution of BSM.

DESIGN OF A NEW RF DEFLECTOR WORKING IN 324 MHz

According to the S-parameter measurement results of the prototype RF deflector [3], we decided to design and fabricate a new one with a higher Q-factor (> 3000) and S11 < -30 dB in order to decrease the thermal electron emission and increase the screen image SNR. The requirement of the phase resolution of BSM is better than 1°.

A new RF deflector was designed and simulated in CST to get a proper resonant frequency f_0 (324 MHz) and to optimize the s-parameters. The components of the new RF deflector are showed in Fig. 10. S-parameters and Q-factor are still in optimization now, and the latest result is showed in Fig. 11, with a Q-factor > 4000 up to now.

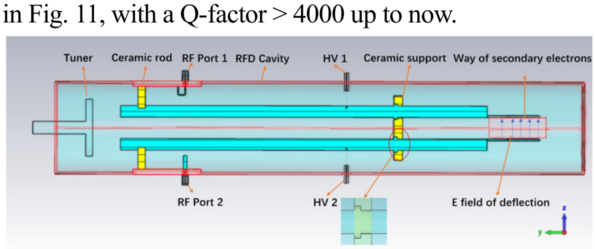

Figure 10: Components of the new RF deflector working at 324 MHz.

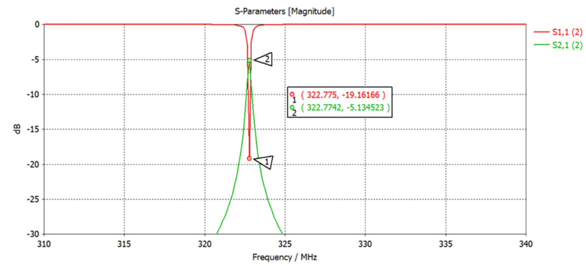

Figure 11: S-parameters of the new RF deflector.

CONCLUSION

A test bench was built for both the prototype RF deflector and new designed ones in CSNS campus. Particle tracking for the prototype RFD was done in CST PIC module and will be verified on this test bench after the control and DAQ system completes. The optimization of a new RF deflector is undergone by using CST. The new RF deflector will be fabricated and tested in this test bench next year, and it's planned to be installed in the linac tunnel of CSNS in 2026.

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