Longitudinal Impedance Measurements and Simulations of a Three-metal-strip Kicker

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Introduction

The ceramic slat injection kicker was proposed and applied in the BEPCII. It meets the requirements of the BEPCII storage ring injection system for wide good field region, high field uniformity, and low beam-coupling impedance [1]. However, according to the BEPCII 2019 annual meeting proceedings, the ceramic slat injection kicker malfunctioned for several times. The possible reason for the failure is that the beam or synchrotron radiation directly hit TiN coating, causing the coating detached from the ceramic slat. To solve the coating detachment, three metal strips are chosen to replace the TiN-plated ceramic slat as the image current path. In order to prevent the eddy current shielding effect and ensure the magnetic field uniformity, two metal strips are disconnected from the middle with a slit of $1\,\mathrm{mm}$. Two important issues of designing a kicker are the beam coupling impedance and the heat deposition on the kicker. The beam coupling impedance can cause collective beam instabilities. In order to ensure good beam quality and stable operation, the impedance of components should be strictly limited. The heat load can cause localized heating which may burn components or destroy vacuum in severe cases. Therefore, it is necessary to perform detailed impedance simulations for the three-metal-strip kicker. It is also useful to conduct bench measurements of the impedance to verify the impedance simulations.

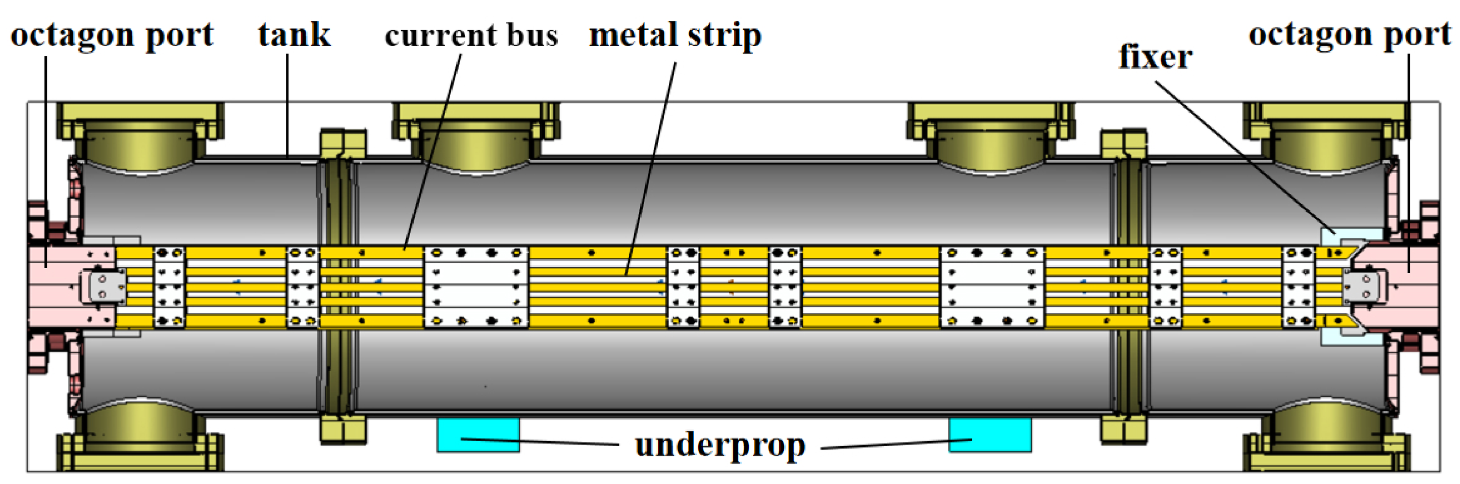

Figure 1: Mechanical structure of the three-metal-strip kicker.

Impedance Measurements and Simulations

With the coaxial wire method [2, 3], the longitudinal impedance of a three-metal-strip kicker prototype was measured by Vector Network Analyzer. Fig.2 shows the layout of experiment setup. And impedance simulations were also performed with CST.

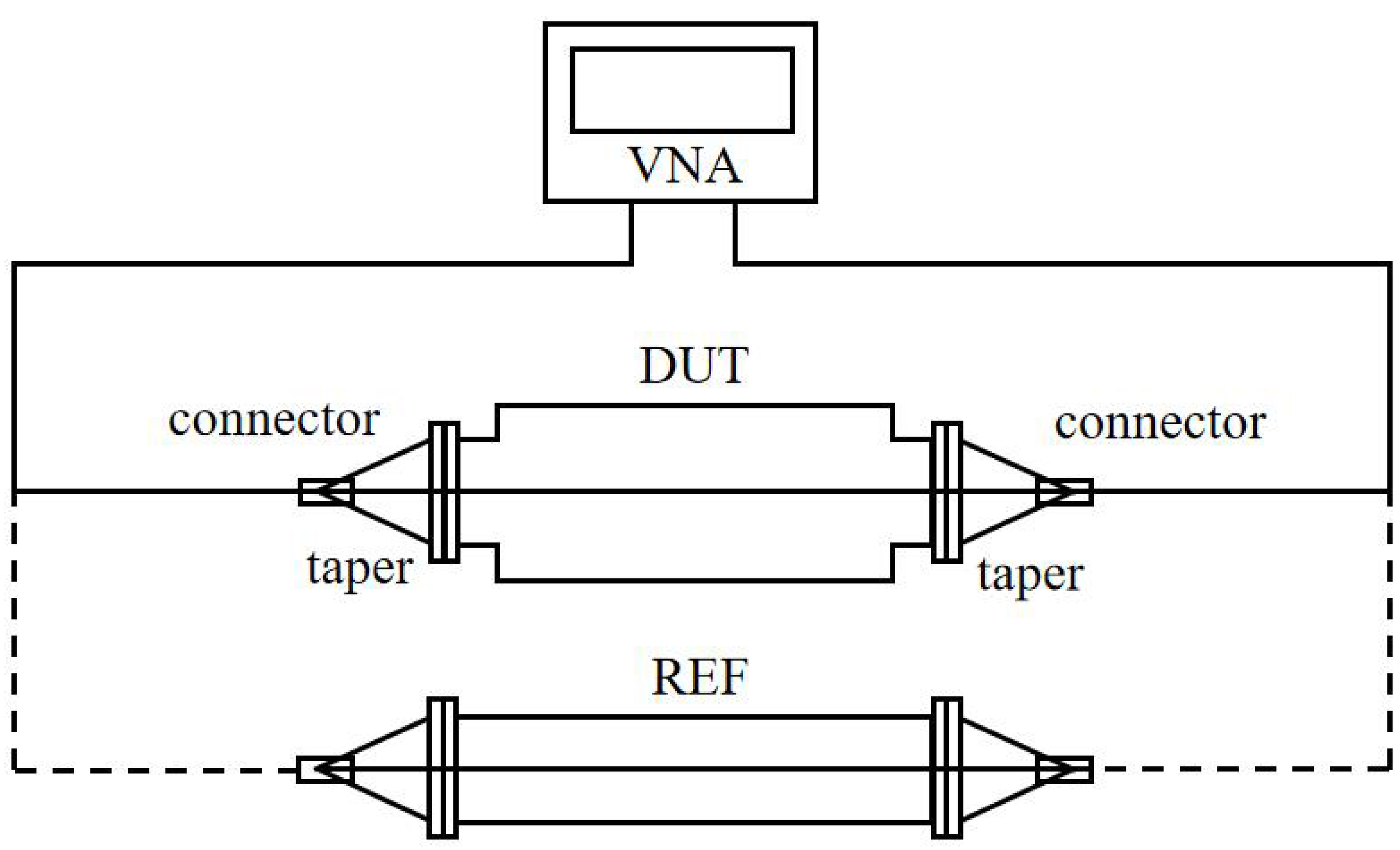

Figure 2: Layout of coaxial wire experiment setup.

A satisfactory agreement was obtained between numerical simulations and measurements. According to bench measurements, the loss factor up to $2\,\mathrm{GHz}$ is $0.017\,23\,\mathrm{V/pC}$ and the longitudinal effective impedance $\frac{Z_{\|}}{n}$ up to $2\,\mathrm{GHz}$ is $5.45\,\mathrm{m\Omega}$ ($\sigma = 10\,\mathrm{mm}$). According to simulations, the loss factor up to $2\,\mathrm{GHz}$ is $0.017\,44\,\mathrm{V/pC}$ and the longitudinal effective impedance $\frac{Z_{\|}}{n}$ up to $2\,\mathrm{GHz}$ is $3.62\,\mathrm{m\Omega}$ ($\sigma = 10\,\mathrm{mm}$).

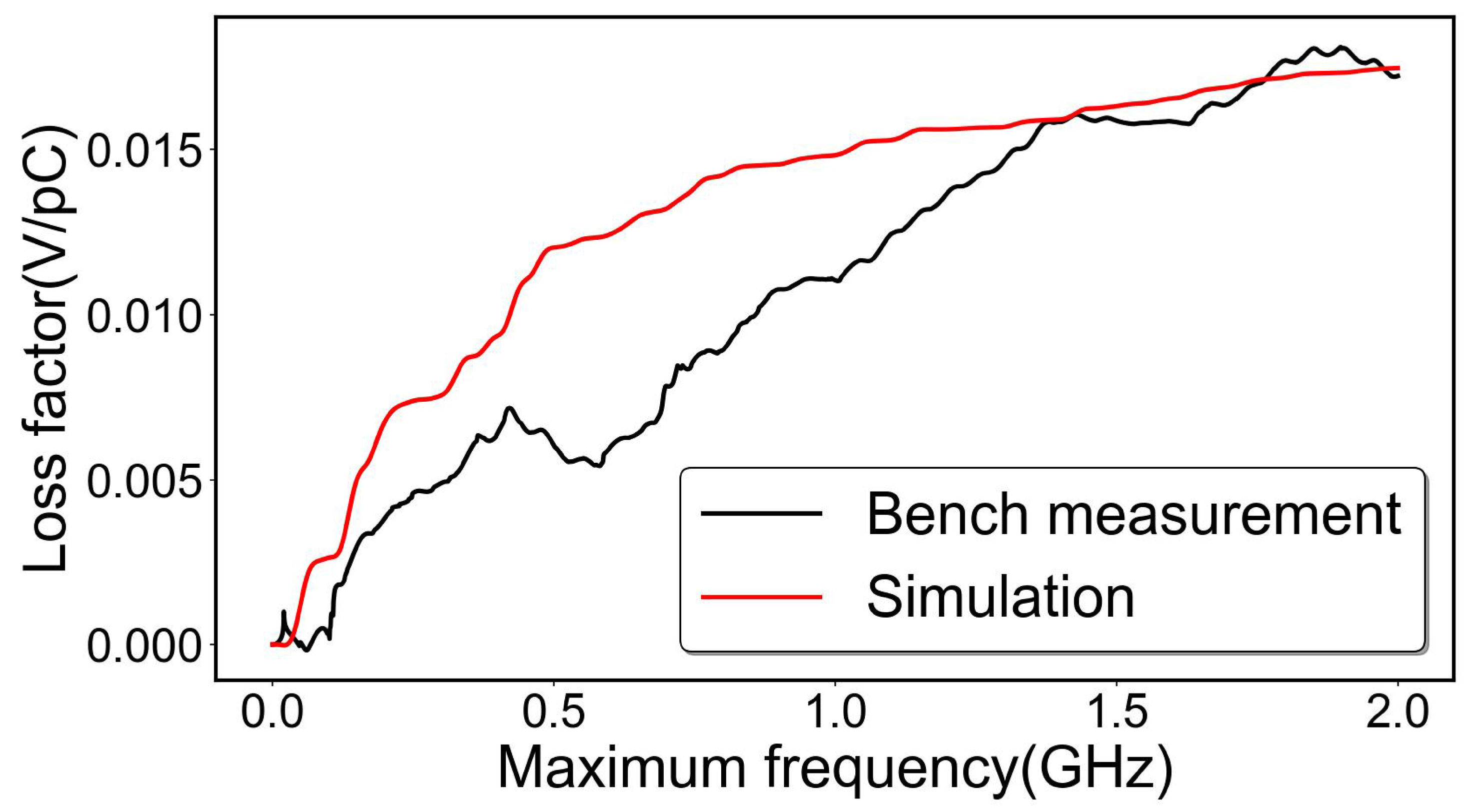

Figure 3: Longitudinal loss factor within different frequency ranges.

Heat Deposition on Different Parts of Kicker

The heat deposition on every part of kicker was simulated with CST. To conquer the limitation of computing resources, data fitting with an exponential function was applied. Fig.4 shows the final heat deposition after overlying about 10 turns with the bunch current of $9.8\,\mathrm{mA}$.

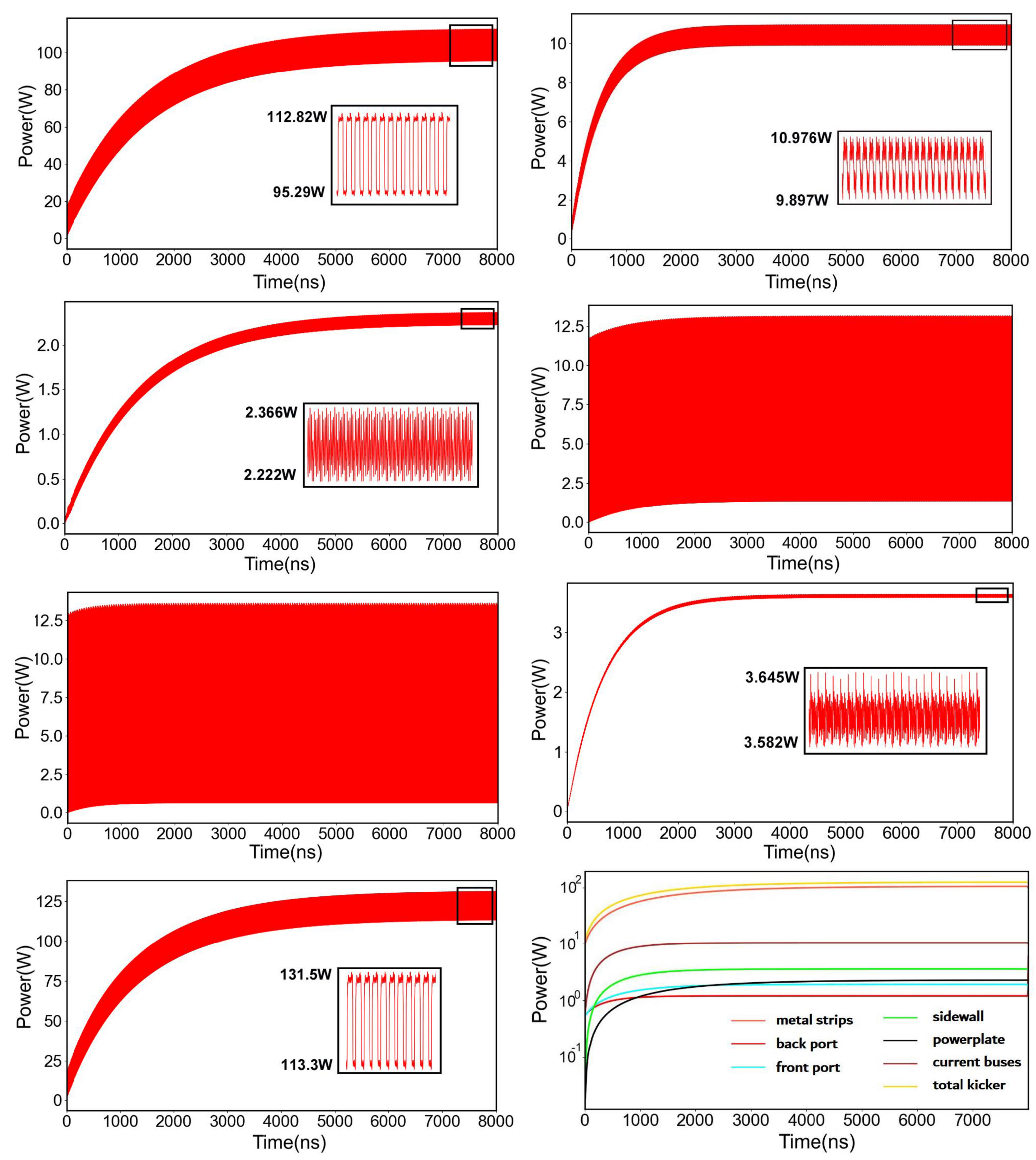

Figure 4: The heat deposition power on every part of the kicker from CST simulation and data fitting: metal strips, current buses, power plates, front port, back port, and comparison.

The parasitic loss power of the beam over one turn can be calculated with $P_{beam} = n_b q^2 k_{\|} f_r$. The measured longitudinal impedance gives the loss factor $0.017\,23\,\mathrm{V/pC}$ and P_{beam}=$122.50\,\mathrm{W}$ correspondingly. The CST simulation gives loss factor $0.017\,44\,\mathrm{V/pC}$ and P_{beam}=$123.99\,\mathrm{W}$ correspondingly. The direct CST simulation of heat deposition on the kicker gives the average heat deposition power $124.63\,\mathrm{W}$ which is consistent with the parasitic loss power of the beam.

References

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