Measurement and optimization of the beam coupling impedance of a novel 3D-printed titanium alloy cage inside the thin-wall vacuum chamber

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Dipole magnet vacuum chambers are among the critical and costly components of rapid-cycling accelerator facilities. Alternative approaches to traditional ceramic chambers have been explored for the implementation of fast-ramping dipole-magnet vacuum chambers, including thin-wall metallic beam pipe chambers strengthened with transverse ribs. Here, we report a novel 3D-printed titanium alloy cage inside the thin-wall vacuum chamber, which is designed for HIAF project to reduce manufacturing difficulty and cost, shorten the production cycle, and improve the quality. Because the beam impedance aspects are highly important for beam stability, comprehensive studies were undertaken to characterize the impedance of the 3D-printed titanium alloy cage inside thin-wall vacuum chamber. The beam-coupling impedance of the new thin-wall vacuum chamber were studied numerically. Strategies for further reducing the beam-coupling impedance were explored. In addition, impedance bench measurements using the "half wavelength" resonant method were conducted to identify the longitudinal and transverse impedance of this thin-wall vacuum chamber prototype experimentally. The simulated and measured results for the impedance were consistent. Furthermore, a campaign for resonance-check measurements on this thin-wall vacuum chamber prototype was launched. This novel thin-wall vacuum chamber structure has been ready for installation in the BRing.

➢ 3D-printed titanium alloy cage inside 0.3 mm thin wall vacuum chamber model

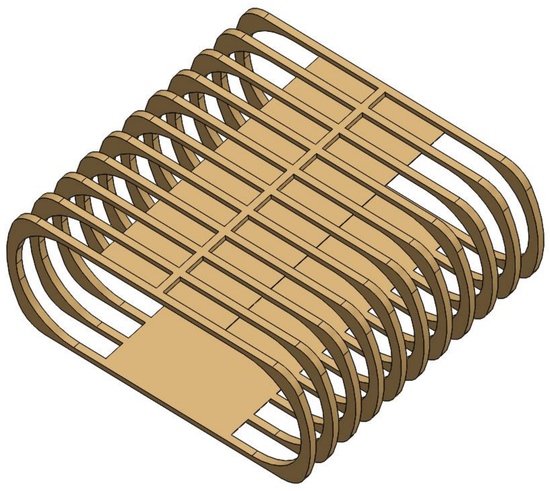


Figure 1 3D-printed titanium alloy cage

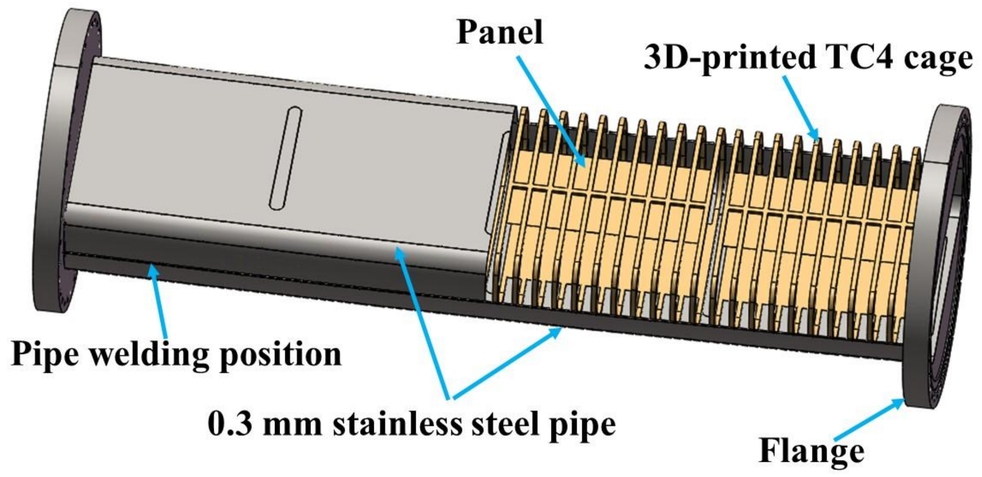


Figure 2 CAD drawing of the 3D-printed TC4 cage inside 0.3mm vacuum chamber

➢ Longidinal beam impedance measurement

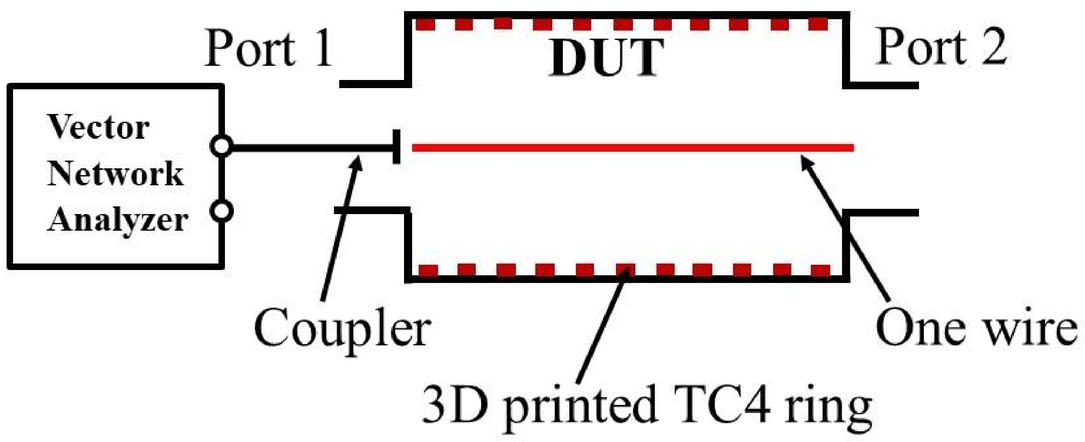


Figure 3 Longitudinal impedance measurement setup

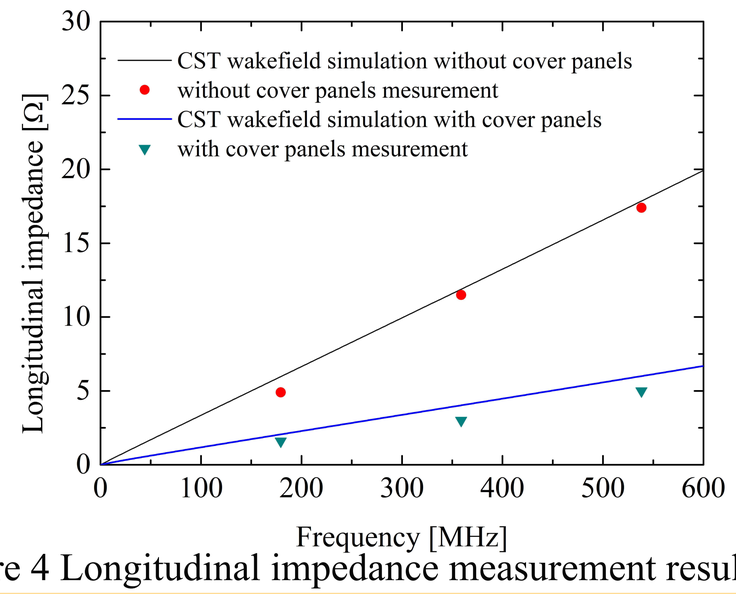


Figure 4 Longitudinal impedance measurement results

➢ Transverse beam impedance measurement

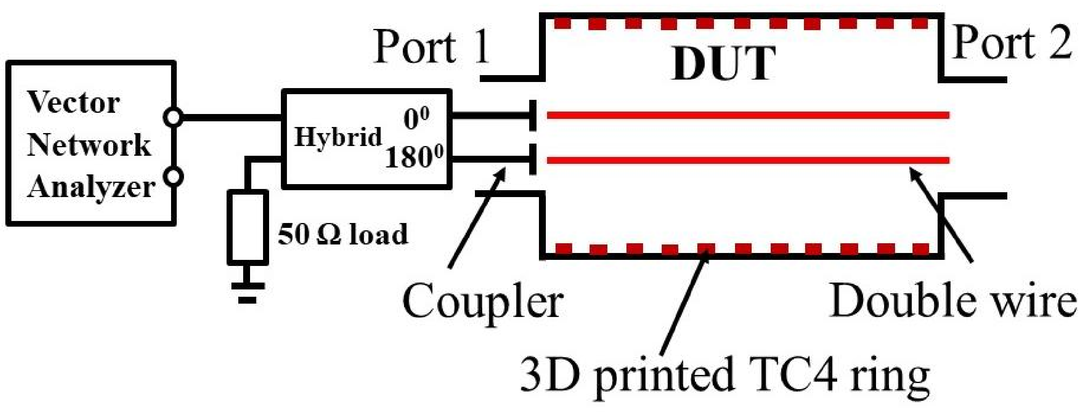


Figure 5 Transverse impedance measurement setup

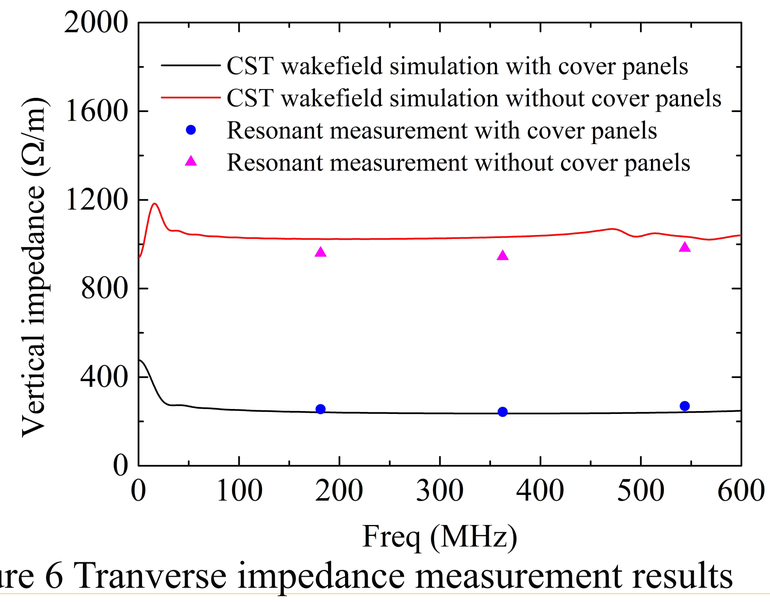
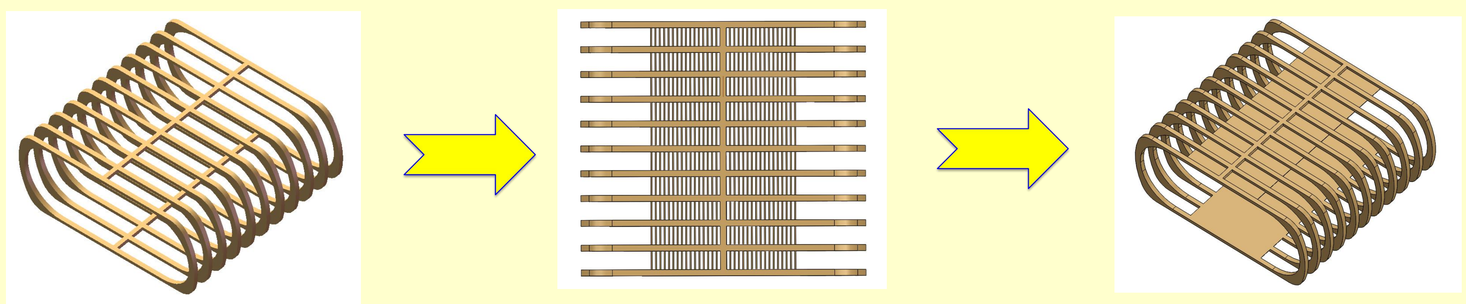


Figure 6 Tranverse impedance measurement results

➢ Beam impedance reduction



Vertion 1 **Version 2: with strip distribution** **Verstion 3: with cover panels**

- ✓ The longitudinal impedance reduced from 10 Ω to 2.5 Ω for version 3.
- ✓ The transverse impedance reduced from 1000 Ω/m to 250 Ω/m for version 3.

Reference: *[1] Guangyu Zhu, Junxia Wu, etal. IEEE Transactions on Nulear Science, 67(7), 2020;*
[2] Xiaoqiang Chen, Guangyu Zhu, etal. Physical Review Accelerators and Beams, 23, 034402, 2020;
[3] Shaohui Du, Jie Liu etal. Review of Scientific Instruments, 94, 103308, 2023

Conclusion:

- **Comprehensive studies were undertaken to characterize the impedances of 3D-printed TC4 cages inside thin-wall vacuum chambers.**
- **By adding two cover panels inside the cage, the impedance was significantly mitigated,the imaginary parts of the longitudinal and horizontal impedances were reduced by more than 65%, and the vertical impedance was reduced by more than 75%.**

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