TUPAB261
May. 24 ~ 28, 2021

The ferrite loaded cavity impedance simulation

Liangsheng Huang*, Bin Wu, Shouyan Xu, Xiao Li, Sheng Wang
CSNS/IHEP, CAS, Dongguan, 523803, P.R. China.

Abstract

The Rapid Cycling Synchrotron of the China Spallation Neutron Source is a high intensity proton accelerator, it accumulates the 80 MeV proton beam and accelerates it to 1.6 GeV in 20 ms. The transverse coupling bunch instability is observed in beam commissioning. The source has been investigating from the commission. The RF acceleration system consists of eight ferrite loaded cavities. The impedance is simulated and there is a narrow-band impedance of the ferrite cavity at about 17 MHz.

INTRODUCTION

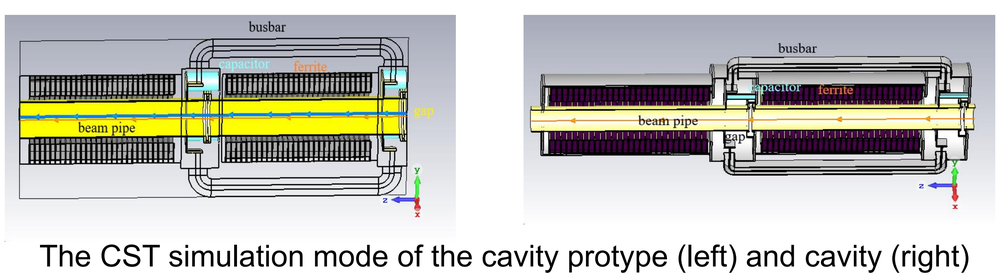
The RF acceleration system consists of eight ferrite loaded cavities in the RCS of the CSNS. The maximum voltage offered by eight cavities is 165 kV with a maximum synchronous phase of 45 degrees. With a classical and conservative NiZn load-ferrite, the coaxial resonant cavity has two accelerating gaps with single ended. The ferrite material is Ferrox-cube 4M2. There are 56 ferrite cores installed in a cavity. The gap inductance can be shifted from 8.1 μH to 1.4 μH as a bias current varies from 200 A to 3000 A. The gap capacitance is 3nF. The resonant frequency of the cavity can sweep within 1.02~2.44 MHz to meet the need of the energy ramping.

The transverse coupling bunch instability is observed as the beam power increasing in beam commissioning. Characterization, simulation mitigation and the source were carried out in the beam commissioning. The instability was mitigated by the tune adjusting and the chromaticity correction, but the beam power will be upgraded to 500 kW with protons per bunch of 3.9×10^{13} and the instability will be observed and limit the beam power. The source of the instability is not be determined based on the impedance budget and the source was also investigated. The longitudinal impedance is simulated in the cavity design and the third high-order-mode (HOM) of the ferrite cavity is the main HOM. The HOM frequency is moved to about 12 MHz by busbar optimization. The transverse impedance of the cavity was ignored in the simulation and it is simulated recently based on CST Studio Suite. According to the beam-based simulation, it may be the source of the instability.

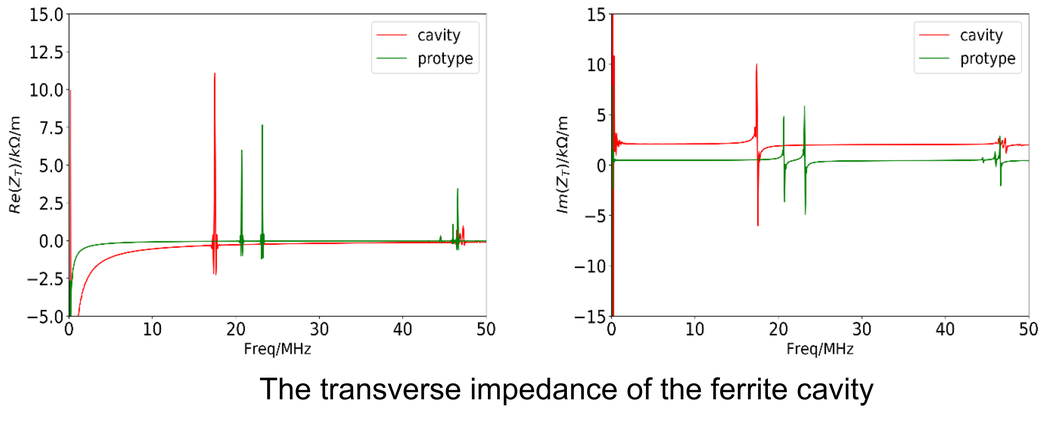
THE CAVITY IMPEDANCE SIMULATION

It is a coaxial-resonant cavity consisted of internal and external conductors and the inner conductor is also the beam pipe with thickness of 2 mm copper. The acceleration gap is sealed by the ceramic ring, and the induced current from the beam will penetrate into the gap. The distributed capacitance is connected at the both ends of the acceleration gap. The resonance frequency of 1.02 MHz at injection energy is firstly considered in the simulation. To resonance the cavity, the permeability of the ferrite ring is 77 and the capacitance is replaced by the cylinder with radius of 20 mm and the dielectric constant of 14400. The frequency at extraction is also compared with the permeability of 17. The black ferrite ring and the cooling plate are placed between the inner and outer conductors. The circular busbar is used, but the runway busbar is adopted for the real cavity.

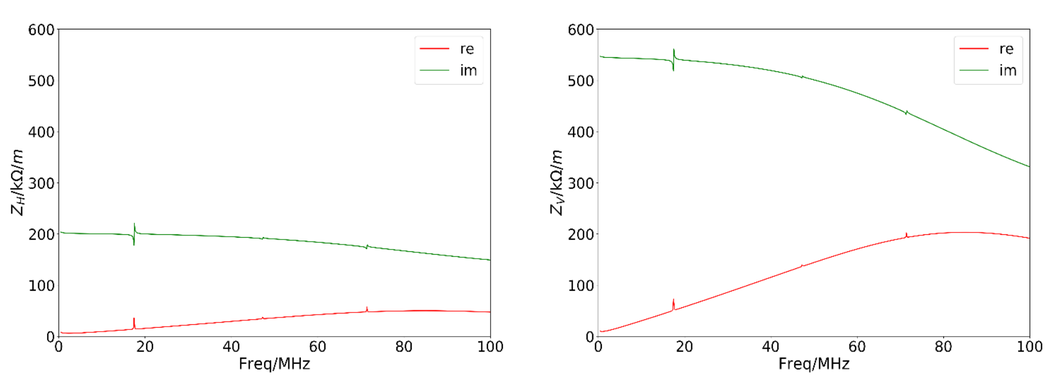
Based on the simulated mode, the hexahedral meshes of 20 million is used. The wake-field length of 500 m is calculated. The simulated impedance result is shown. The impedance of the prototype in horizontal plane has two peaks at about 21 MHz and 23 MHz, but the only one peak about 17 MHz appears in the real cavity. The vertical impedance is also simulated and it is same with the horizontal impedance. The impedance frequency at extraction energy is mostly same with that at injection energy. Based on the cavity impedance estimation, the RCS transverse impedance mode is updated.



The CST simulation mode of the cavity protype (left) and cavity (right)



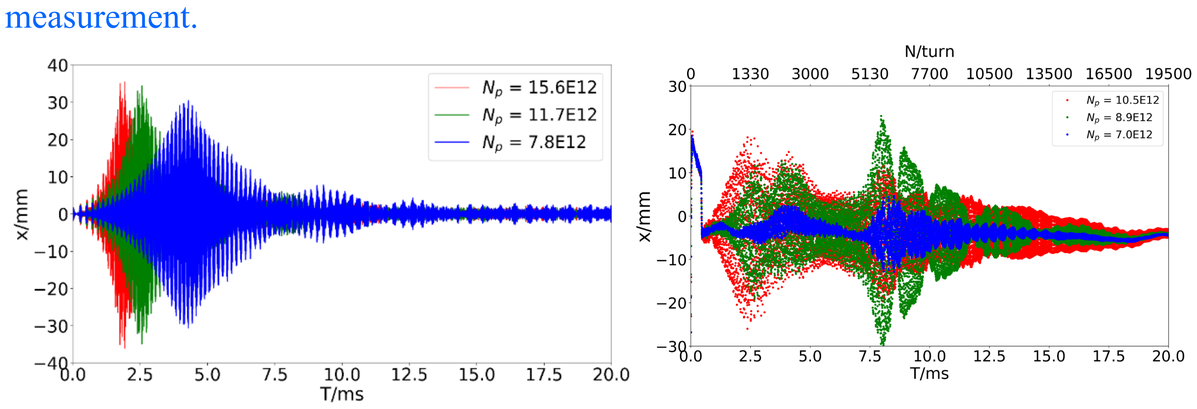
The transverse impedance of the ferrite cavity



The RCS transverse impedance mode

BEAM BASED SIMULATION

The beam dynamic simulation code has been developed and updated to reappear the instability. The nominal tune of (4.86, 4.78) with natural chromaticity of (-4.64, -8.27) in the RCS is simulated and the used impedance of eight-cavity is about 20 kohm/m. The two buckets are perfectly filled with two bunches and the beam position and the mode in longitudinal plane is observed. The turn-by-turn beam position with different beam intensity in horizontal plane roughly agree with the measurement.



The beam position driven by the cavity impedance (left) and measuremet (right)

SUMMARY

The transverse coupling bunch instability is observed and the source is investigated in beam commissioning. The impedance of the ferrite cavity at about 17 MHz may be the source of the instability. The impedance measurement by a bench method is planning to check it.

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* **huangls@ihep.ac.cn**