Bench measurements of beam coupling impedances for SIS100 components

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Introduction

Coupling impedance describes the force acting back on the beam due to the electromagnetic properties of the accelerator environment. The development of the high intensity Synchrotron SIS100 requires a detailed knowledge of the impedance contribution of individual components to prevent beam instabilities and additional heat load. Besides analytic calculations, which are only possible for simplified structures, numerical calculations are in progress. Bench measurements are required to cross-check simulations and their input parameters.

Measurement system

Measurements are performed by adding a central conductor on the beam axis to a DUT (Device Under Test) and connecting this formed transmission line to a VNA (Vector Network Analyzer). Describing this transmission line by an equivalent circuit the DUT adds a serial impedance to the equivalent line of a reference beam pipe. This additional impedance causes a variation of the wave number, which can be determined by changes of the scattering matrix. Assuming a successful matching of the transmission line to the VNA, the reflections vanish and the correlation for the longitudinal coupling impedance is [1]:

$$Z_{\parallel} = Z_0 \cdot \ln\left(\frac{S_{21}^R}{S_{21}^D}\right) \cdot \left(1 + \frac{\ln(S_{21}^D)}{\ln(S_{21}^R)}\right) \qquad (1)$$

where S_{21}^R / S_{21}^D describes the transmission component of the scattering matrix for the reference/DUT. To determine the transverse coupling impedance two anti-parallel driven wires are needed [2]:

$$Z_{\perp} = \frac{cZ}{\omega\Delta^2} \qquad (2)$$

where Δ is the displacement of the wires and Z comes from Eq. 1.
For low frequencies the accuracy can be increased by using a multiturn coil instead of two anti-parallel driven wires and measuring directly impedance variations by a LCR-meter. The sensitivity increases by number of turns squared:

$$Z_{\perp} = \frac{c \cdot (Z_{DUT} - Z_{Ref})}{\omega\Delta^2 N^2} \qquad (3)$$

As example the low frequency transverse impedance of a circular pipe will be discussed. The coupling impedance has been determined by several numerical and analytical calculations [3, 4]. A very good agreement between measurements and calculations has been achieved as seen in Fig. (1). The drawback of using coils with many turns is the lower resonance frequency. Nearby the resonance measurements are not possible, so this method is limited up to several MHz. To achieve good results in a broad frequency range two different coils were produced. One for high accuracy at low frequencies and one for measurements up to 2 MHz.

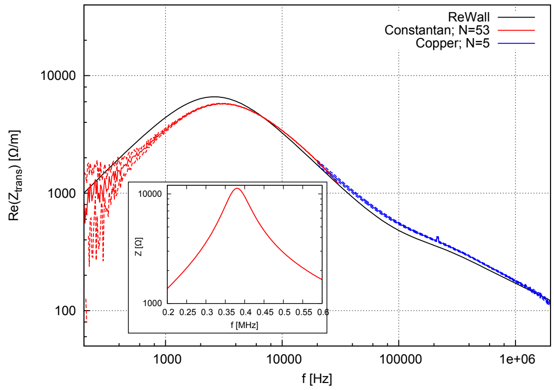

Figure 1: Measurement of the real part of the coupling impedance for a circular beam pipe compared to analytical results made by Rewall [4], the small picture shows the first resonance of the coil with 53 turns.

Conclusion and Outlook

The experimental setup for measuring coupling impedances in the low frequency regime has been build sucessfully. The measurement results for a reference beam pipe structure were compared to analytic calculations. The experimental setup for measurements above 2 MHz is presently under construction. The first planed device under test will be a kicker magnet module, where the ferrite and also the supply network cause to large impedances. The results of both measurement methods will be compared with numerical calculations of the measurement setup using CST MWS [5].

References

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