Introduction

At the high beam intensity, needed to reach the high luminosity, the wake field acts back on the beam, perturbing the external guiding fields and the beam dynamics leading to instabilities. Due to the 100 km beam pipe length, at injection one critical issue will be the resistive wall impedance. To mitigate beam instabilities the coupling impedance of the beam screen has to be sufficiently low. So far, in the baseline design copper coatings are intended, but the resulting impedance is not low enough to provide a stable beam. To overcome the arising limitations, a new approach using thin films of high-temperature superconducting (HTS) material is investigated aiming to reduce the coupling impedance.

Hybrid Beam Screen Coating

Basic Idea

To minimise the coupling impedance, the main idea proposed is to display HTS coated conductors along with the intended copper in several selected positions, symmetrically distributed, in form of alternating stripes in the beam screen. It provides a lower impedance by effectively screening the beam induced radio frequency currents. Further, this hybrid system can be combined with a very thin surface layer of amorphous carbon coating to reduce the electron cloud effect.

- Normal Conductors
  - Skin depth
  \[ \delta = \frac{2}{\mu_0 \sigma} \sqrt{\frac{\mu_0}{\sigma}} \]
  - Surface impedance
  \[ Z_s = \frac{1 + j}{\delta} = R_s + jX_s \]
- Superconductors
  - London Theory & Two-Fluid Model
  \[ \kappa = \kappa_L - j\kappa_T \]
  - London penetration depth
  \[ \lambda_L = \left( \frac{m}{2\mu_0 n_e^2} \right)^{\frac{1}{2}} \]
  - Surface impedance
  \[ R_s = 0.5\mu_0 \omega^2 s \lambda_L^2 \]
  \[ X_s = \omega s \mu_0 \lambda_L \]

Effect of the antechamber on the impedance

BeaImpedance2D [1]

- Frequency domain solver
- Computational tool for longitudinal and transverse coupling impedance
- Finite Element Method (FEM)
- Input: mesh of the geometry

Position dependent coating

- Increasing the percentage of HTS yields a gradual reduction of the impedance
- Narrow striped systems more effective in low frequency region than wide stripes
- Longitudinal impedance shows similar behaviour as transverse
- Carbon coating of 10 nm shows no impedance change in the frequency range of interest

Baseline Design

The baseline design of the FCC-hh beam screen is based on a 1 mm thick octagonal shaped stainless steel tube coated in the inside with a 300 µm layer of RRR = 100 copper. In the foreseen operating temperature of 40 K to 60 K the intended coating provides an impedance already close to the acceptable limit for a stable beam.

Summary and References

The results show that the hybrid system reveals great potential to drastically reduce the beam coupling impedance especially for low frequencies. Regarding the strong magnetic field, the hybrid beam screen system has a higher impedance than pure copper coating for high frequencies due to the appearing flux tubes. Furthermore, the distortion of one single tube is negligible small after few nanometers.


References

[1] L. Niedermayer, O. Boine-Frankenheim, Patrick Krkotic, Oliver Boine-Frankenheim, Schloßgartenstraße 8, 64289 Darmstadt, Germany

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