Feasibility of impedance measurements with beam

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Request

• Prospects of beam tests at the LHC with a MoGR-based collimator prototype design for low impedance before LS2.

• Could 3 different coatings be tested on the same jaws of that prototype, each of a height of 10mm?
Items

- CST Simulations
- RF loop measurements
- Impedance vs frequency and transverse offset
- Expected tune shifts
Collimator simulation setup with three coatings

- **MoGr bulk (54mm thick, full gap=10mm)**

  - **TiN coating**
    - Thickness = 5um
    - Width=10mm
    - \( \rho_{\text{DC}} = 4 \times 10^{-7} \text{Ohm.m} \)

  - **Mo coating**
    - Thickness = 5um
    - Width=10mm
    - \( \rho_{\text{DC}} = 5.35 \times 10^{-8} \text{Ohm.m} \)

  - **No coating**
    - MoGr bulk
    - Width=10mm
    - \( \rho_{\text{DC}} = 1 \times 10^{-6} \text{Ohm.m} \)

![Integration path](image)
Impedance at the center of the stripes

- **IW2D (Nicolas Mounet’s code):** two parallel plates, single material
- **CST simulations:** 3D model, three coating materials

→ Reasonably good agreement between IW2D and CST!
→ Wiggles at low frequencies are usual non zero transverse wakes at the end of the simulation.
Cross-talk between different coatings

- It would be safe to allow for a ~2mm transition from one type of coating to another.
- In the simulations the stripes are 10mm wide, this means we can go safely up to 6mm (2mm transition left + 2mm transition right + 2mm center).
- This should be kept in mind for the alignment constraints during beam measurements.
Conclusions from simulations

• Ensuring stripes 6mm wide, the impedance seen by a beam centered on the stripes is equivalent to a full 2D structure.

• Simulations were done with an ideal beam without transverse size (normally few hundreds of um, still ok.)

• Simulations were done at 5mm half gap, closer gap should help (wider surface seen by the beam)
RF loop measurements

• Measuring with a loop we can excite a magnetic field that couples to the DUT and induces currents that are source of magnetic field acting back to the loop.

• The transverse impedance can be then deduced looking at the input impedance from a VNA:

\[ Z_y^{\text{dip}}(\omega) \approx \frac{c}{\omega} \frac{Z_{RLC}}{N^2 \Delta^2} \]

• We can neglect the induced electric field below the self-resonance of the loop.
RF loop measurements

• In the measurement, it is embedded the loop contribution.

• We can isolate it doing a reference measurement with respect to free space using a good conductor of the same shape of the DUT.

Example of reference blocks used so far for blocks and pipes characterization
RF loop measurements

Measurements performed on CFC block with three coatings:
• Cu stripe: 2um thick, 2.5 cm wide.
• Mo stripe: 7um thick, 2.5 cm wide.
• CFC stripe: what is left from the bulk.

Resistivity measurement procedure:
• We use a N=2 coil moving it at the center of each stripe
• We measure at frequencies below the coil self resonance (< 10 MHz)
• We calculate the transverse impedance,
• We run IW2D simulation varying resistivity in order to match the measurements.
RF loop measurements

Inferred resistivity Vs frequency for the 3 stripes at different half gaps (h.g.):

Cu stripe

Inferred resistivities in the range of analysis:
Cu: 43 +/- 10 nOhm.m
CFC: 6.9 +/- 0.5 uOhm.m
Mo*: 140 +/- 40 nOhm.m

*Not constant resistivity: some systematic affected the Mo stripe measurement and could not be disentangled yet. The order of magnitude is anyway higher than Cu and lower than CFC.
RF loop measurements

Reconstructed impedance (real part):

Reconstructed impedance (imaginary part):

Cu stripe

CFC stripe

Mo stripe
Source of errors

- A rather “poor man” setup in wood-rods and glue
- Source of errors / improvement targets:
  - Relative coil/block alignment
  - Measurement of block – coil distance
  - Coil manufacturing (loops straightness and parallelism)
  - Sliders

As these measurements are becoming routine, could we plan a setup improvement?
Conclusions from measurements

• With a 2-turns coil we can distinguish the stripes and reconstruct resistivity close to expectations for CFC and Cu.

• Issue for the Mo stripes is probably due to the setup alignment errors: plans to perform new measurements on Mo+MoGr blocks next week (Wil).

• Strong need for measurement setup upgrade.
Tune shifts from coatings
(at $<\beta> \sim 70$ m and with nominal bunch intensity)

→ tiny tune shifts at 2 mm half gap
Tune shifts from coatings (at $\langle \beta \rangle \sim 70$ m and with nominal bunch intensity)

→ tiny tune shifts at 2 mm: -1e-6 to -3e-6
Tune shifts from coatings
(at $<\beta>\sim 70$ m and with nominal bunch intensity)

- Tiny tune shifts at 2 mm: $1\times 10^{-6}$ to $3\times 10^{-6}$
- If smallest visible tune shift of the order of $1\times 10^{-5}$, the collimator jaws should be at $\sim 1$ mm from the beam to hope distinguishing Mo from both other coatings.
- At 0.5 mm from the beam, the 3 coatings should have distinguishable tune shifts ($>4\times 10^{-5}$)
Conclusions and next steps for beam measurements

• Measurable tune shift (i.e. >4e-5) is corresponding to very close half gaps (<1mm), maybe not reachable w/o scraping the beam. Efforts on going to improve the measurement resolution in MD block 1.

• Use actual reachable beta functions and scale tune shift to optimal conditions (N.B. that the tune shifts are inv. proportional to the sqrt(beta) function at the collimator accounting for gap and impedance change). Needed possible installation positions.

• Check if the beam (or collimator) can be moved from one stripe to the next while keeping the beam in the machine (in order to make a direct comparison).

• Perform DELPHI simulations to see if growth rates or instability thresholds are strongly affected. However, this is much more lengthy and difficult to perform in practice.