Impact of NEG Coating on the Impedance

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List of Contents

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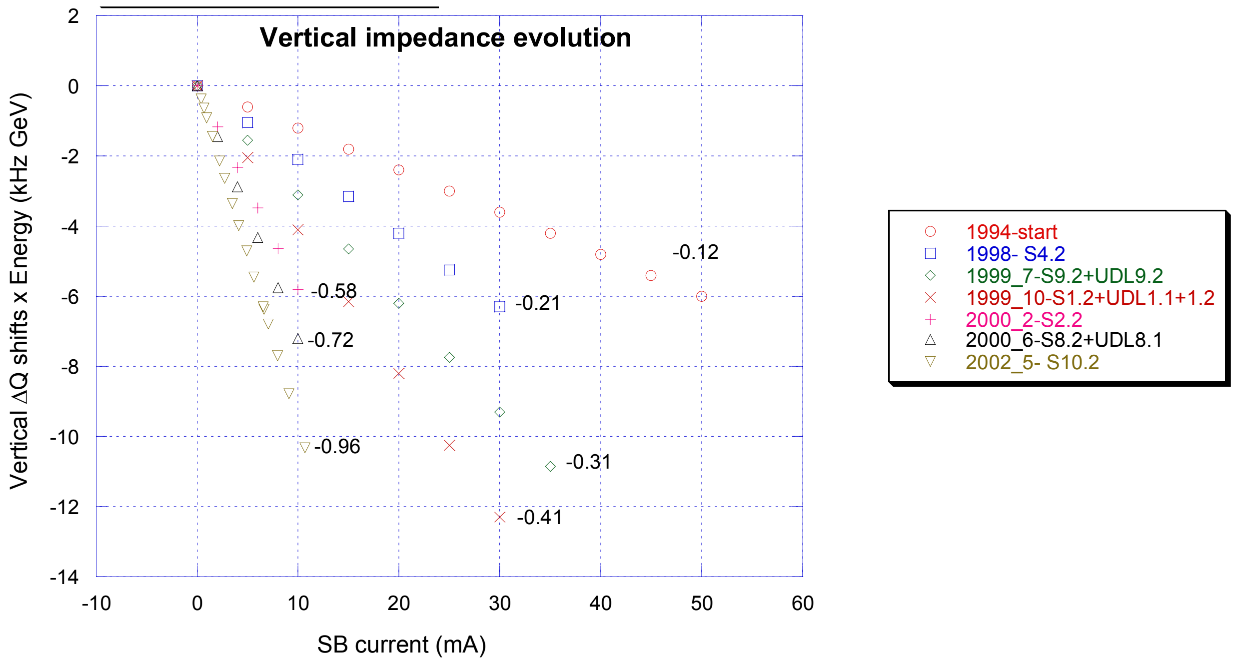
1 Introduction

◊ In the SOLEIL ring, nearly all straight sections shall be equipped with NEG coated Al vessels.

◊ Recently, however, installation of such chamber in ELETTRA apparently associated an anomalous increase of the impedance.



Courtesy E. Karantzoulis (ELETTRA)

◊ At ELETTRA, this anomalous increase was later confirmed when second such chamber was installed in spring 2003.

⇒ Preliminary studies, made at SOLEIL on the effect of NEG coating on the impedance, including the collaboration with ELETTRA on the analysis of their observations, are reported.

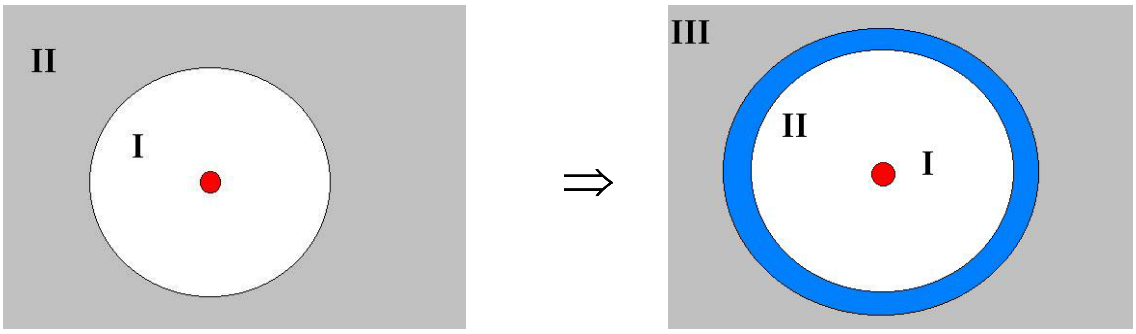
2 Impedance model

◊ One may assume that it is Z_{RW} (Resistive-Wall) in question.

◊ To evaluate Z_{NEG}, one needs a formula that takes account of a metallic layer on the chamber surface.

Standard formula $$Z_{\perp}^{RW}(\omega) = \frac{[\mathrm{sgn}(\omega)-i]}{2\pi}\cdot\frac{1}{b^3}\sqrt{\frac{2cZ_0\rho}{|\omega|}}\times L$$

- Assumes a circular chamber with an infinitely thick wall
- Maxwell solutions in regions I and II matched on the boundary.

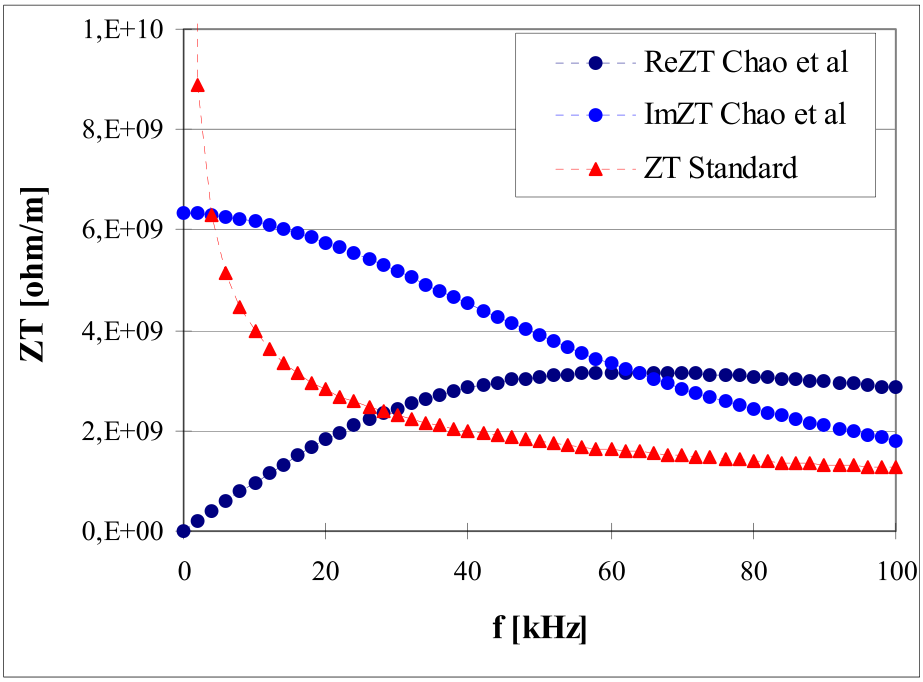


Matching must now be made on both sides of a metallic layer.
We have derived $Z_{\perp}$ and $Z_{//}$ using the formalism of A.W. Chao.

◊ Verified that the obtained formulae
- Reduce to the standard ones when $\rho_{II} = \rho_{III}$.
- Are numerically identical to those of Burov and Lebedev (EPAC 2002), derived in a different approach.

⇒ Led us to suppose that these formulae, as well as those of Burov and Lebedev for *flat chambers* are reliable.

◊ Inapplicability of the standard formula elsewhere (*a side aspect*).
- In large machines where $\delta_{skin} > \boldsymbol{d_{wall}}$.
- Incoherent tune shifts due to asymmetric chambers.



(b = 4 mm, chamber thickness = 1 mm, material = SS)

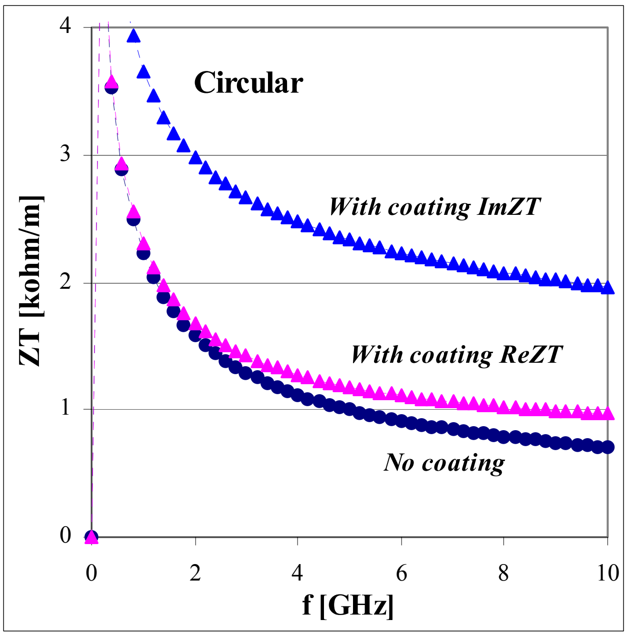
Critical importance of the different behaviour of $Z_\perp$ at low frequencies in understanding the incoherent tune shift.
(Chao, Heifets and Zotter; PRST ***5****, Nov02)*

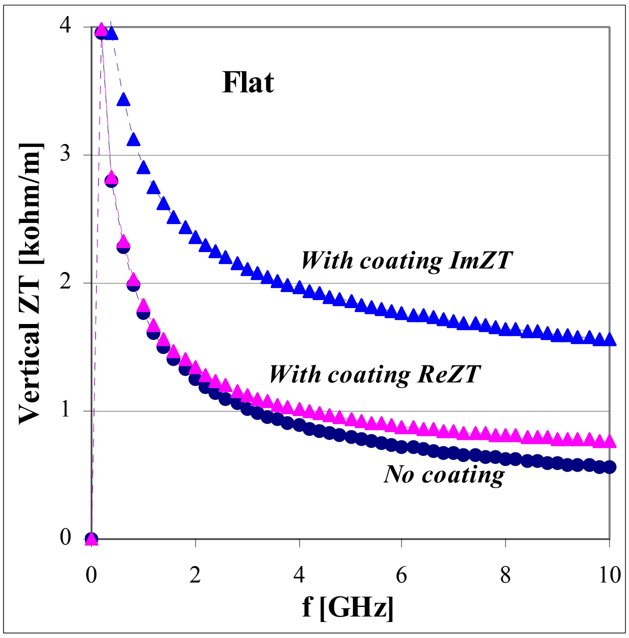
3 Properties of the impedance of a coated chamber

◊ In applying the formulae, ρ of the coated NEG is a priori unknown.
⇒ Started with $\rho = 25\times10^{-8}$ Ωm, i.e. the lowest of (Ti, Zr, V) of NEG.

◊ With 1 μm NEG coating on an Al chamber (7 mm radius);
- Im$Z_\perp$ increases by roughly a factor of 2
- Increase of Re$Z_\perp$ is relatively small.

Behaviour of Im$Z_\perp$ is in *qualitative agreement* with the observation in ELETTRA.

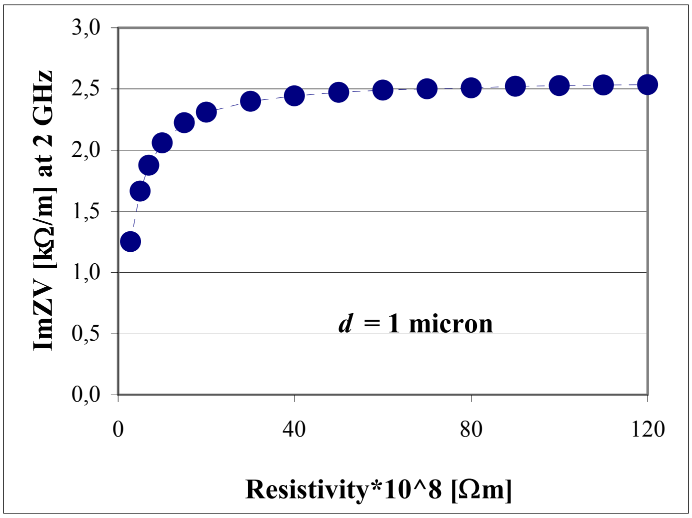




◊ Same trend for flat chambers. Amplitudes are scaled
- Vertically by roughly the form factor $\pi^2/12 \sim 0.82$.
- Horizontally $\pi^2/24 \sim 0.41$.
- Elliptical and rectangular chambers lie in between the 2 extremities.

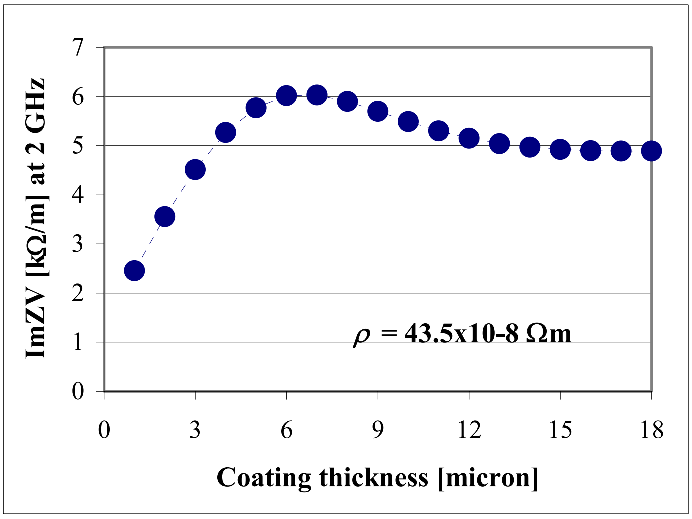
◊ Variation of ρ at a constant coating thickness ***d*** of 1 μm

- A steep increase of $\mathrm{Im}Z_\perp$
- Saturation at a ratio of ~2 above $\rho \sim 50\times10^{-8}$ Ωm.



◊ Variation of ***d*** at a constant ρ (43.5×10^{-8} Ωm)

⇒ The same trend that the impedance saturates rather rapidly.



- Saturation at ***d*** > δ_{skin} (~7 μm in the example).
- $\mathrm{Im}Z_\perp$ converges to that of a chamber made of the coating material.

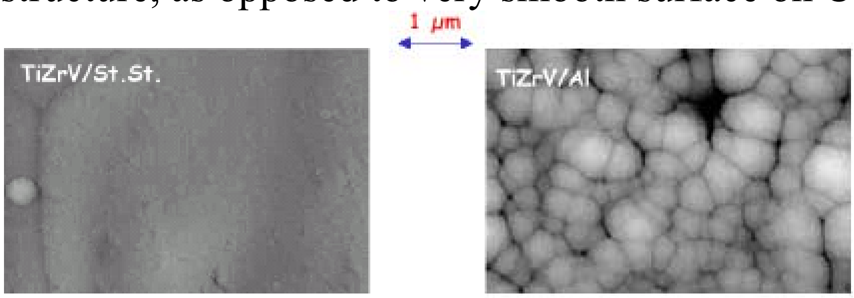
⇒ A significant increase of $\mathrm{Im}Z_\perp$ can only be expected when both ρ and ***d*** are increased simultaneously. $Z_{//}$ behaves similarly.

4 Effective resistivity of NEG

◊ Is $\rho_{NEG} \approx \rho$ of the constituent elements?
$\{\rho_{Ti}(30\%),\ \rho_{Zr}(30\%),\ \rho_{V}(40\%)\} \sim \{40, 44, 25\}\times10^{-8}\ \Omega\text{m}$
$\Rightarrow\ \rho_{<elements>} \sim 35\times10^{-8}\ \Omega\text{m}$.

◊ Information from *SAES Getters* :
- NEGs once reduced in powder form have poor conductivity, being powder grain covered by an oxide layer.
- High compression should ideally lower ρ to that of graphite.

◊ V. Ruzinov (CERN) pointed out that NEG on Al and Be have a granular structure, as opposed to very smooth surface on Cu and S.S.



("NEG coatings", V. Ruzinov, Workshop on NEG ..., ASTEC, Sep 2002)

◊ E. Plouviez (ESRF) made a direct measurement of ρ_{NEG} at 14 GHz, with thin NEG films (~ 1 μm) on a kapton sample.
$\Rightarrow\ \rho_{NEG} \sim 1600\times10^{-8}\ \Omega\text{m}$ was concluded ($\rho_{NEG}/\rho_{<elements>} \sim 50$).
$\Rightarrow\ \delta_{skin} > 1$ μm coating even at 14 GHz.

◊ D. Proch et al. (DESY) assume $\rho_{NEG} \sim 350\times10^{-8}\ \Omega\text{m}$.
("RF Losses in CU Surface with TiZrV Coating", D. Proch and A. Zavadtsev)

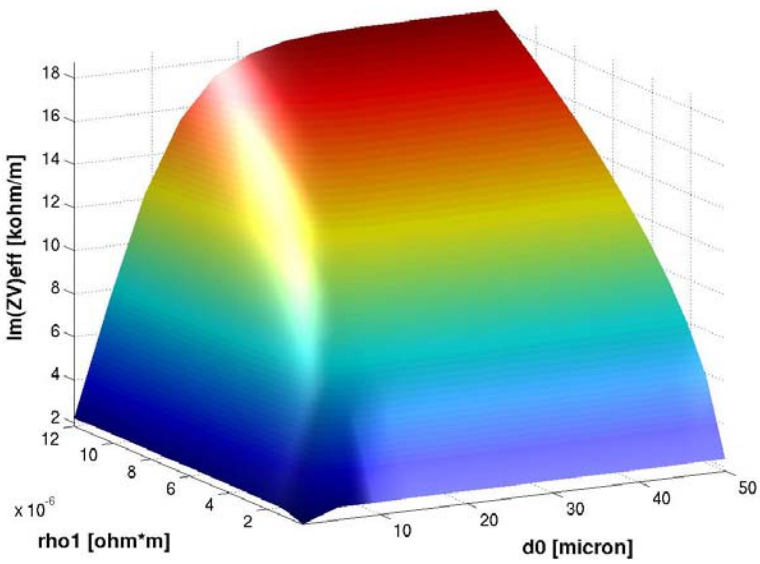
5 Some analysis of observations in Elettra

◊ Collaboration is made with ELETTRA (E. Karantzoulis) to identify the observed anomalous detuning.

◊ Try firstly to understand the approximately constant increase of the detuning, every time a low-gap chamber (no coating) is installed.

◊ RW and geometric impedance both seem important because;
- Detuning is nearly equal for SS and Al chambers
- Measured horizontal detuning > calculated with Z_{RW} alone

◊ By varying ρ and $\boldsymbol{d}$ of the coating, find that only when $\boldsymbol{d}$ > ~10 μm and $\rho >$ ~500×10^{-8} Ωm, can Im$(Z_{eff})_{NEG}$ explain the observation.

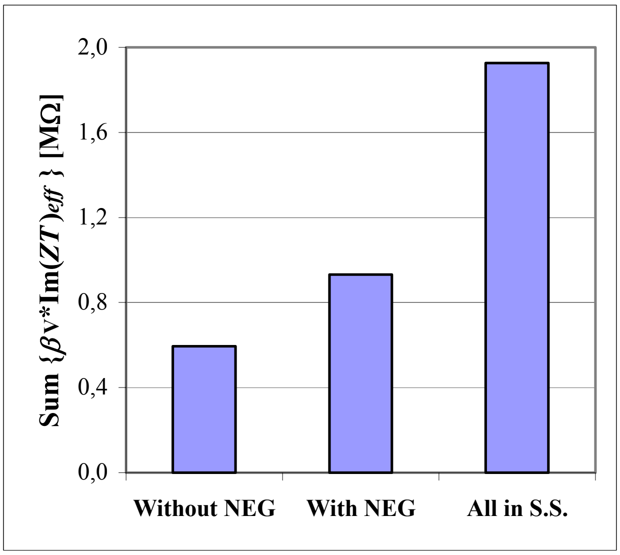


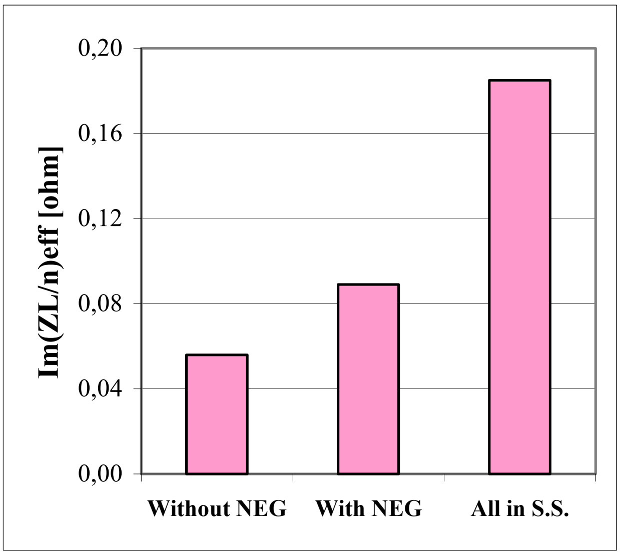
Plot of Im$(Z_{\perp})_{eff}$ versus resistivity ρ and thickness d.

6 Impact on SOLEIL

◊ The following 3 cases are compared:
1) Without NEG coating (Al + SS chambers)
2) With NEG coating (NEG coated Al + SS chambers)
3) All chambers made of S.S. (No NEG)

- ***b*** and ρ values taken according to realistic configuration of the ring
- Coating thickness ***d*** = 1 μm
- $\rho_{NEG} = 50\times10^{-8}$ Ωm (a value already in the saturation)
- β values according to the nominal optics

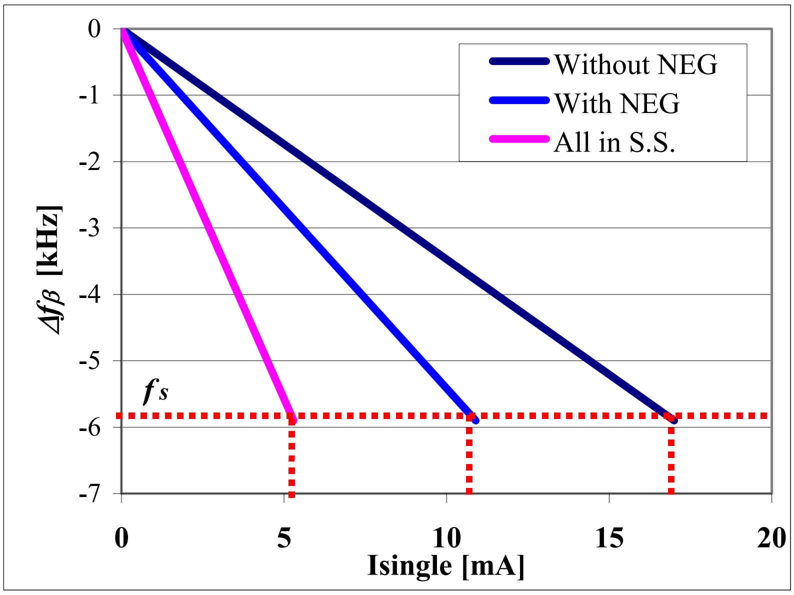




⇒ There is ~50% increase due to NEG in both transverse and longitudinal

◊ Increase of Im*Z* may not a priori be detrimental for instabilities

- RW instabilities should not be sensitive
- Could even be beneficial in the PWD regime
- However, $(I_{th})_{TMCI}$ is expected to decrease proportionally



- Could be harmful in the high current/bunch regime (microwave, post head-tail, …)
- Short range incoherent tune shift may also be affected

7 Conclusion

◊ The NEG coated chamber impedance was estimated with formulae that take into account a metallic layer on the chamber surface.

◊ Found that $\mathrm{Im}(\mathbf{Z})_{eff}$ increases by ~50% with 1 μm coating, while $\mathrm{Re}(\mathbf{Z})_{eff}$ remains roughly unchanged.

◊ Fortunately, $\mathrm{Im}(\mathbf{Z})_{eff}$ saturates rather fast in both ρ and $\boldsymbol{d}$.

◊ The increase of $\mathrm{Im}(\mathbf{Z})_{eff}$ would have a non-negligible impact of reducing $(I_{th})_{TMCI}$ on SOLEIL ring.

◊ To explain the anomalous observation in ELETTRA, one has to assume $\rho \gg \rho_{<elements>}$ and $\boldsymbol{d} \gg 1$ μm.

Acknowledgement

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