Attempt to measure NEG coating effect on impedance

Motivations

Precise transverse impedance measurement are carried out at the ESRF

+

NEG coating is done in-house on a significant number of chambers

⇩

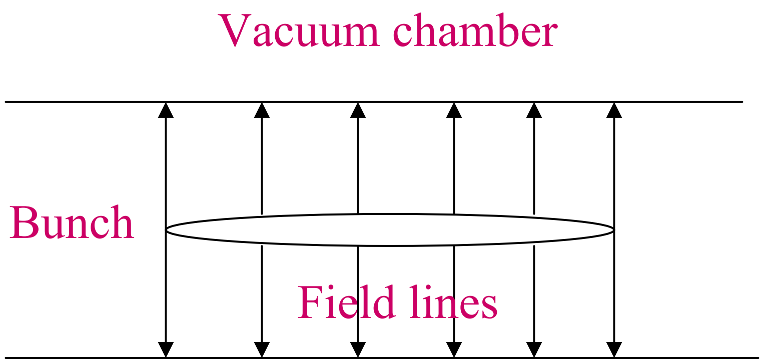
We have a unique opportunity to evaluate NEG influence on Impedance

+

Opportunity to perform comparative measurements at ELETTRA

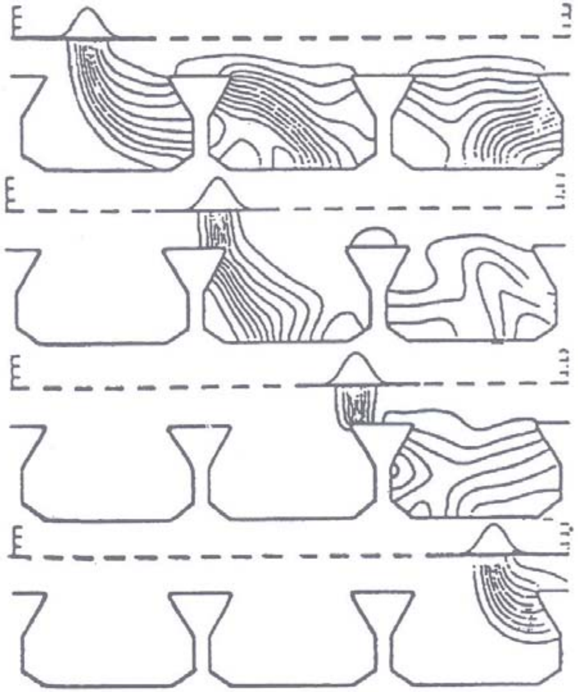
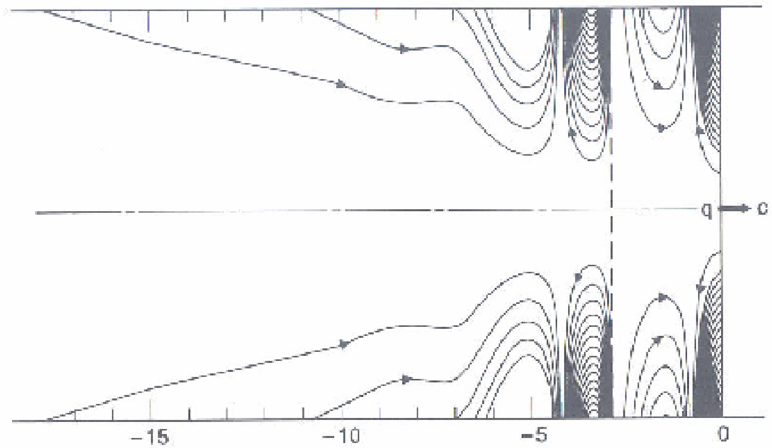
Impedance definition

An ultra relativistic beam circulating in a perfectly conducting round pipe is not subject to coherent forces, particle do not see each other.



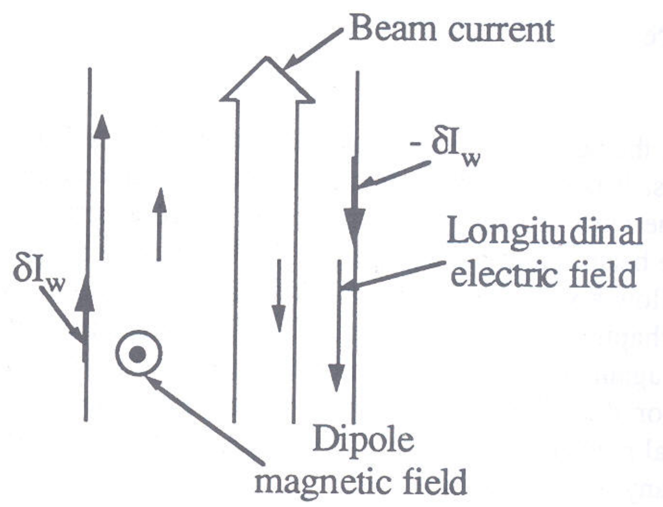
- No longitudinal field.
- Transverse electric force canceled by transverse magnetic force.

In the real world there are two main sources of wake fields:

Discontinuities of the vacuum chamber cross section	Finite conductivity of the chamber walls
	

Transverse impedance definition

If the particle is centered in the vacuum chamber, there is no transverse collective force, but once it is displaced, a transverse magnetic force appears.



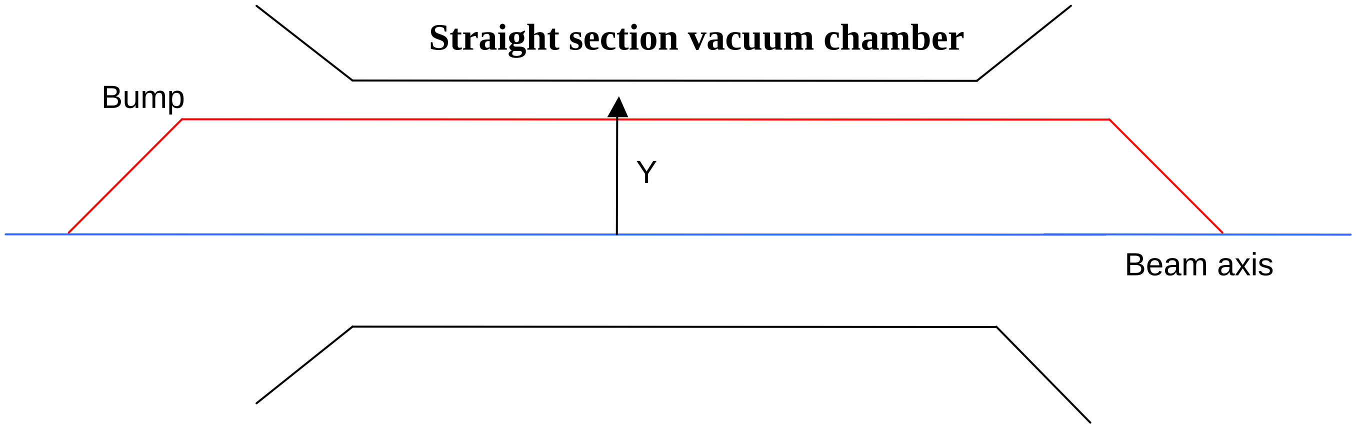
$$Z_{\perp} = \frac{i \times 2\pi \times R}{d} \int_{-\infty}^{+\infty} W(\tau) \times e^{-i\omega\tau} d\tau$$

- d is the transverse offset
- R the ring circumference
- W(τ) the average wake field

Local bump method for Vertical effective impedance measurements

Introduced by : **L.Emery, G.Decker, and J.Galayda at APS and**

V.Kiselev and V.Zorin at BINP



If Z is $\neq 0$ impedance induces a kick to the beam proportional to the displacement Y and the bunch current.

$$\theta_{Kick} = \frac{I \times Y_{Bump}}{2\sqrt{\pi} \times f_0 \times \sigma_\tau \times \left(E/e\right)} \times \Im\left(Z_{\perp eff}\right)$$

Effective impedance of a mode

Definition:

$$Z_{\perp eff} = \frac{\int_{-\infty}^{+\infty} Z_{\perp}(\omega) \times |\sigma(\omega)|^2 \times d\omega}{\int_{-\infty}^{+\infty} |\sigma(\omega)|^2 \times d\omega}$$

In this case σ(ω) is the mode 0 without chromaticity, which corresponds to the longitudinal particle distribution.

The only difference is that no betatron motion is involved. The lines of the spectrum are at the harmonics of the revolution frequency.

Incoherent effects

If the chamber cross section is not round, transverse fields of higher order appear, especially quadrupolar wake fields.

⇩

- Incoherent current dependent tune shift. It does not affect stability issues.

- A particle displaced from its axes will receive a kick proportional to its displacement. If the test and emitting particle have the same displacement the dipolar and quadrupolar effects can not be distinguished.

- The close bump measurement includes quadrupolar effects. It is only an approximated measurement of dipolar impedance.

- In the parallel plate approximation, the ratio between both effects is known for the resistive wall impedance. Numerical simulations showed that these ratios are fairly conserved for broad band impedance in the ESRF case.

	Vertical	Horizontal
$\frac{\langle \Delta Y' \rangle_{dipolar\,\|\,\|}}{\langle \Delta Y' \rangle_{dipolaro}}$	$\pi^2/12$	$\pi^2/24$
$\frac{\langle \Delta Y' \rangle_{Quadrupolar\,\|\,\|}}{\langle \Delta Y' \rangle_{dipolaro}}$	$\pi^2/24$	$-\pi^2/24$
$\frac{\langle \Delta Y' \rangle_{total\,\|\,\|}}{\langle \Delta Y' \rangle_{totalo}}$	$\pi^2/8$	0

Measurement sequence

Single bunch high current closed orbit

–

Zero current closed orbit

=

Closed orbit distortion due to impedance kick

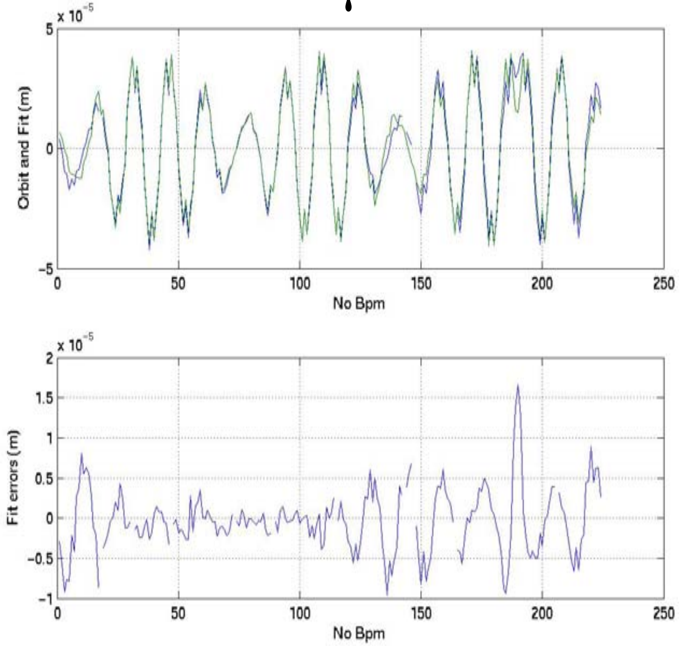
The closed orbit distortion due to the impedance kick can be fitted using response matrices. The fit gives the strength of the kick.

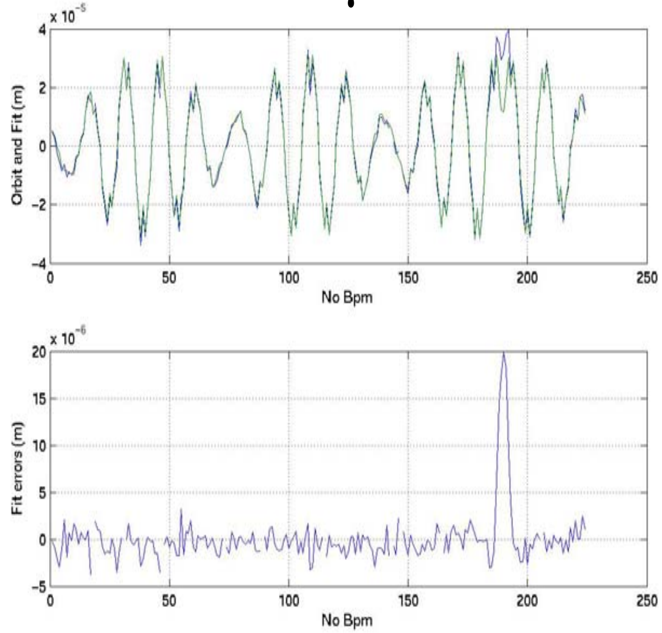
Correction schemes

Bump correction
Error=2-5µm

+

Parasitic impedance corrections
Error < 2µm

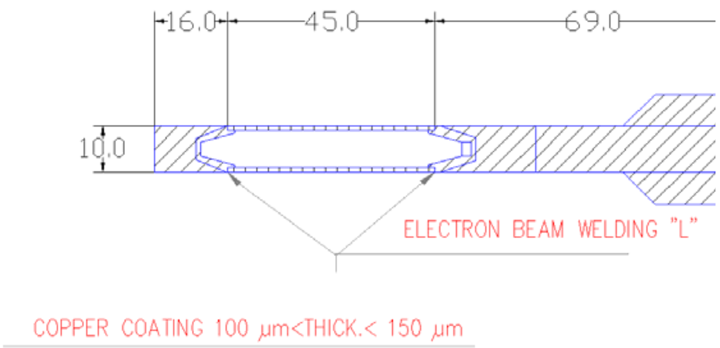




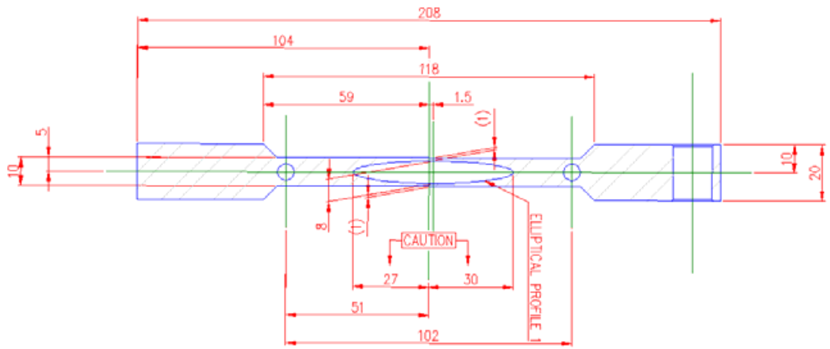
- Reproducibility of a few kΩ/m
- Overall precision of about 10 kΩ/m

Straight section vacuum chambers

8 mm stainless steel, NEG and copper coated
5m long

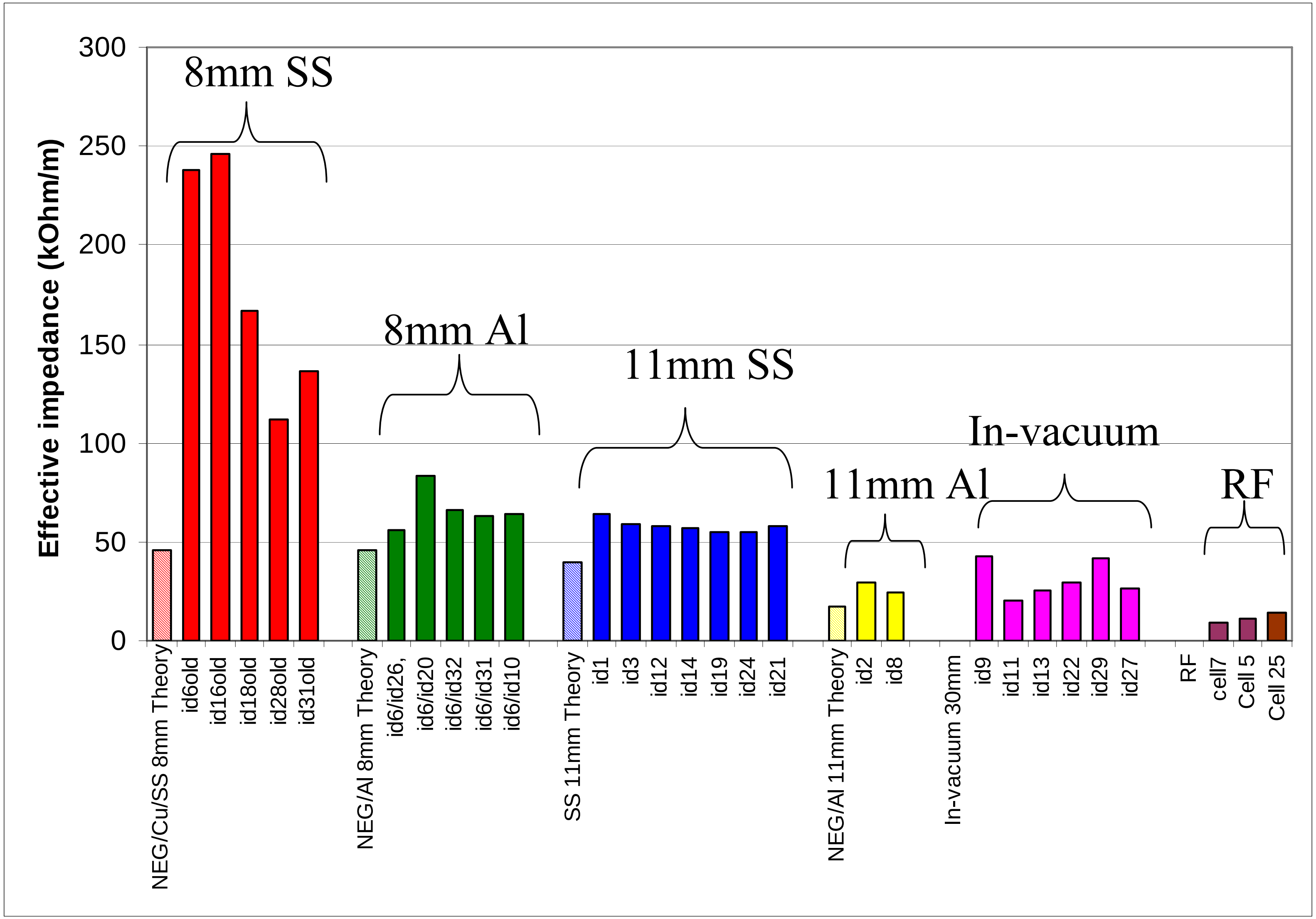


8mm aluminum NEG coated
5m long



- 11mm stainless steel
- 11mm aluminum
- In-vacuum insertion devices
- RF cavities

Results



Effective impedance (kOhm/m)
300
250
200
150
100
50
0
8mm SS
8mm Al
11mm SS
11mm Al
In-vacuum
RF
NEG/Cu/SS 8mm Theory
id6old
id16old
id18old
id28old
id31old
NEG/Al 8mm Theory
id6/id26,
id6/id20
id6/id32
id6/id31
id6/id10
SS 11mm Theory
id1
id3
id12
id14
id19
id24
id21
NEG/Al 11mm Theory
id2
id8
In-vacuum 30mm
id9
id11
id13
id22
id29
id27
RF
cell7
Cell 5
Cell 25

Characterization of NEG coating

NEG coating has been a great step in the vacuum technology for accelerators.

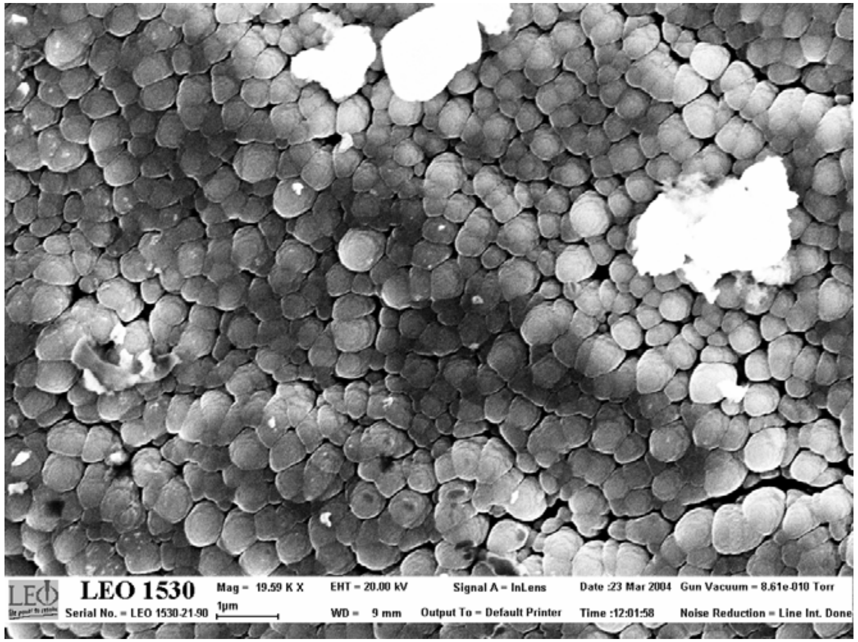
⇩

In term of impedance the coating has two effects, because of its roughness and because of its bad conductivity.

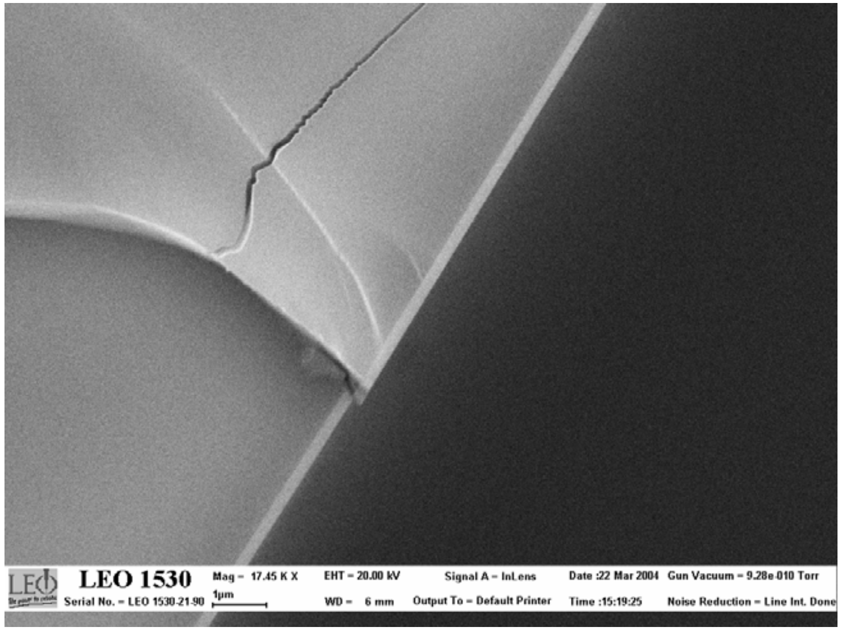
⇩

What is the influence of the NEG layer on the low gap chamber impedance installed at the ESRF?

Roughness characterization

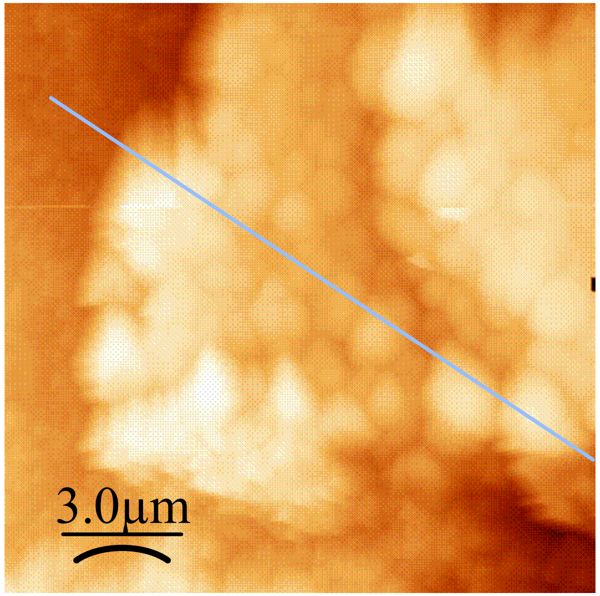


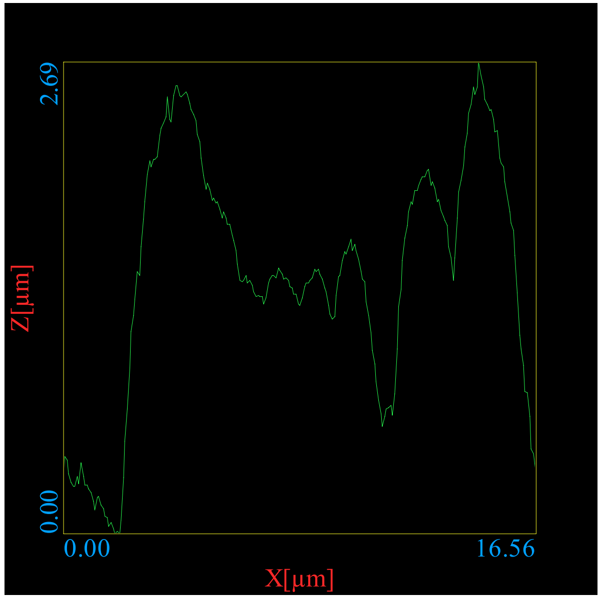
NEG on Al



NEG on Si

Courtesy of Irina SNIGIREVA, Technical beamline, ESRF.





Courtesy of Emilie DUBARD, SSL lab, ESRF

The roughness is impressive but should not have a significant effect on bunches with a length of the order of 5mm.

Resistive effects

Using the formulas of A. Burov and V. Lebedev for two layers chambers:

- ESRF Al chambers (5m long and 8mm gap) Zeff =46 kΩ/m :
  The NEG should increase the result by **10 kΩ/m**.

- ELETTRA chambers (5m long 14 mm gap) Zeff ≈10kΩ/m :
  The NEG should increase the result by **1-2 kΩ/m.**

Thickness of the NEG layer=1µm ρ_{NEG}=350 10^{-8} Ω/m

Elettra measurements

Measurement could be done on cell 2 before and after the coating of an aluminum chamber. Could also be done on various types of chambers installed on other cells.

Cell	Chamber type	Length (m)	Inner gap(mm)	Result1 (kOhm/m)	Result2 (kOhm/m)
2	Al NEG	4,8	14	51±6	44,1±6
2	Al	4,8	14	47±5,5	
1	Al	4,8	14	43,5±5,5	38,1±5,5
8	Al	4,8	14	36,5±5	23,1±5
5	SS	4,8	15	29±5	24,1±5
6	SS	4,8	20	10±3,5	
7	Al NEG	3	14	34,5±7	30±5
9	Al NEG	4,8	14	14,5±5	12±5
11	CU	1,5	11		11±5

No clear conclusions can be drawn except that the NEG layer effect is not dominating the chamber impedance. From the measurement of cells 1, 2, and 7 we can expect it to be less than 10 kΩ/m.

ESRF measurements

Coating is done in-house on aluminum chambers. Parameters can be controlled.

Overall effect of 1µm NEG layer

0.5 µm layer (5 measurements): Zeff=58 kΩ/m

=10-16 kΩ/m (factor 1-1.5)

1µm layer (12 measurements): Z_{eff}=63-66 kΩ/m

=31-34 kΩ/m (factor 3-3.5)

2 µm layer (1 measurement): Zeff=97 kΩ/m
Not coated in house

No clear measurement of the thickness is available.

Conclusions

- The overall effect can be explained within a factor 3 by resistive effects (roughness??).

- The thickness parameter is not well known and is a key parameter.

- The effect of a 0.5µm layer is small compared to the overall impedance of an ESRF chamber .

- Mastering the thickness is the key to reduce the effects of impedance without spoiling the vacuum properties of the layer.

Acknoledgements:

-L.Farvacque and E.Plouviez for the set up of the bump method.

-E.Karantzoulis who gave us machine time on the ELETTRA storage ring.

-R. Nagaoka who took part in the ELETTRA measurements and for all the useful discussions we had about impedance effects.

Bibliography:

[1] L. Emery, G. Decker and J. Galayda, "Local Bump Method for Measurement of Transverse Impedance of Narow Gap ID Chambers In Storage Rings. In PAC 2002 proceedings, Chicago (2001).

[2] A. Burov and V.Lebved, "Transverse resistive Wall Impedance for Flat Cambers". In EPAC 2002 proceedings, Paris (2002).

[3] G. V. Stupakov, "Surface roughness Impedance", Stanford Linear Accelerator Center, CA 94309.

[4] K. L. F. Bane, C.K. Ng and A.W. Chao "Estimation of impedance due to surface roughness", SLAC-PUB –7514 May 1997.

[5] R. Nagaoka, Private communications.