Resistive Effects in Ceramic Kicker Chamber.
Roughness Effects in Undulator Chamber.

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DESY, 16 April 2007

Topics

- Impedance Structure Investigation for Ceramic Kicker Vacuum Chamber with metallic coats.
- Resistive and Geometrical Wakes.
- Influence of Surface Roughness in Undulator Chamber on the Beam.

Impedance Structure Investigation of Ceramic Kicker Vacuum Chamber with Metallic Coats.

Longitudinal Impedance. Monopole term.

$$Z(k) = -\frac{jZ_0}{\pi k U}$$

$$U = a_2^2 - 2\frac{a_2\varepsilon_3}{\chi_3\varepsilon_0} \times \frac{\varepsilon_3\chi_4 R_4(a_3)S_3'(a_2) - \varepsilon_4\chi_3 R_3'(a_2)R_4'(a_3)}{\varepsilon_3\chi_4 R_4(a_3)S_3(a_2) - \varepsilon_4\chi_3 R_3(a_2)R_4'(a_3)}$$

R, R', S, S' - combination of Bessel functions.

Single layer cylindrical tube

$$U = a^2 - 2\frac{a\varepsilon}{\varepsilon_0\chi}\frac{K_0(\chi b)I_1(\chi a) + I_0(\chi b)K_1(\chi a)}{K_0(\chi b)I_0(\chi a) - I_0(\chi b)K_0(\chi a)}$$

M. Ivanyan, V. Tsakanov, Phys. Rev. ST-AB, 2004

Metallic type layers

$$\varepsilon_i = \varepsilon_0 - j\sigma_i/\omega \qquad \chi_i = \sqrt{j\mu_0\sigma_i\omega}$$

Good approximation - the smallness of each layer skin depth with respect to the layer inner radius $\delta_i / a_i << 1$

$$U = a^2 - 2\frac{a\varepsilon_3}{\varepsilon_0\chi_3} \times \frac{1 + \alpha th\chi_3 d_3 th\chi_4 d_4}{th\chi_3 d_3 + \alpha th\chi_4 d_4}$$

$$|a_2\chi_3| >> 1$$

$$\alpha \approx (\sigma_3/\sigma_4)^{1/2}$$

Single layer tube $\alpha = 1$

$$U = a^2 - 2\frac{a\varepsilon}{\varepsilon_0\chi} cth\chi d$$

Ceramic type layers with metallic coats

Good approximation:

$|a_2\chi_3| >> 1$ *Metallic layer* $\varepsilon_3 = \varepsilon_0 - j\frac{\sigma}{ck}$ $\chi_3 = \sqrt{jc\mu_0\sigma k}$

$|a_3\chi_4| >> 1$ *Ceramic layer* $\varepsilon_4 = \varepsilon_0 n^2$ $\chi_4 = jk\sqrt{n^2 - 1}$

$$n' = \sqrt{n^2 - 1}$$

$$* \quad U = a^2 + 2\frac{a\varepsilon_3}{\varepsilon_0\chi_3} \times \frac{1 - j\alpha\, th(\chi_3 d_3) th(kn'd_4)}{th(\chi_3 d_3) - j\alpha\, th(kn'd_4)}$$

$$\alpha = \frac{\chi_4}{\chi_3}\frac{\varepsilon_3}{\varepsilon_4}$$

$$U = a^2 + 2\frac{a\varepsilon_3}{\varepsilon_0\chi_3} cth(\chi_3 d_3) \qquad kn'd_4 = \pi l$$

$$l \in N$$

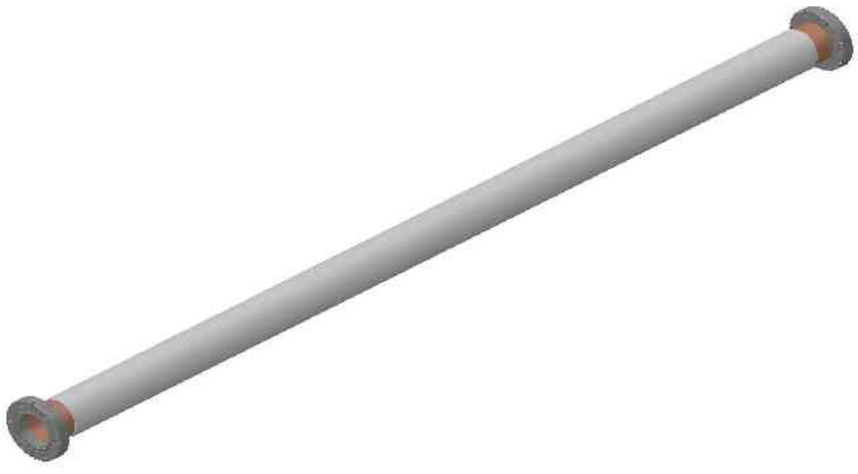
$$U = a^2 + 2\frac{a\varepsilon_3}{\varepsilon_0\chi_3} th(\chi_3 d_3) \qquad kn'd_4 = \frac{\pi}{2} + \pi l$$

Actually for all the practical applications, the formula (*) is valid and well approximates the exact solution.

Numerical Examples

Ceramic Kicker Vacuum chamber:

Ceramic with Titanium-Stabilized High Gradient Steel (TSHGS) coats



Vacuum Chamber Parameters

Radius - 0.01 m

Lenght - 0.9 m

TSHGS Parameters →

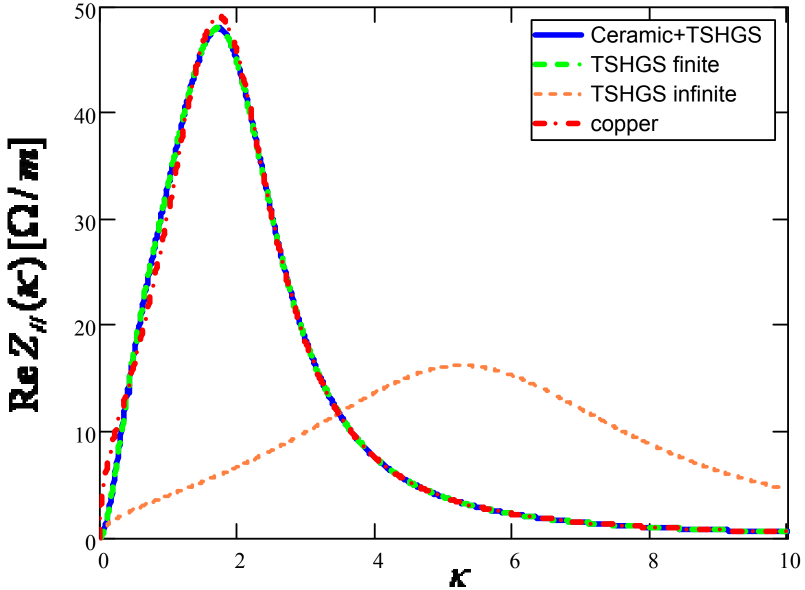
Thickness - 0.7 μm

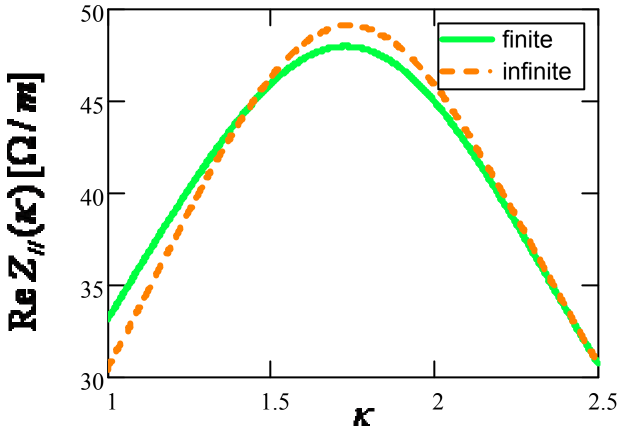
Resistance - $R/L = 10 - 12\ \Omega m^{-1}$

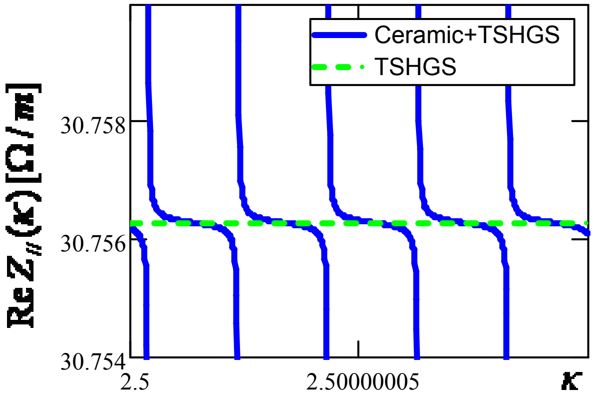
$\sigma \approx (2.0841 \pm 0.18946) \times 10^{6}\ \Omega^{-1} m^{-1}$

Parameters from T. Wohlenberg

Longitudinal Impedance Per Unit Length. Monopole term.







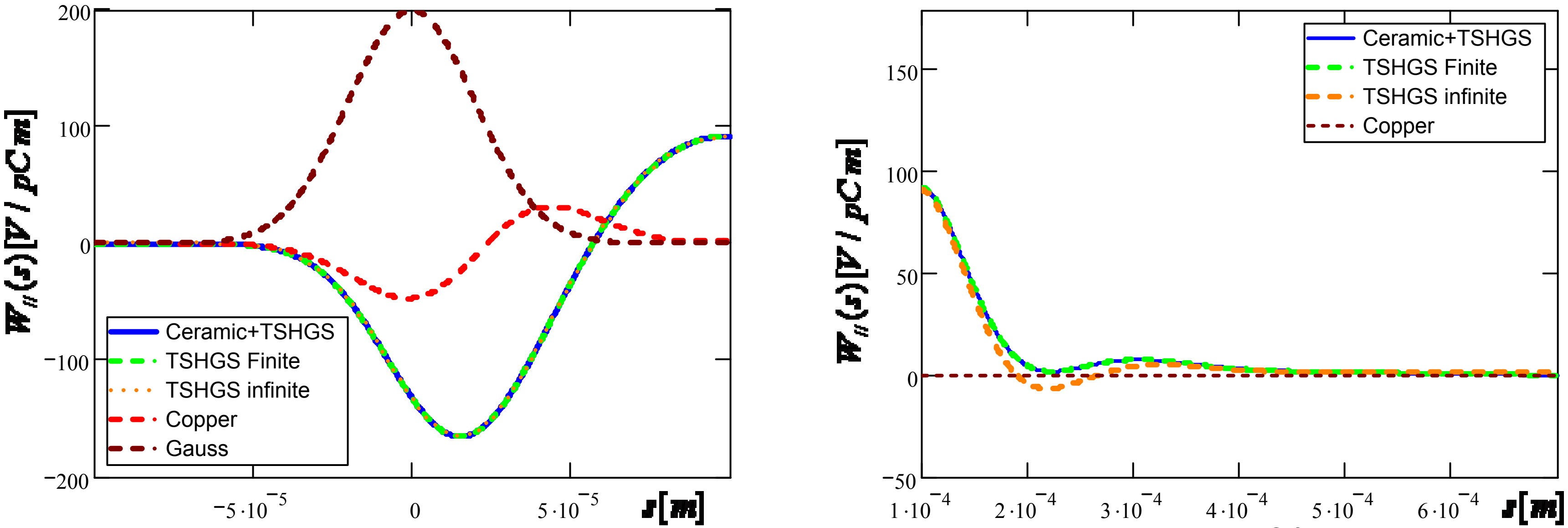
Longitudinal monopole impedance as function of dimensionless wave number $\kappa = k \cdot s_0$ for several cases of vacuum chamber material:

1. Ceramic with TSHGS coats.
2. TSHGS single layer tube with finite and infinite thickness.
3. Copper single layer tube.

$$\kappa = k s_0$$

s_0 characteristic distance: $s_0 = \left(2ca^2\varepsilon_0/\sigma\right)^{1/3} \approx 63.4\,\mu m$

Resistive Wall Wakes



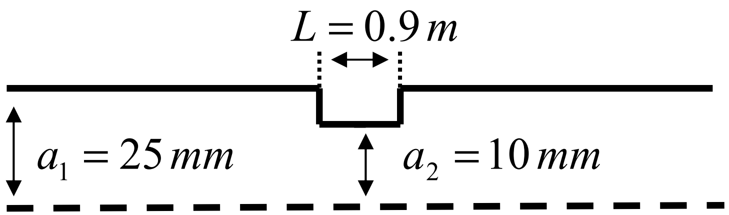
Resistive wall longitudinal wake potentials of Gaussian bunch with $\sigma_b = 20\,\mu m$ for several cases of vacuum chamber material:

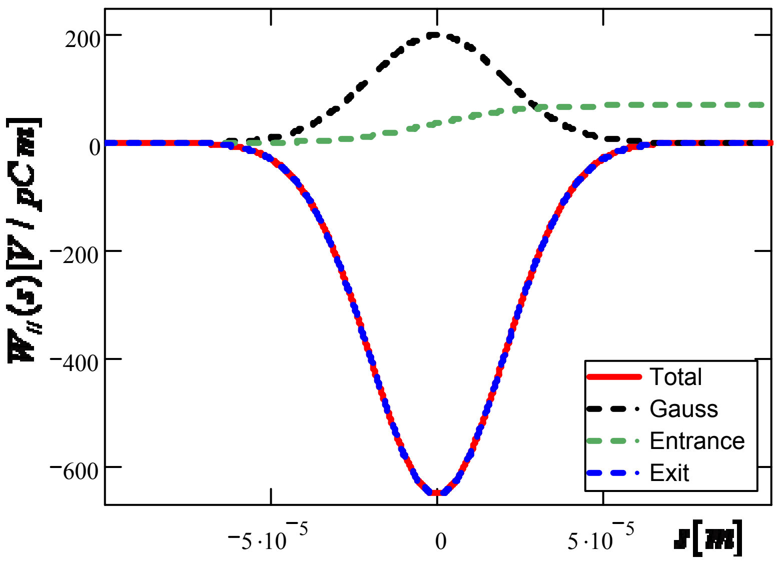
1. Ceramic with TSHGS coats.
2. TSHGS single layer tube with finite and infinite thickness.
3. Copper single layer tube.

$$E = 17.5\,GeV$$

	Ceramic+TSHGS	TSHGS	Copper
Loss Factor[kV / nC]	-108.43	-108.4	-26.29
Energy Spread [%]	0.288	0.288	0.12

Geometrical Wakes



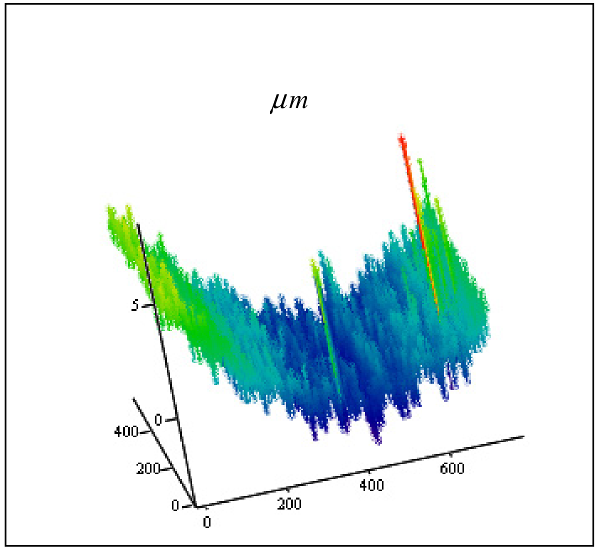


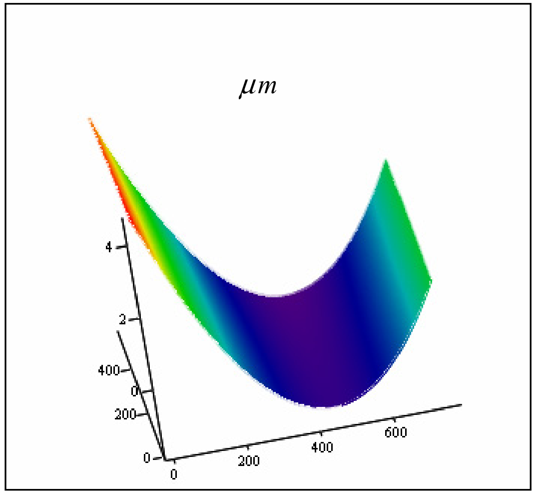
Geometrical longitudinal wake potentials of Gaussian bunch $\sigma_b = 20\,\mu m$

$E = 17.5\,GeV$

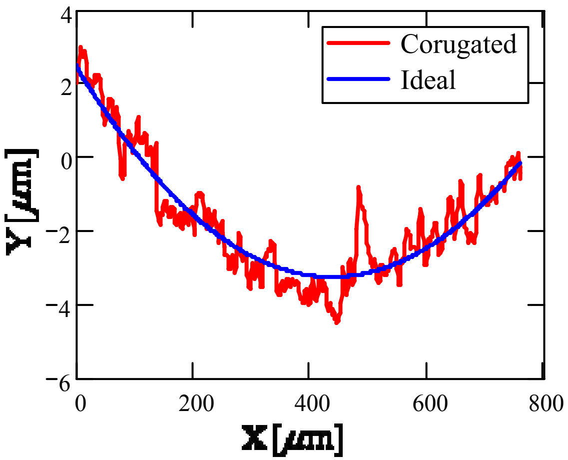
	Entrance	Exit	Total
Loss Factor[kV / nC]	0.36	-462.39	-462.1
Energy Spread [%]	1.12*10^(-3)	1.057	1.058

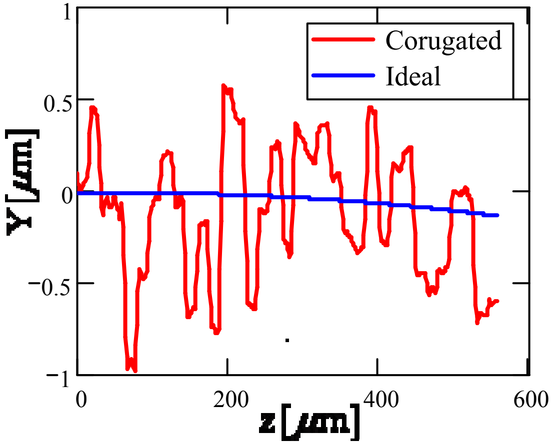
Surface Roughness in Undulator Section





R.m.s. distortion $\Delta \approx 0.568\ \mu m$





Measurement data from T. Wohlenberg

$$Z(\omega) = \frac{Z_s(\omega)}{2\pi R}\left[1 + i\frac{\omega}{c}\frac{R}{2}\frac{Z_s(\omega)}{Z_0}\right]^{-1}$$

$\sigma = 58\times10^{6}\,\Omega^{-1}\mathrm{m}^{-1}$

$R = 4.4\,mm$

Surface Impedance

$$Z_s(\omega) = Z_s^{\sigma}(\omega) + Z_s^{L}(\omega)$$

where

$$Z_s^{\sigma}(\omega) \approx \sqrt{\frac{i\omega\mu}{\sigma(\omega)}}$$

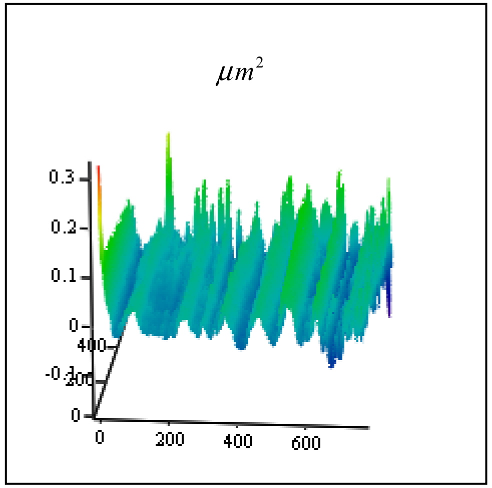
$$Z_s^{L}(\omega) \approx i\omega L$$

Inductance define as

$$L = \frac{Z_0}{2\pi c a}\int dk_x dk_z \widetilde{R}(k_x,k_z)\frac{k_z^2}{\sqrt{k_x^2+k_z^2}}$$

Where $\widetilde{R}(k_x,k_z)$ is *spectral density* defined as Fourier Transformation of *Autocorrelation* function:

$$R(x,z) = \frac{1}{A(x,z)}\int_{A(x,z)}[\delta r(\hat{x},\hat{z})\delta r(\hat{x}-x,\hat{z}-z)]d\hat{x}d\hat{z}$$

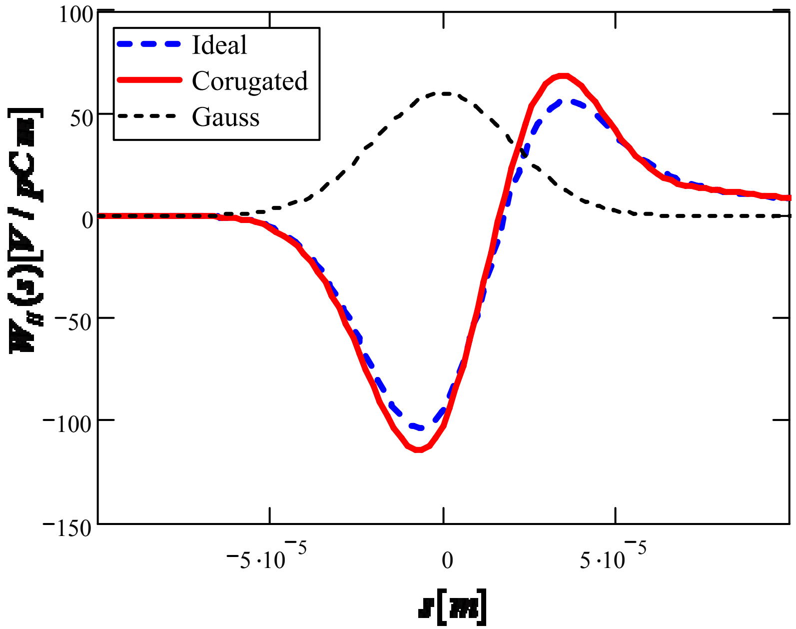


G.V.Stupakov, SLAC-PUB-8208, 1999

M.Dohlus, M.I. Ivanyan, V.M. Tsakanov, TESLA-FEL 2000-26,2000

M.Dohlus. TESLA 2001-26, 2001

Wake Potential of Corrugated pipe



	Ideal	Corugated
Loss Factor [kV / nC]	-50.698	-52.703
Energy Spread [%]	0.286	0.33

R.m.s. value of the roughness in μm

	AL_AU	AL_CU	AL_ELP	AL_UNB	AL_GEB
Meas. 1	0.568	0.371	0.395	0.567	2.835
Meas. 2	0.547	0.745	0.360	0.520	------------
Meas. 3	0.514	0.418	0.346	0.457	------------

Arithmetical Mean Roughness Ra $[\mu m]$

	AL_AU	AL_CU	AL_ELP	AL_UNB	AL_GEB
Meas. 1	0.425	0.288	0.312	0.463	2.202
Meas. 2	0.430	0.362	0.285	0.418	------------
Meas. 3	0.410	0.333	0.274	0.356	------------

Abbreviations

AU	Gold
CU	Copper
ELP	Electro polish
UNB	Untreated (Unbehandelt)
GEB	Etched (Gebeizt)

Summary

- Impedance Structure for Ceramic Kicker Vacuum Chamber was Investigated. For Kicker was shown that Wake Potential for two layer tube can be estimated by single layer tube formula.
- Was analyzed the transition Wakes influence on the beam.
- Influence of surface corrugation in Undulator vacuum chamber on the beam was calculated.

Acknowledgements:

Thanks to Martin Dohlus, I. Zagorodnov,T. Wohlenberg, M. Ivanyan and V. Tsakanov for stimulating discussions.