CANDLE –DESY-PSI

COLLABORATION WORKSHOP

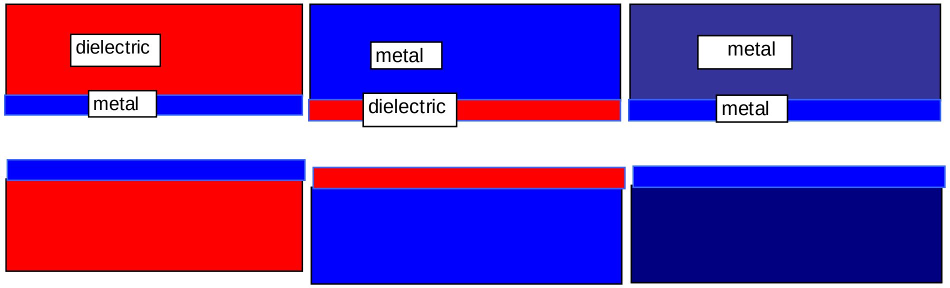
Impedances and Wakes in Beam Distribution and Undulator Sections for XFEL

M. Ivanyan, (CANDLE, Armenia).

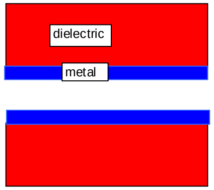
Center for the Advancement of Natural Discoveries using Light Emission

CONTENT

1. Introduction
2. Metallized ceramic vacuum chamber
   (kicker magnet vacuum chamber of XFEL)
3. Metallic undulator vacuum chamber with the inner dielectric cover (model of the surface roughness)
4. Metallic chamber with the inner NEG cover
5. Surface impedance

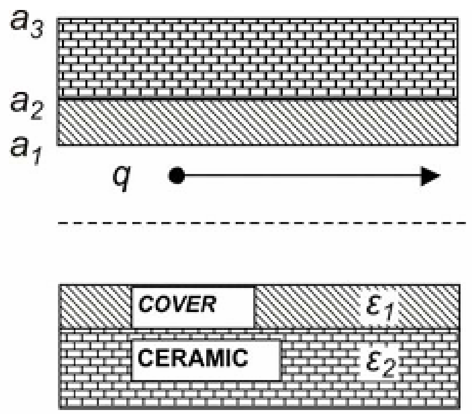


M.Ivanyan, E.Laziev, A.Tsakanian, V.Tsakanov, A.Vardanyan, S.Heifets, Multi-layer Tube Impedance and External Radiation, PRST-AB, 11, 084001 (2008).



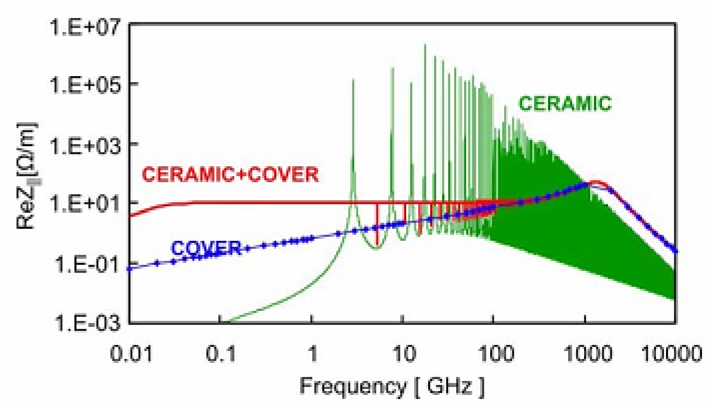
Dielectric-metal walls

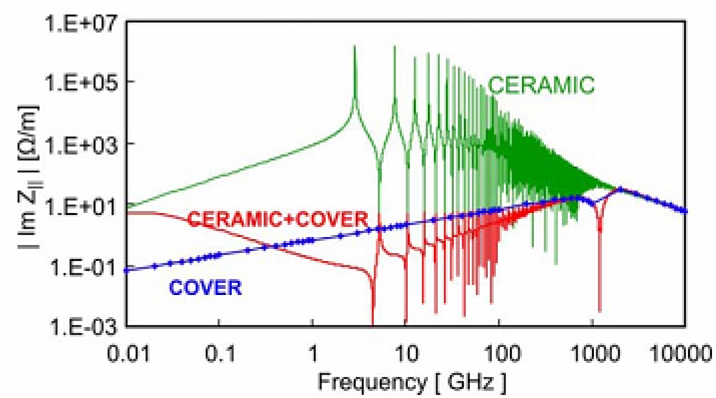
CERAMIC - METAL ROUND TUBE



LONGITUDINAL AND TRANSVERSE IMPEDANCES OF XFEL KICKERVACUUM CHAMBER

Longitudinal impedance





$$a_1 = 10mm$$

$$a_2 - a_1 = 0.7\mu m$$

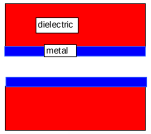
$$\varepsilon_2 = 9.1\varepsilon_0\left(1 + j10^{-4}\right)$$

$$\sigma_1 = 2\cdot 10^6\Omega^{-1}m^{-1}$$

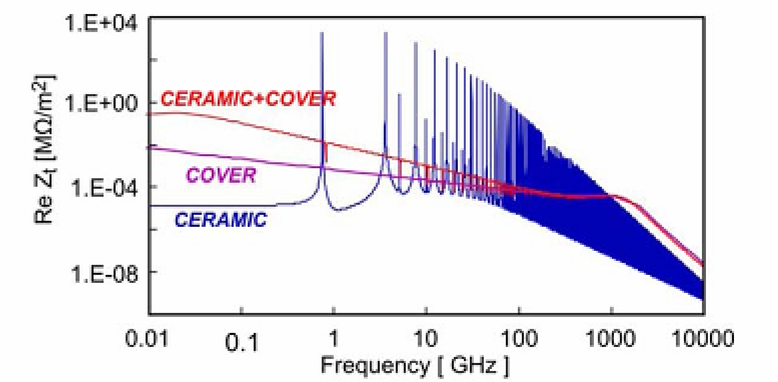
COVER:

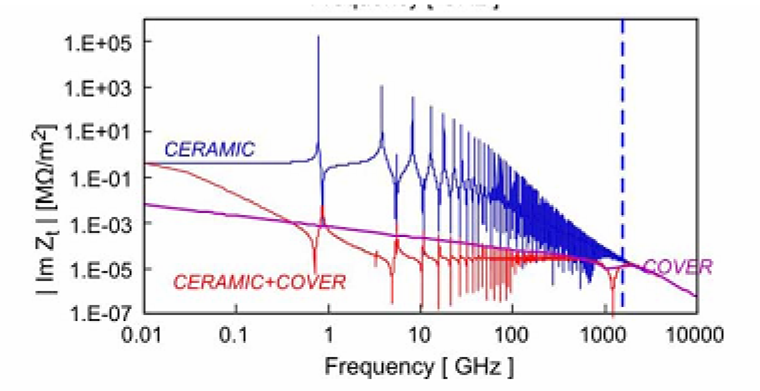
Titanium-Stabilized High-Grade Steel

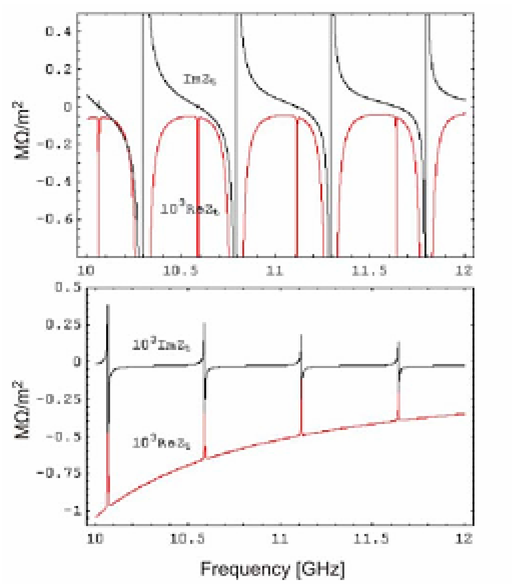
(TSHGS) of 0.7 μm thickness.



TRANSVERSE IMPEDANCE

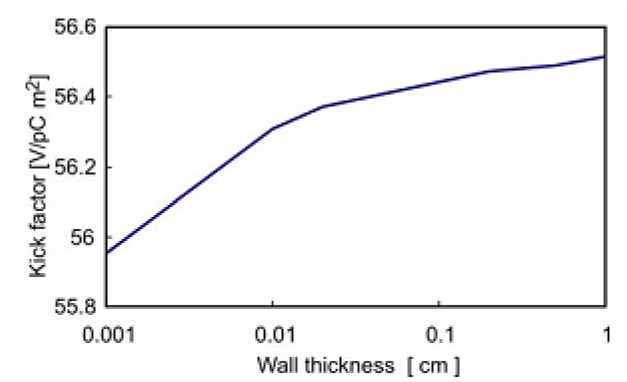


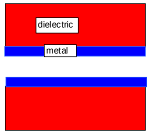




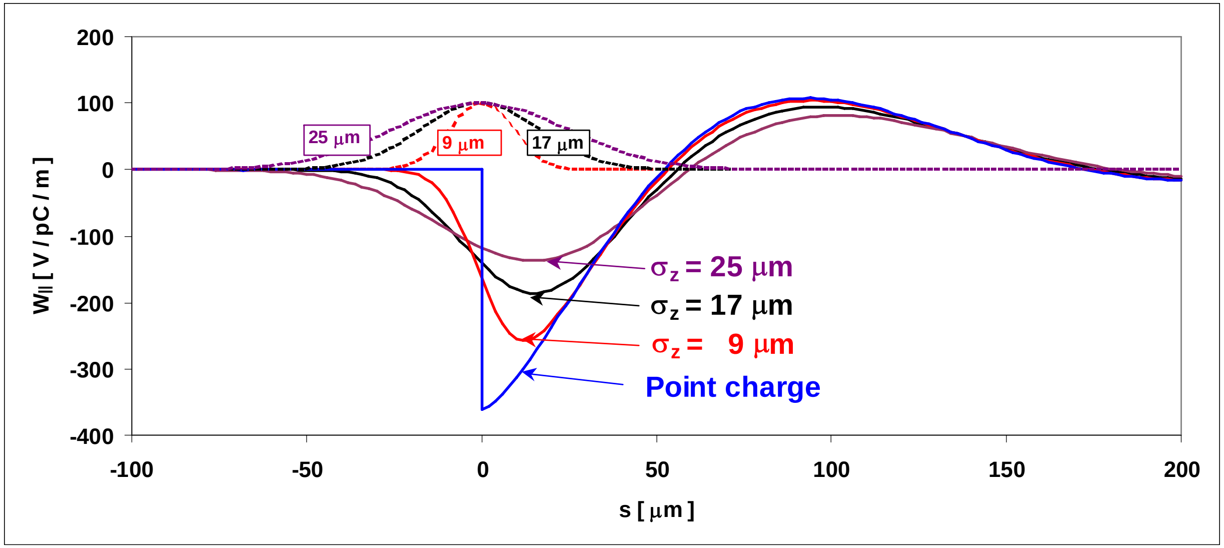
Fine structure

Kick - factor





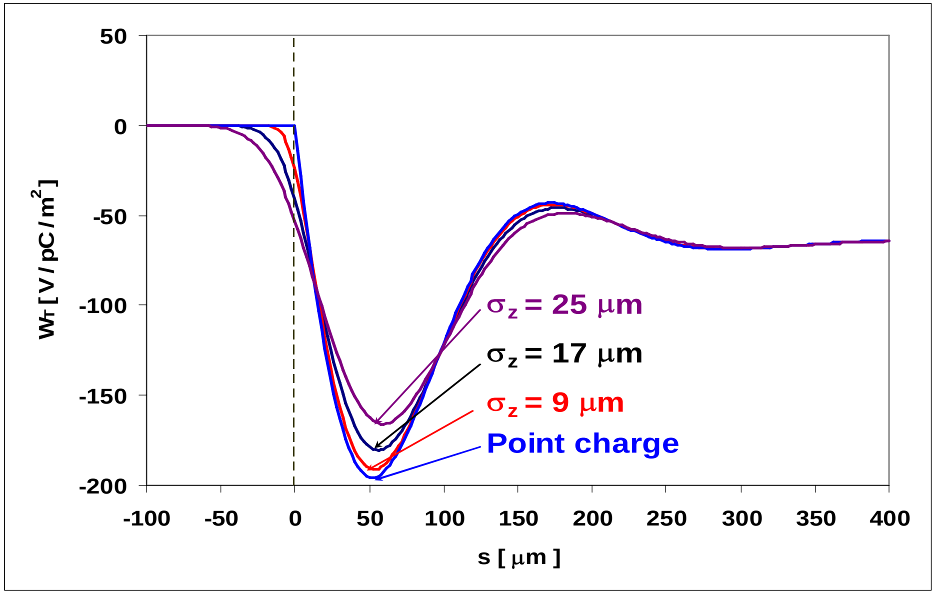
WAKEFIELDS



LONGITUDINAL

A. V. Tsakanian, J. Rossbach, M. Ivanyan, Wake Fields and Impedances of XFEL Kicker Vacuum Chamber, Presented to EPAC2008, Genova, Italy, June 23-28, 2008; ID: 3734

TRANSVERSE



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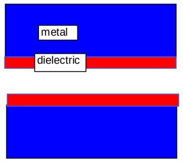
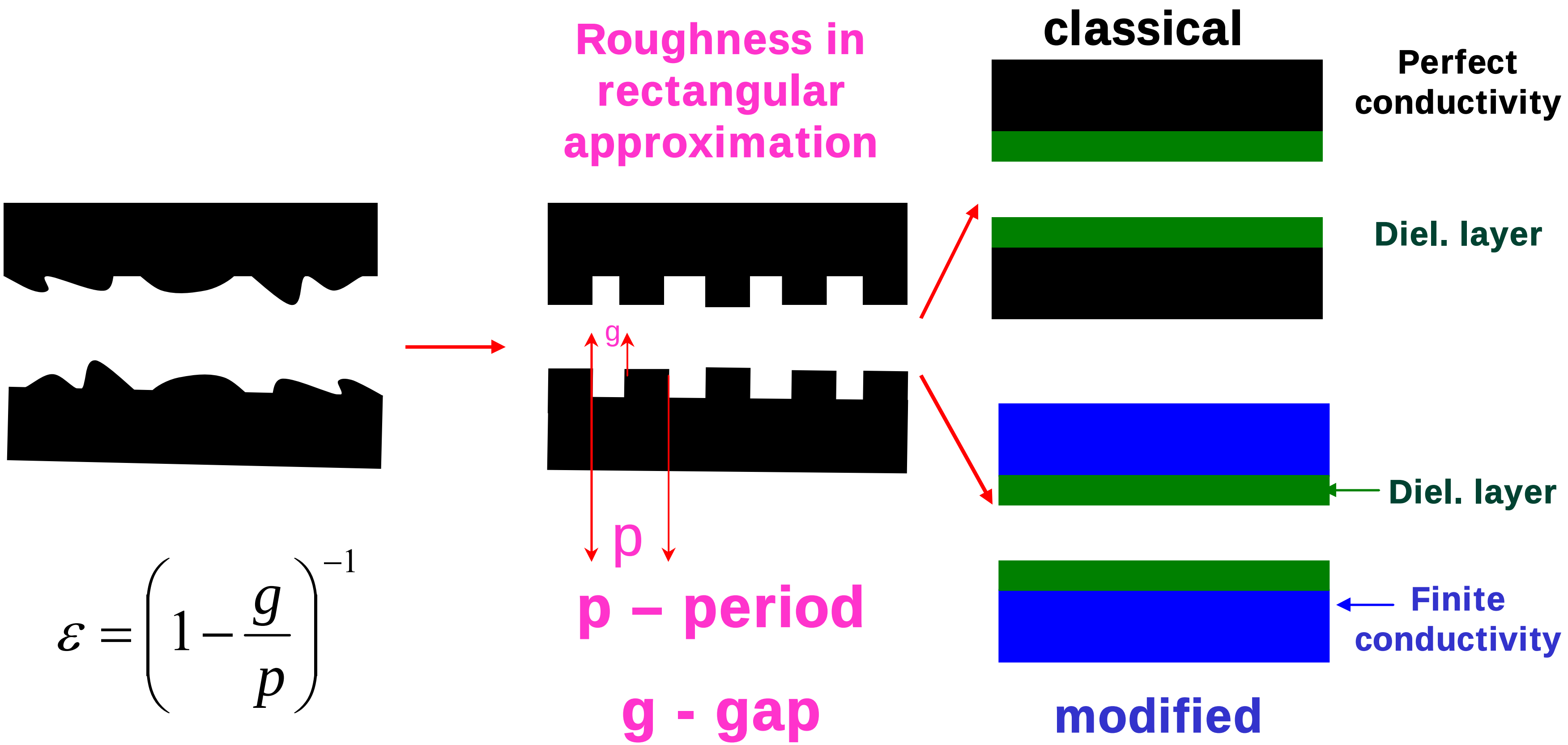
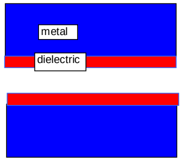
The roughness wake fields in undulator of XFEL. Modified NTW model



NTW – Novokhatskii - Timm - Weiland



$$\varepsilon = \left(1 - \frac{g}{p}\right)^{-1}$$



Examples

Investigation is performed for the SwissFEL undulator vacuum chamber

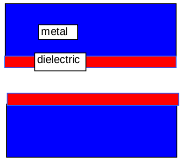
Material - Al

Round tube approximation

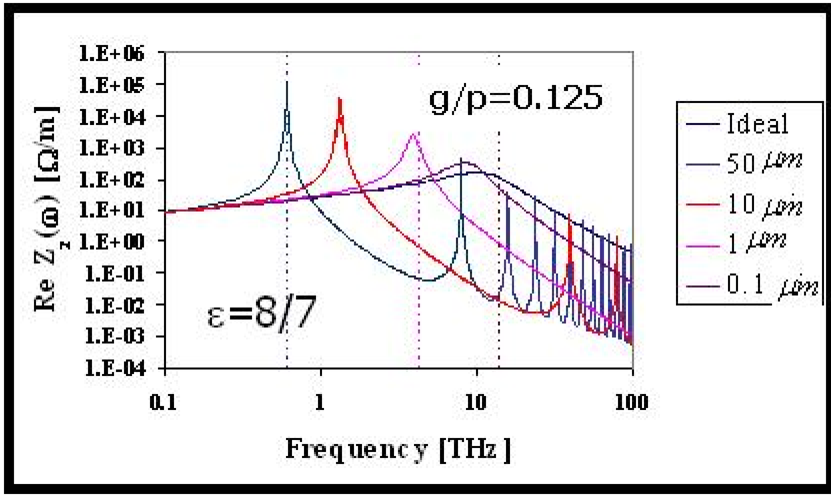
$$k_0 = \sqrt{\frac{2\varepsilon}{(\varepsilon - 1) b \delta}}$$

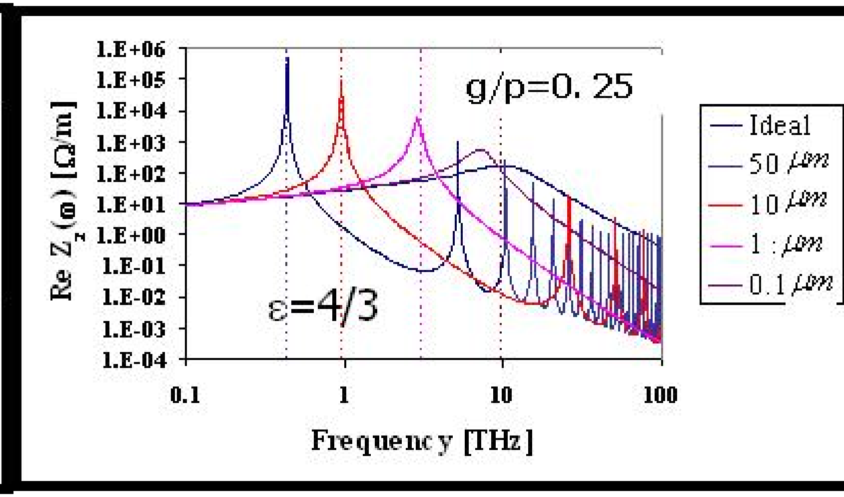
← Resonance wave number

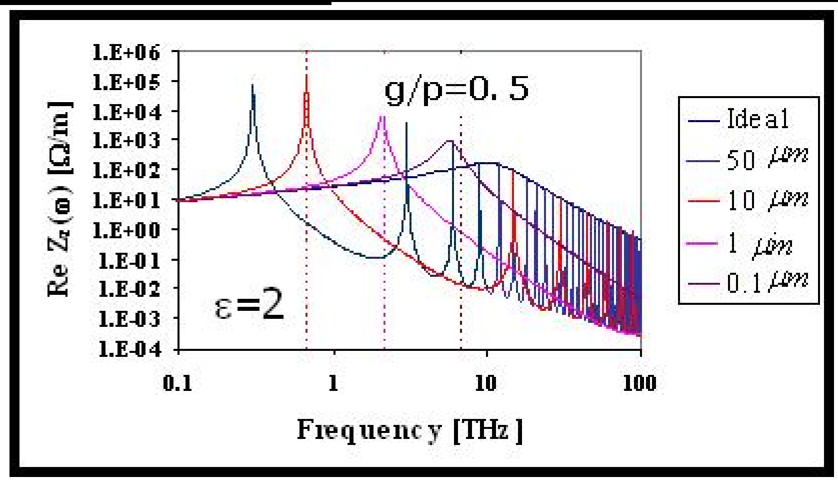
b – inner radius, δ – depth of roughness



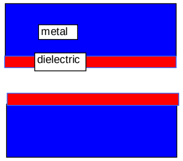
Longitudinal Impedance



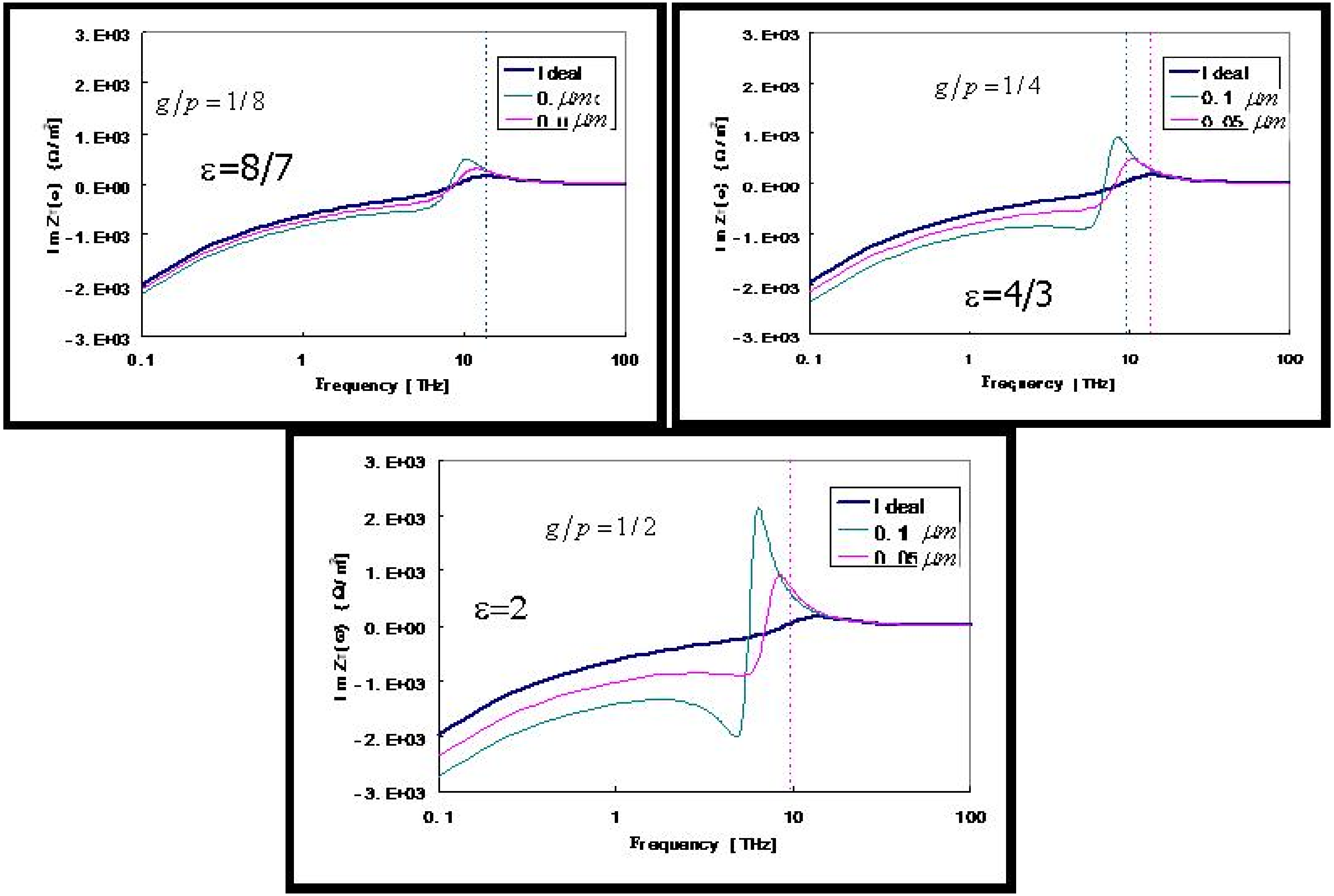




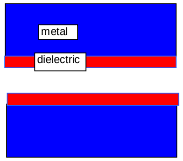
$$\varepsilon = \left(1 - \frac{g}{p}\right)^{-1}$$



Transverse Impedance



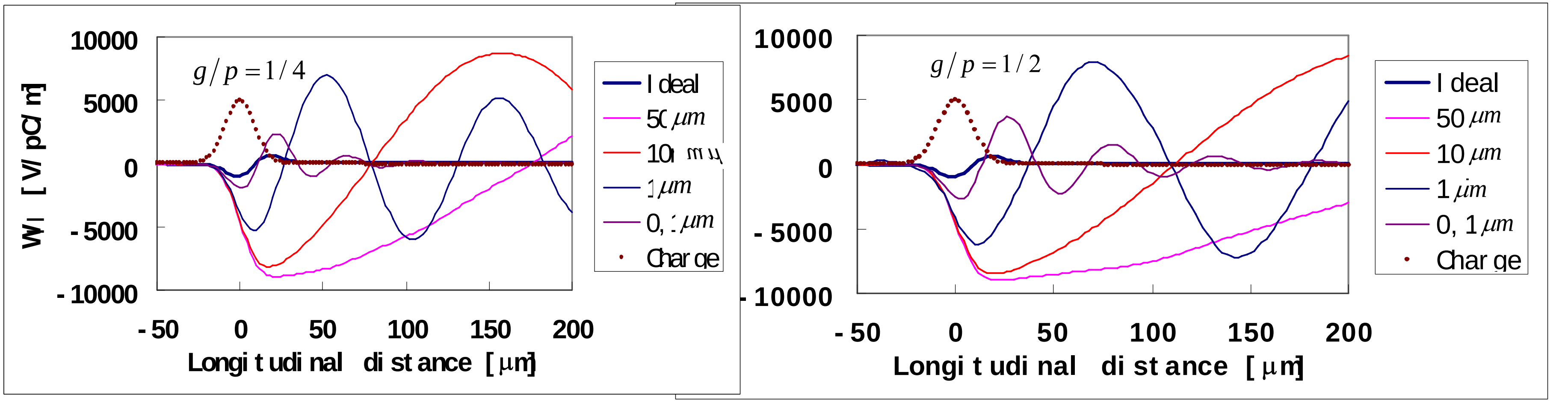
Center for the **A**dvancement of **N**atural **D**iscoveries using **L**ight **E**mission

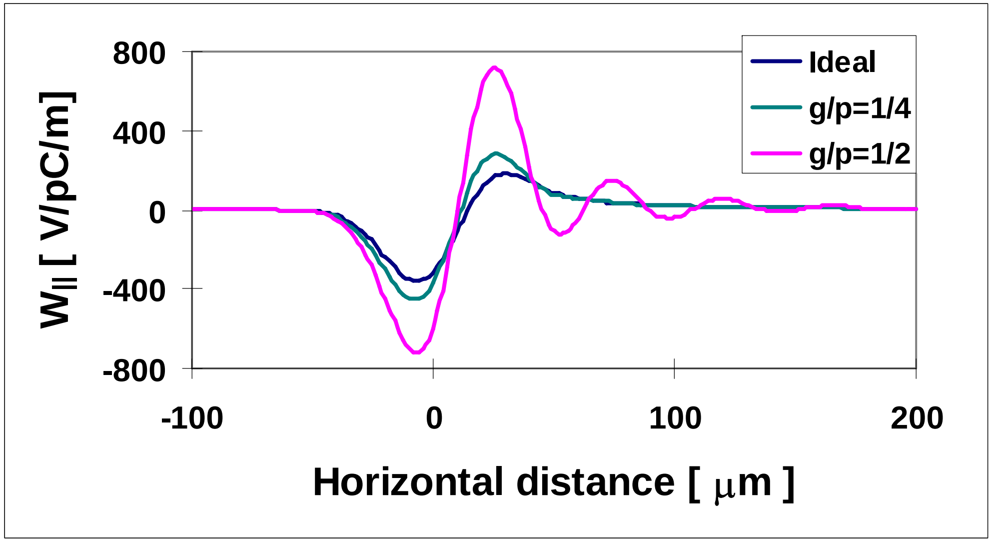


Longitudinal Wakefunction

$\sigma_z = 9\mu m$

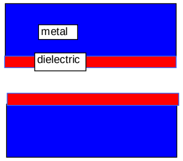
Aluminum vacuum chamber.





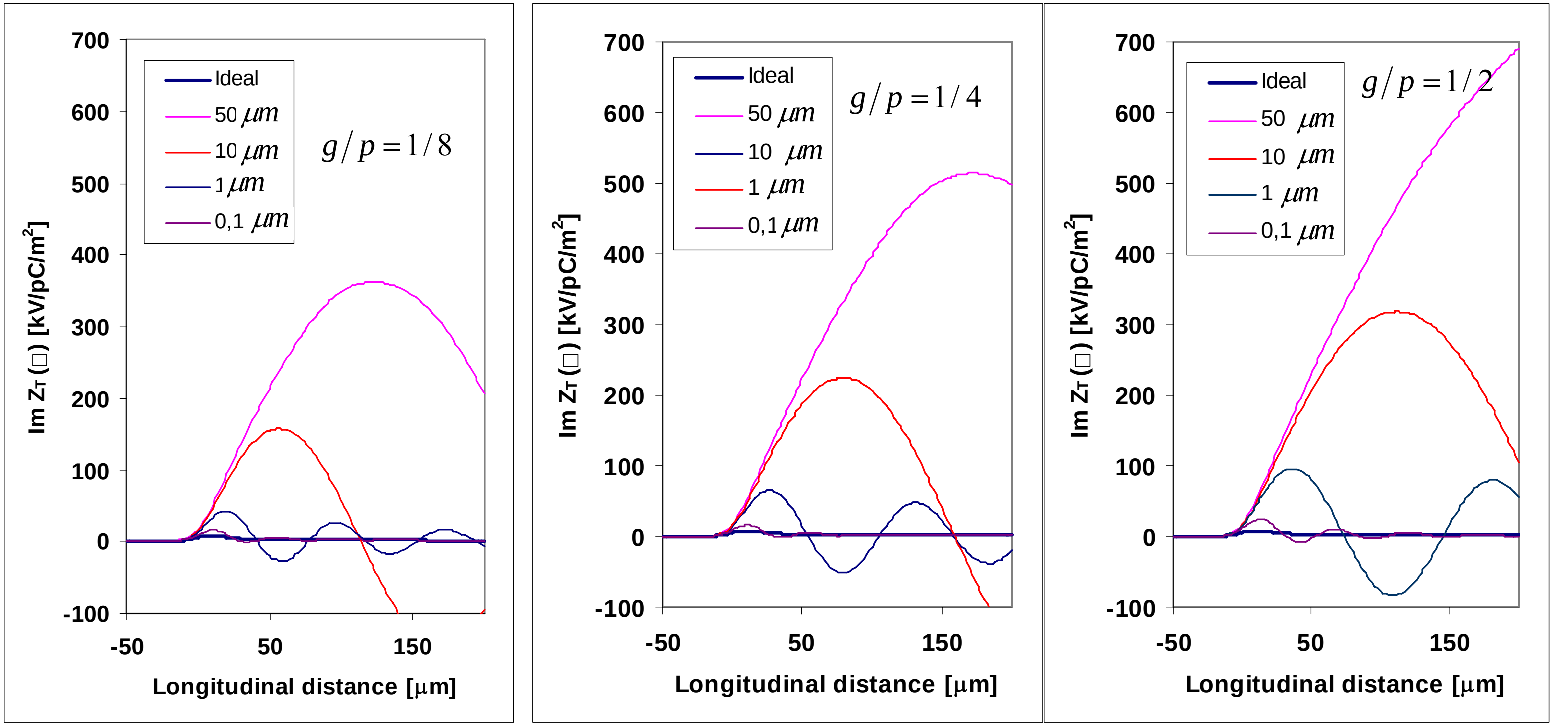
R.M.S. depth of roughness – 0.1μm.

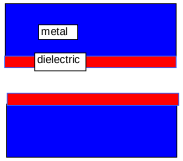
Center for the **A**dvancement of **N**atural **D**iscoveries using **L**ight **E**mission



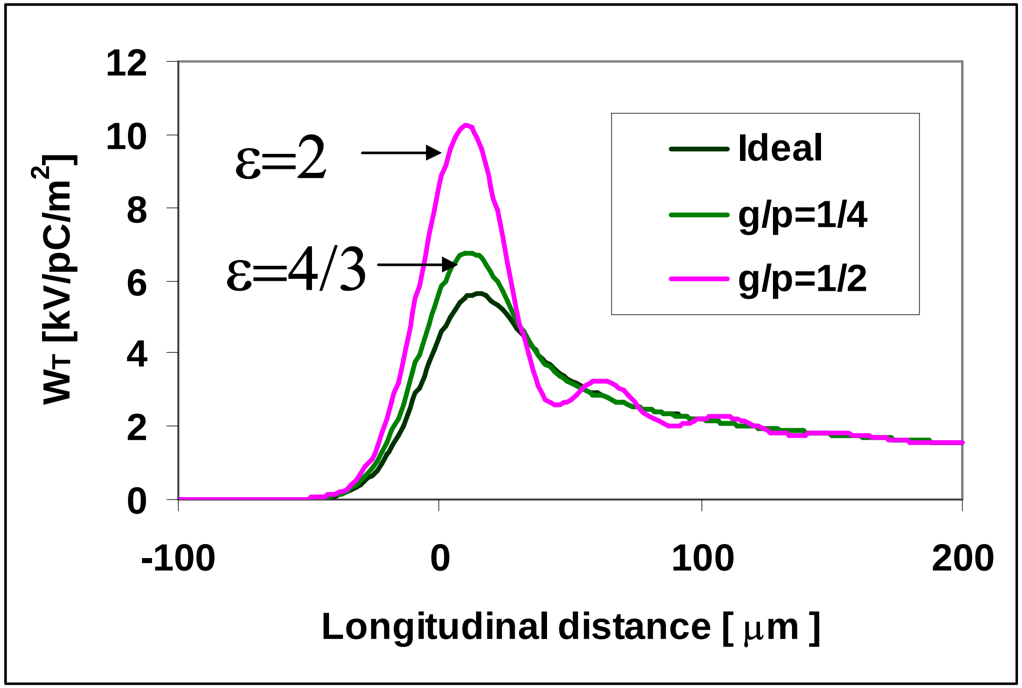
Transverse Wakefunction

$$\sigma_z = 9\,\mu m$$



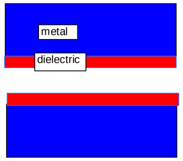


Transverse Wakefunction



Aluminum vacuum chamber.

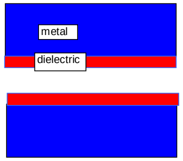
R.M.S. depth of roughness – 0.1μm.



Loss factor for PSI-XFEL undulator vacuum chamber (V/pC/m)

	0.05μm	0.1μm	1μm
g/p=1/8	636	756	2646
g/p=1/4	756	1036	3369
g/p=1/2	1036	1592	3868

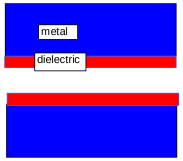
For the resistive walls without roughness the longitudinal loss factor for the PSI-XFEL undulator is equal to 540 V/pC/m.



Kick factor for PSI-XFEL undulator vacuum chamber (kV/pC/m^2)

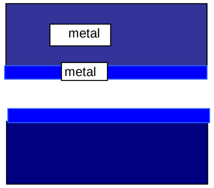
	0.05μm	0.1μm	1μm
g/p=1/8	6	7	16
g/p=1/4	7	8.8	20.1
g/p=1/2	8.8	11	28

For the resistive walls without roughness the transverse kick factor for the PSI-XFEL undulator is equal to 5 kV/pC/m^2.



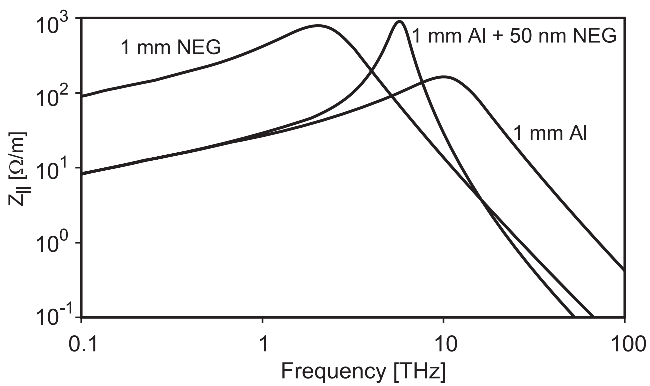
CONCLUSION

1. The method of resistive – roughness coupling impedance and wake functions calculation is obtained.
2. The main properties of the impedance behaviors are investigated

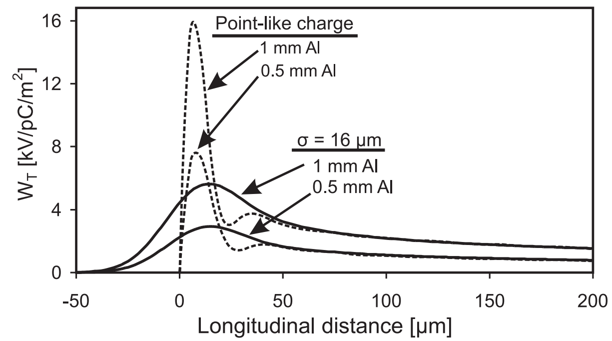


Longitudinal and Transverse Resistive Wake Fields in the Undulator of an XFEL

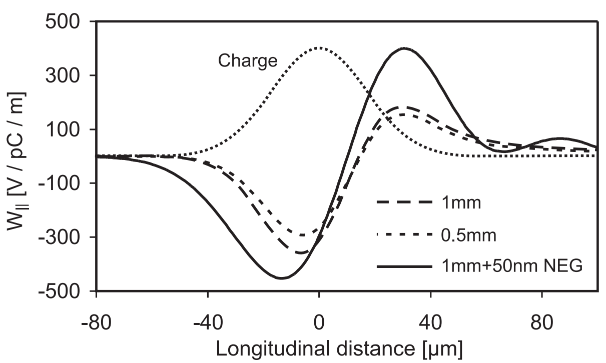
Longitudinal Impedances



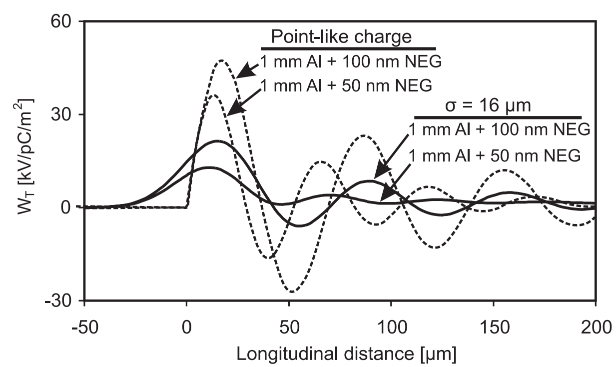
Transverse Wake, Al

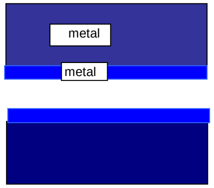


Longitudinal Wakes



Transverse Wake, Al+NEG

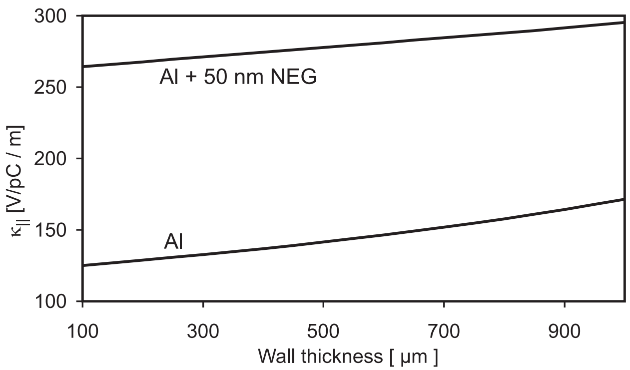




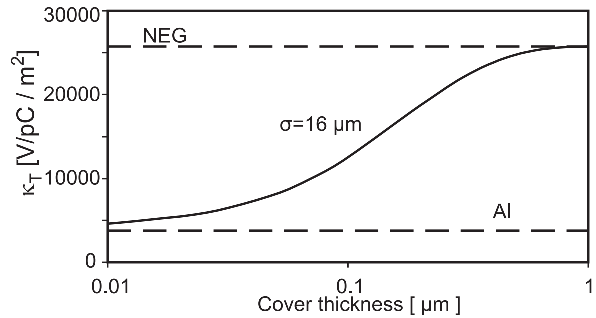
INTEGRAL PARAMETERS

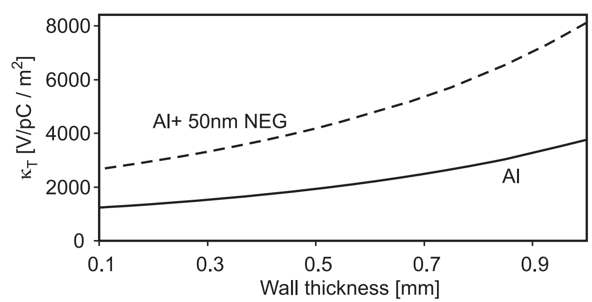
Michael Ivanyan, Vasili Mkrtich Tsakanov (CANDLE, Yerevan), Micha Dehler (PSI, Villigen), Armen Grigoryan (YSU, Yerevan), Longitudinal and Transverse Resistive Wake Fields in PSI-XFEL Undulator, ID: 3085, PAC09

Loss factor



Kick factor

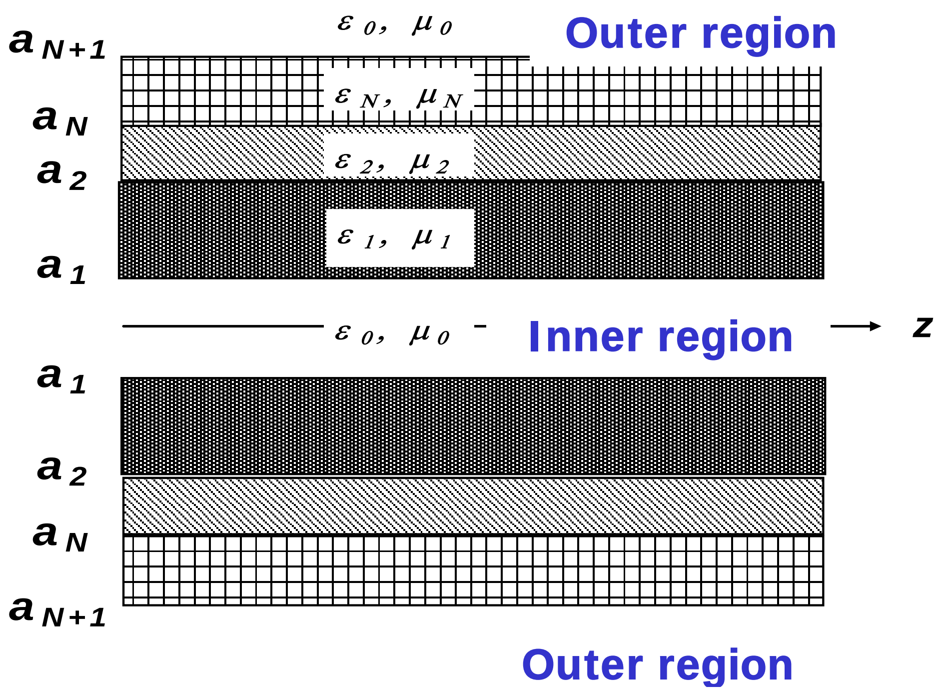




Conclusion

The NEG cover presence due to bunch short size and smallness of the gap increase both the loss and kick factors more than twice for the thin enough cover sheet. On the other hand, reduction of the wall thickness leads to almost two times decrease of the loss and kick parameters without any distortion of impedance and wake curves.

SURFACE IMPEDANCE AND WAVENUMBERS OF MULTI-LAYER ROUND TUBE



$$\xi = Z_0 \frac{(1+j)}{2k_0 a_1} \kappa^{3/2} = (1+j)\left(\frac{\mu_0 \omega}{2\sigma_1}\right)^{1/2}$$

Monopole mode (m=0), N -arbitrary

Separation of the modes

$$\hat{Q} = \begin{Bmatrix} h_{11} & 0 & 0 & h_{12} \\ 0 & g_{11} & g_{12} & 0 \\ 0 & g_{21} & g_{22} & 0 \\ h_{21} & 0 & 0 & h_{22} \end{Bmatrix}$$

$$\hat{h} = \begin{Bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{Bmatrix} = \prod_{i=1}^{N} \hat{h}^{(i)},$$

$$\hat{g} = \begin{Bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{Bmatrix} = \prod_{i=1}^{N} \hat{g}^{(i)}$$

$$Det\ \hat{h} = 0$$

$$Det\ \hat{g} = 0$$

$$E_z = \varsigma\, H_\theta \qquad E_\vartheta = \varsigma\, H_z$$

Equation for wavenumbers

TM modes

$$\frac{J_0(\nu_0 a_1)}{J_1(\nu_0 a_1)} = \frac{jk_0}{\nu_0} \frac{\hat{g}_{11} + \hat{g}_{12} \dfrac{jk_0}{\nu_0} \dfrac{H_1(\nu_0 a_{N+1})}{H_0(\nu_0 a_{N+1})}}{\hat{g}_{21} + \hat{g}_{22} \dfrac{jk_0}{\nu_0} \dfrac{H_1(\nu_0 a_{N+1})}{H_0(\nu_0 a_{N+1})}}$$

TE modes

$$\frac{J_0(\nu_0 a_1)}{J_1(\nu_0 a_1)} = \frac{jk_0}{\nu_0} \frac{\dfrac{jk_0}{\nu_0} \hat{h}_{21} + \dfrac{H_0(\nu_0 a_{N+1})}{H_1(\nu_0 a_{N+1})} \hat{h}_{22}}{\dfrac{jk_0}{\nu_0} \hat{h}_{11} + \dfrac{H_0(\nu_0 a_{N+1})}{H_1(\nu_0 a_{N+1})} \hat{h}_{12}}$$

Monopole mode (m=0), N -arbitrary

Surface impedance

TM modes

$$E_z = \varsigma H_\theta$$

$$\varsigma = Z_0 \frac{\hat{g}_{11} + \hat{g}_{12} \dfrac{jk_0}{\nu_0} \dfrac{H_1(\nu_0 a_{N+1})}{H_0(\nu_0 a_{N+1})}}{\hat{g}_{21} + \hat{g}_{22} \dfrac{jk_0}{\nu_0} \dfrac{H_1(\nu_0 a_{N+1})}{H_0(\nu_0 a_{N+1})}}$$

TH modes

$$E_\vartheta = \varsigma H_z$$

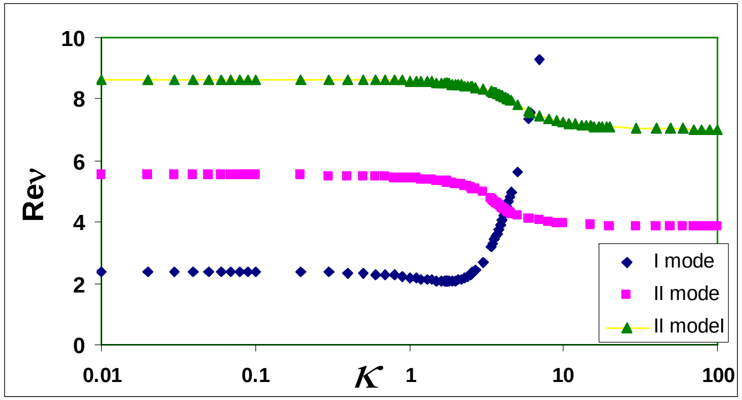
$$\varsigma = Z_0 \frac{\dfrac{jk_0}{\nu_0} \hat{h}_{11} + \dfrac{H_0(\nu_0 a_{N+1})}{H_1(\nu_0 a_{N+1})} \hat{h}_{12}}{\dfrac{jk_0}{\nu_0} \hat{h}_{21} + \dfrac{H_0(\nu_0 a_{N+1})}{H_1(\nu_0 a_{N+1})} \hat{h}_{22}}$$

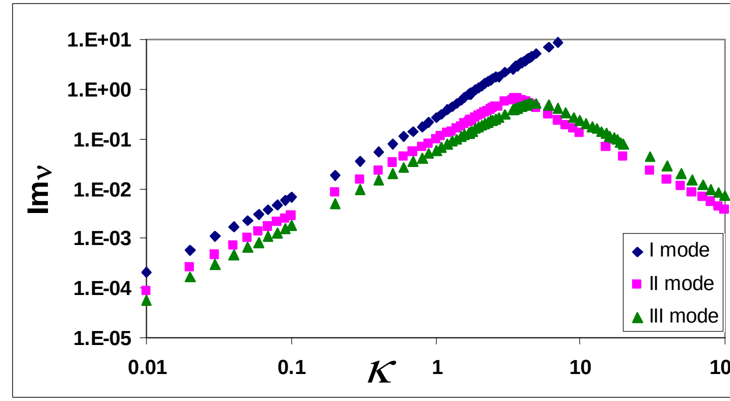
Monopole mode (m=0), N =1

Surface impedance (classical expression)

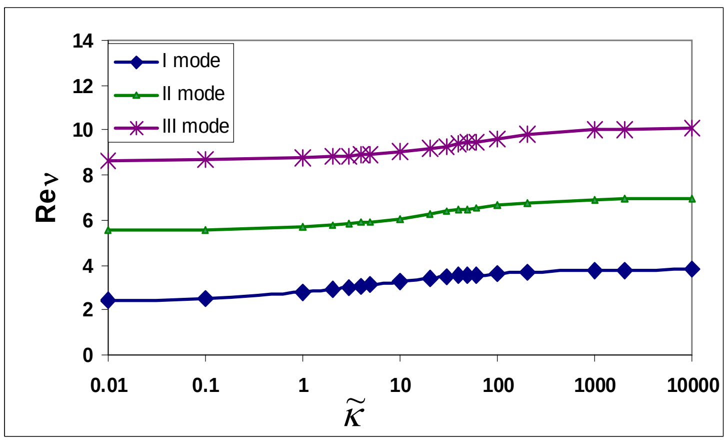
$$\xi = Z_0 \frac{(1+j)}{2k_0 a_1} \kappa^{3/2} = (1+j) \left(\frac{\mu_0 \omega}{2\sigma_1} \right)^{1/2}$$

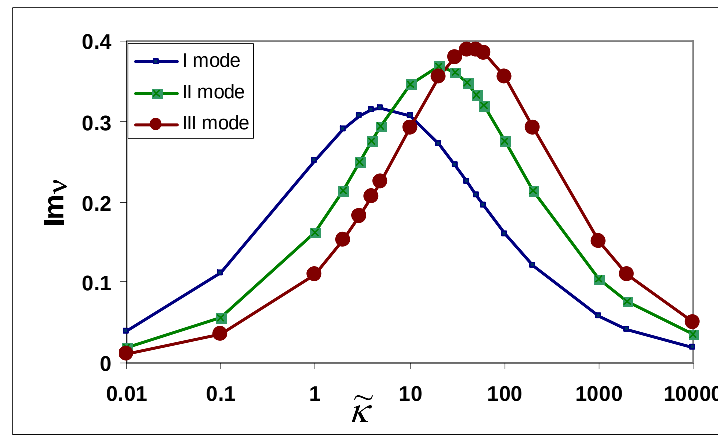
Monopole mode (m=0), N =1 TM mode



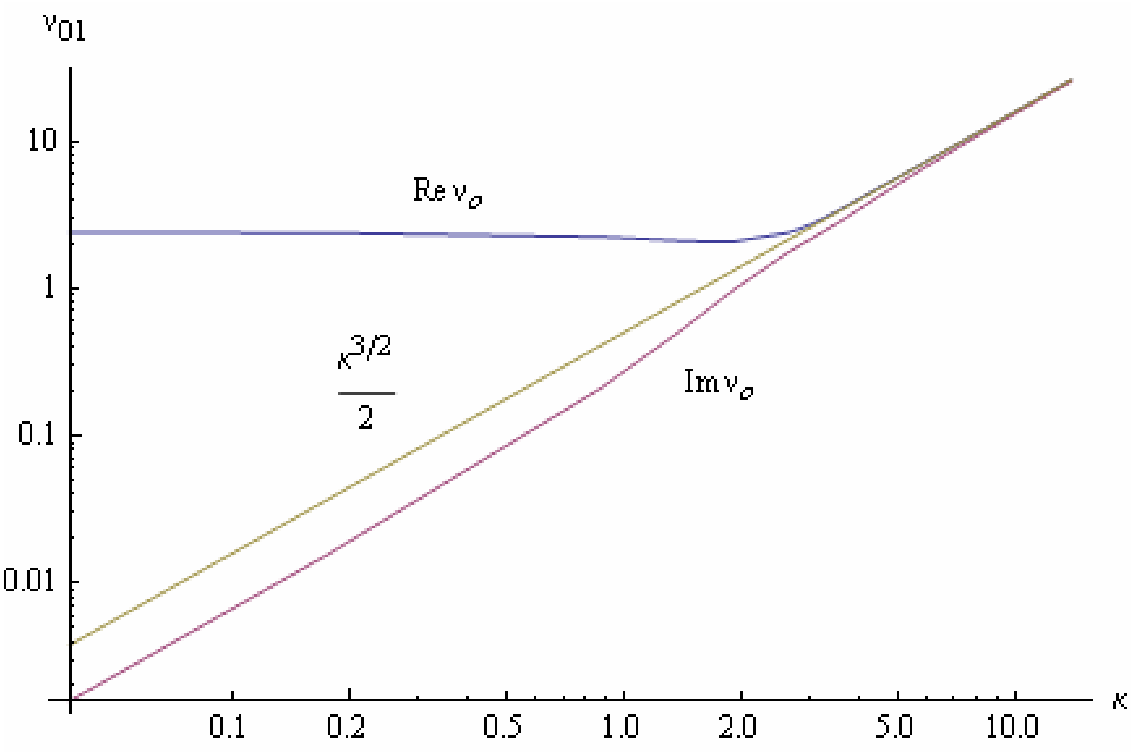


TE mode





Real (left) and imaginary (right) parts of the first three TM and TE modes distribution versus dimensionless wave number



$$\kappa = ks_0$$

$$s_0 = \left(\frac{2ca^2\varepsilon_0}{\sigma}\right)$$

Longitudinal impedance of single-layer resistive tube

$$F_z = -\frac{Z_0 s_0}{2\pi a^2} F(\kappa) \qquad F(\kappa) = \left(\frac{1-j}{\sqrt{\kappa}} + j\frac{\kappa}{2} \right)^{-1}$$

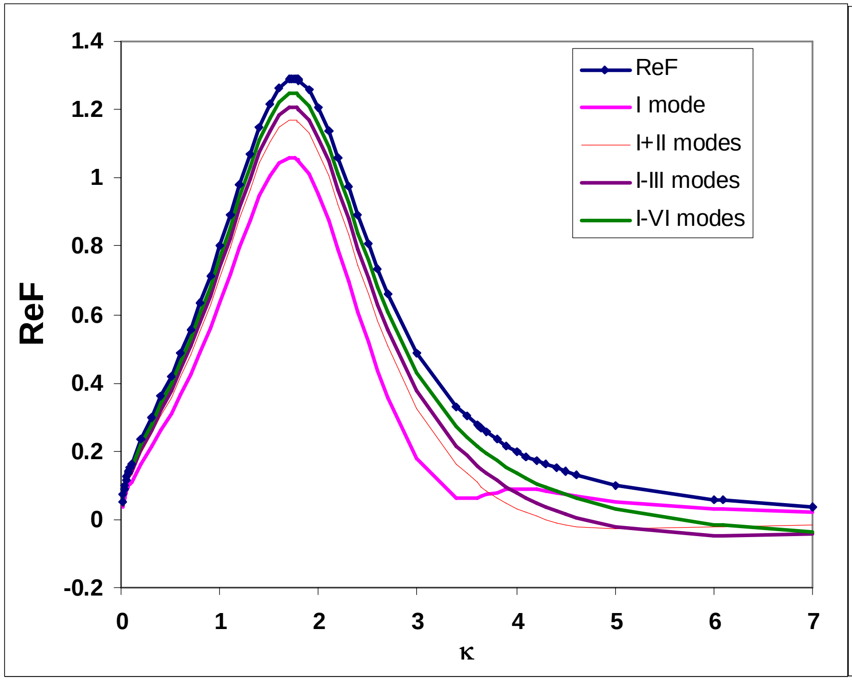
$$s_0 = \left(\frac{2ca^2\varepsilon_0}{\sigma} \right) \qquad \kappa = ks_0$$

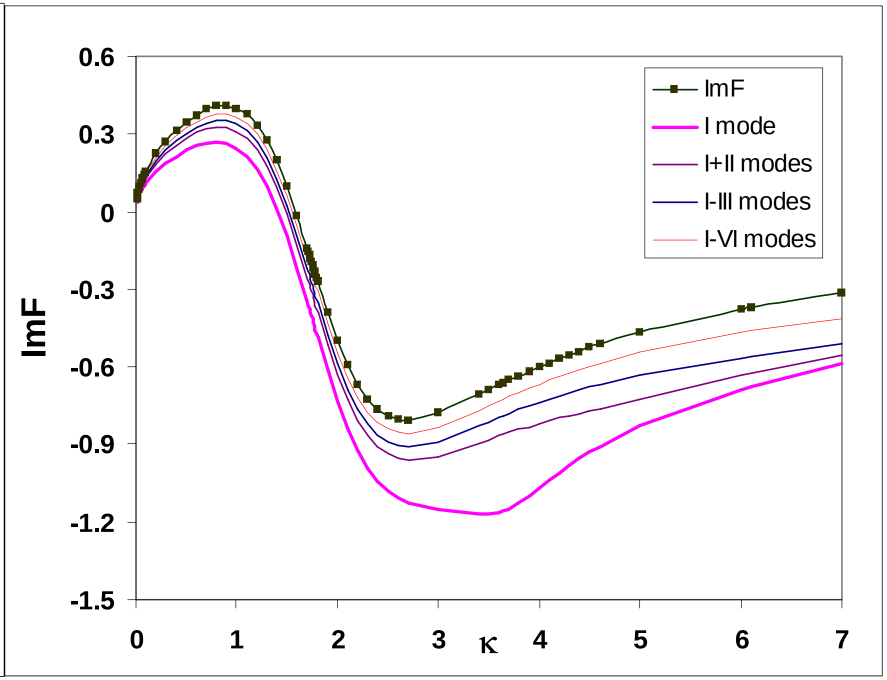
PROPERTIES of ORTHOGONALITY

$\nu_j = \nu_{0j}$

$$\int_0^a J_1\left(\nu_i \frac{r}{a}\right) J_1\left(\nu_j \frac{r}{a}\right) r\,dr = \begin{cases} \frac{a^2}{2}\left(J_1^2(\nu_i) - J_0(\nu_i) J_2(\nu_i)\right) & for\ i = j \\ 0 & for\ i \neq j \end{cases}$$

Series convergence





$$F(\kappa) = 2\frac{a}{r}\sum_{i=1}^{\infty} A_0^{(i)} \frac{J_1\left(\tilde{\nu}_{0i}\, r/a\right)}{\tilde{\nu}_{0i}}$$

$$A_0^{(i)} = \frac{1}{J_0\left(\tilde{\nu}_i\right)} \frac{1}{\frac{\tilde{\nu}_{0i}^{\,2}}{\kappa^2} - \frac{1}{F(\kappa)}}$$

CONCLUSION

The main properties of the resistive impedances and wakes for the main cases of the two-layer tubes, used as a vacuum chambers for the undulators and kickers are presented

The expression for the multi-layer tube monopole surface impedance is developed. The modal analysis of the monopole resistive impedance is performed