Emittance Growth by Transverse Wakes
Wakes from Surface Effects in Round Beam Pipes

from November: longitudinal wakes

relation to transverse wakes

emittance growth

s2e-meeting Nov. 2008 → monopole wake

Wakes from Surface Effects in Round Beam Pipes

beam impedance and surface impedance

dielectric layer, roughness

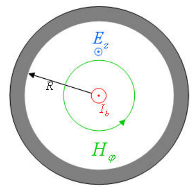
parameters

Gaussian beam

s2e beam

beam impedance and surface impedance

$$Z_b' = -\frac{E_z}{I_b}\bigg|_{r\to 0} \qquad Z_s = -\frac{E_z}{H_\varphi}\bigg|_{r=R}$$



$$Z_b'(\omega) = \frac{Z_s(\omega)}{2\pi R}\frac{1}{1 + i\frac{\omega}{c}\frac{R}{2}\frac{Z_s(\omega)}{Z_0}}$$

metallic conductor (κ): $Z_s^{(\kappa)} \approx \sqrt{\frac{j\omega\mu}{\kappa(\omega)}}$ $\quad \kappa(\omega) \approx \frac{\kappa_0}{1 + i\omega\tau}$
(plane wave approximation)

surface: dielectric layer

surface impedance of thin dielectric layer (ε_r) on perfect conductor:

$$Z_{s,d}^{(\varepsilon)} \approx j\omega L_d \quad \text{with} \quad L_d = \Delta\cdot\mu\frac{\varepsilon_r - 1}{\varepsilon_r}$$

old assumption: ε_r = 2
more realistically: ε_r = 10 (used for the following)

surface: roughness

$$Z_{s,r}^{(\varepsilon)} \approx j\omega L_r \quad \text{with} \quad L_r \approx \frac{\Delta}{100}\cdot\mu$$

used for the following: Δ ≈ 300 nm
(~ 3 nm dielectric layer)

multiple surface effects

$$Z_s = Z_s^{(\kappa)} + j\omega(L_d + L_r)$$

parameters

beam pipe radius 4.4 mm

material properties

$$\kappa_{al,0} = 36.6\cdot10^6\frac{1}{\Omega\mathrm{m}} \quad \tau_{al} = 0.71\cdot10^{-14}\,\mathrm{s}$$

$$\kappa_{cu,0} = 58\cdot10^6\frac{1}{\Omega\mathrm{m}} \quad \tau_{cu} = 2.46\cdot10^{-14}\,\mathrm{s}$$

$$\varepsilon_{r,\mathrm{oxide}} = 10$$

$$\Delta_{\mathrm{rough}} = 300\,\mathrm{nm}$$

bunch charge 1 nC

peak current 5 kA

I.Zagorodnov, 26.Feb 2007:

T .Wohlenberg WP19 Warm Vacuum Staus Report
XFEL Project Meeting 13.12.2006

Chamber dimensions :	length :	5122mm	
	width:	70mm	
	heigh:	9.6mm	
	elliptical aperture:	horizontal: 15mm	vertical: 8.8mm

extruded aluminium chamber

Aluminium

$\sigma = 3.66\cdot10^7[\Omega^{-1}\mathrm{m}^{-1}]$

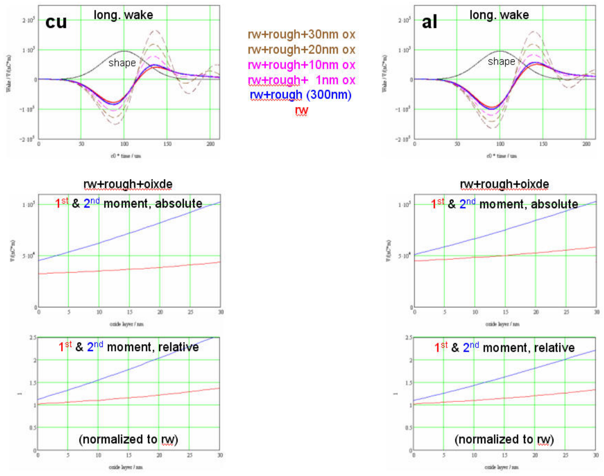
$\tau = 7.1\cdot10^{-15}[\mathrm{sec}]$

$\Delta_{rough} = 600[\mathrm{nm}]$

$\Delta_{oxid} = 5[\mathrm{nm}]$ $\quad \varepsilon_{r,\mathrm{oxide}} = 2$

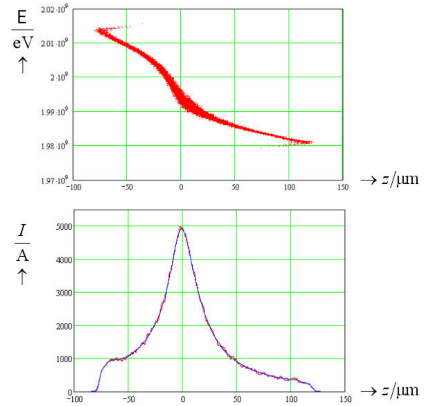
Elliptical chamber length = 5122 mm

Gaussian beam

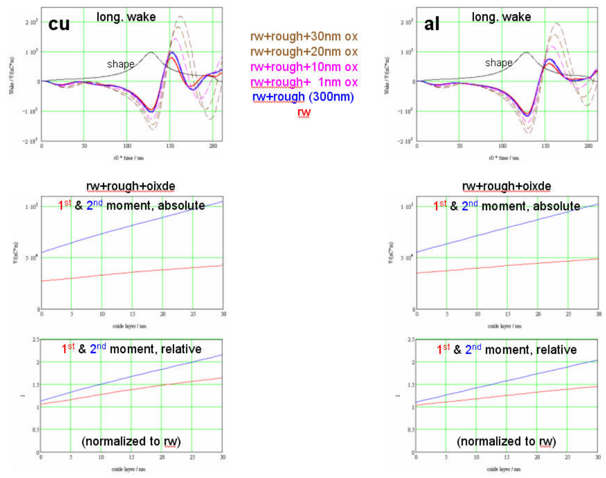


s2e beam

bunch shape from the “official” start to end simulation (December 2005)



s2e beam



relation between monopole and dipole wakes (round pipe)

monopole

$$Z_{\parallel}^{(m)} = \frac{Z_s}{2\pi R} \frac{1}{1 - jk \frac{R}{2} \frac{Z_s}{Z_0}}$$

$$Z_{\perp}^{(m)} = 0$$

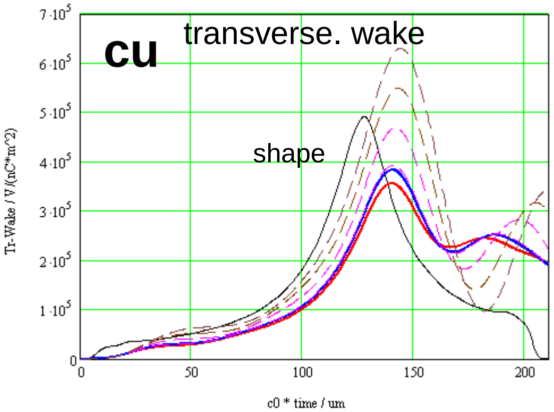
dipole, source at $x_0, y_0 = 0$, test at x, y

$$\begin{pmatrix} Z_{\perp}^{(d)} \\ 0 \\ Z_{\parallel}^{(d)} \end{pmatrix} = \frac{\mathbf{E}_d + c\mathbf{e}_z \times \mathbf{B}_d}{I_z = \lambda_0 c e^{-jkz}} = \frac{Z_s}{2\pi R} \frac{2x_0}{R^2} \frac{1}{1 - jk \frac{R}{2} \frac{Z_s}{Z_0}} \begin{pmatrix} j/k \\ 0 \\ x \end{pmatrix}$$

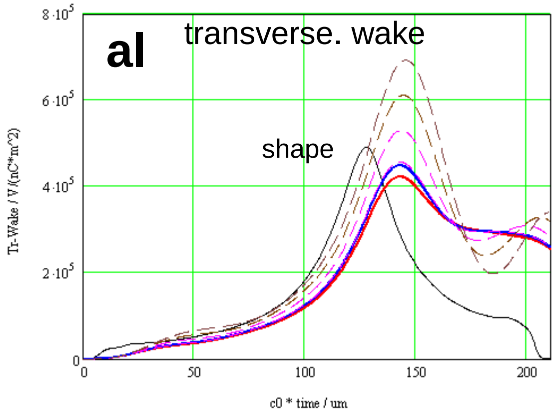
$$Z_{\parallel}^{(d)} = \frac{2xx_0}{R^2} Z_{\parallel}^{(m)}$$

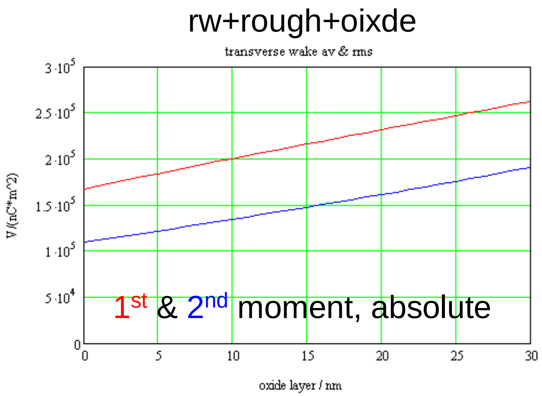
$$Z_{\perp}^{(m)} = \frac{2jx_0}{kR^2} Z_{\parallel}^{(m)}$$

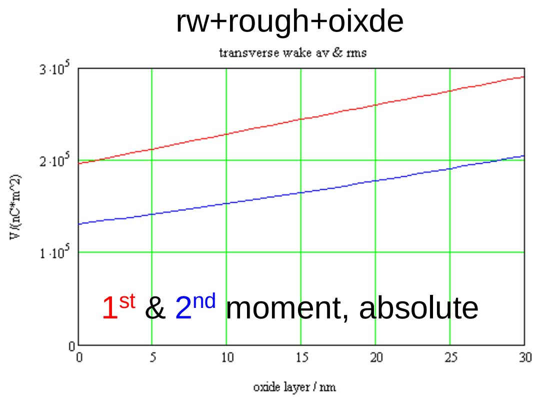
s2e beam

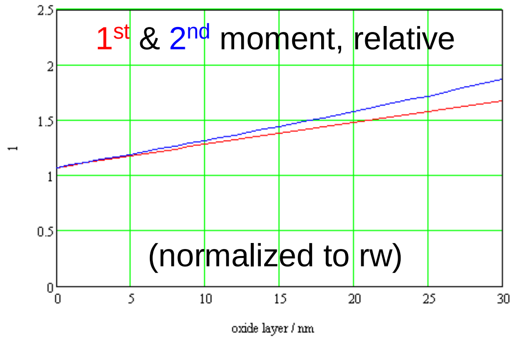


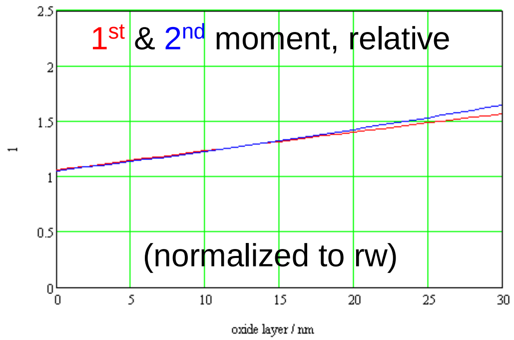
rw+rough+30nm ox
rw+rough+20nm ox
rw+rough+10nm ox
rw+rough+ 1nm ox
rw+rough (300nm)
rw









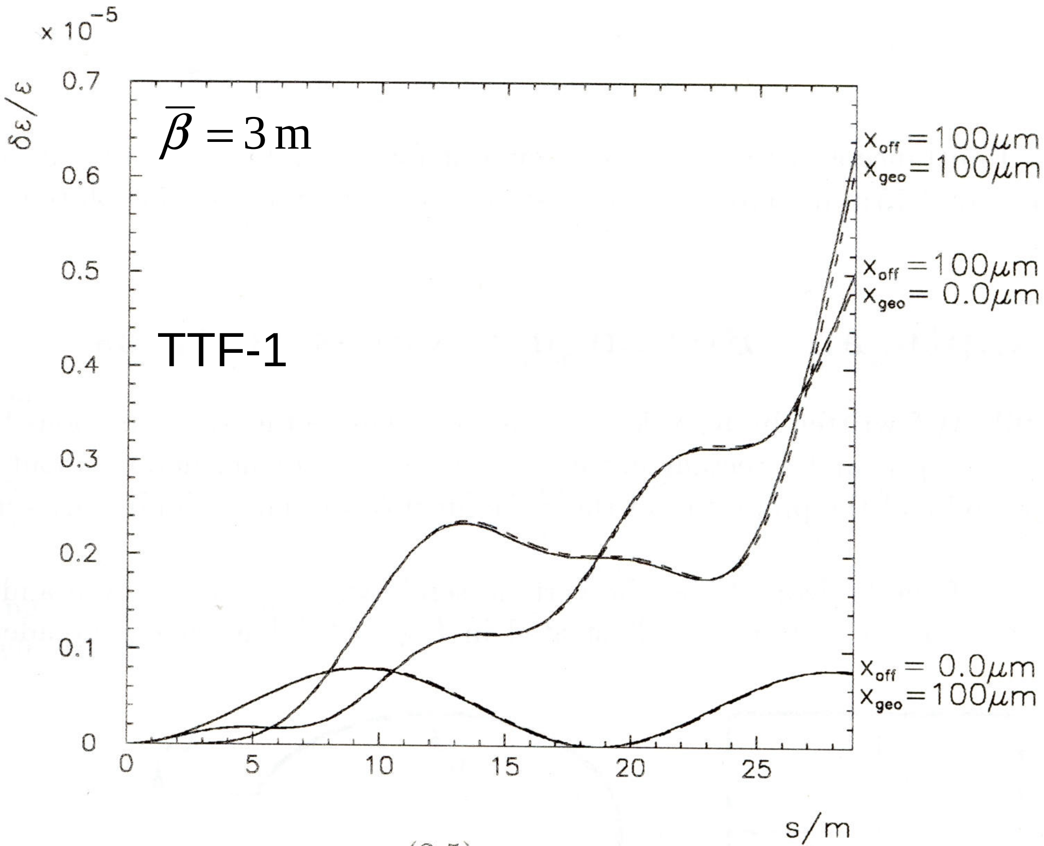


Resistive Wall Wake Fields

Diplomarbeit
zur Erlangung des Grades
eines Diplomphysikers

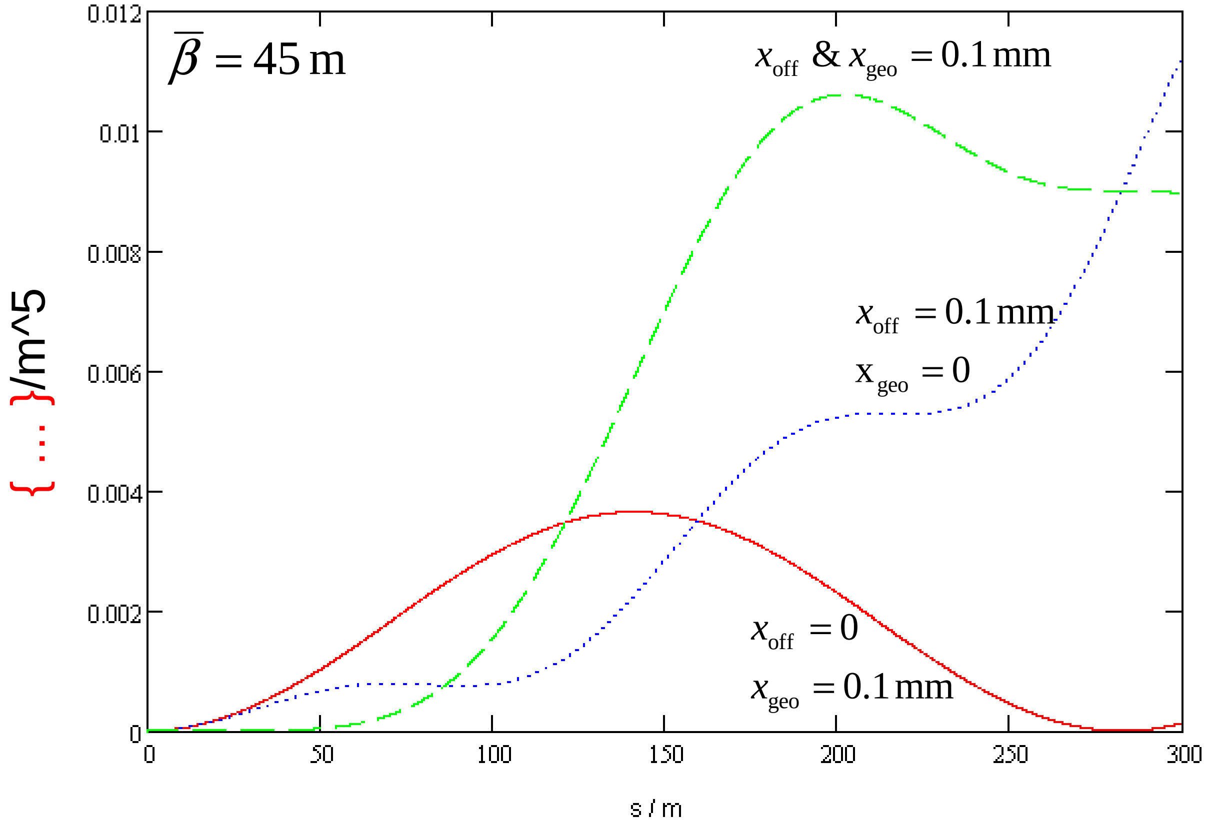
vorgelegt dem Fachbereich Physik
der Universität Hamburg
von Holger Schlarb

Hamburg
August 1997



$$\frac{\delta\epsilon_x(s)}{\epsilon_x} \approx \frac{1}{2\epsilon_x}\cdot\left(\frac{Ne^2}{E_0}\right)^2\cdot\left(<W_\perp^{\lambda\,2}>_\lambda - k_\perp^2\right) \tag{3.5}$$

$$\times \left\{ \left(\frac{x_{off}\sqrt{\overline{\beta}}}{2}\, s\, \sin(k_{\overline{\beta}}\, s) - x_{geo}\,\overline{\beta}^{3/2}\left[1 - \cos(k_{\overline{\beta}}\, s)\right] \right)^2 + \left(\frac{x_{off}\sqrt{\overline{\beta}}}{2}\left[s\,\cos(k_{\overline{\beta}}\, s) + \overline{\beta}\sin(k_{\overline{\beta}}\, s)\right] - x_{geo}\,\overline{\beta}^{3/2}\sin(k_{\overline{\beta}}\, s) \right)^2 \right\} .$$



$$\frac{\delta\epsilon_x(s)}{\epsilon_x} \approx \frac{1}{2\epsilon_x}\cdot\left(\frac{Ne^2}{E_0}\right)^2\cdot\left(<W_\perp^{\lambda 2}>_\lambda - k_\perp^2\right) \qquad (3.5)$$

$$\times \left\{\left(\frac{x_{off}\sqrt{\overline{\beta}}}{2}\, s\, \sin\left(k_{\overline{\beta}}\, s\right) - x_{geo}\, \overline{\beta}^{3/2}\left[1 - \cos\left(k_{\overline{\beta}}\, s\right)\right]\right)^2\right.$$

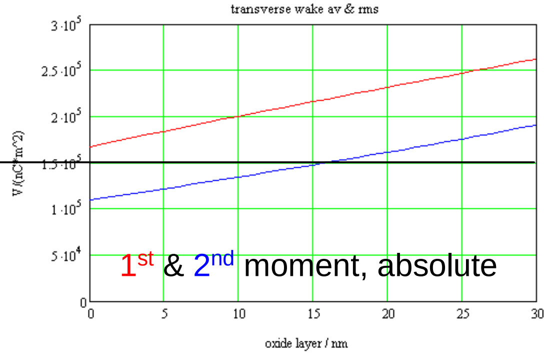
$$\left. + \left(\frac{x_{off}\sqrt{\overline{\beta}}}{2}\left[s\, \cos\left(k_{\overline{\beta}}\, s\right) + \overline{\beta}\sin\left(k_{\overline{\beta}}\, s\right)\right] - x_{geo}\, \overline{\beta}^{3/2}\sin\left(k_{\overline{\beta}}\, s\right)\right)^2\right\}.$$

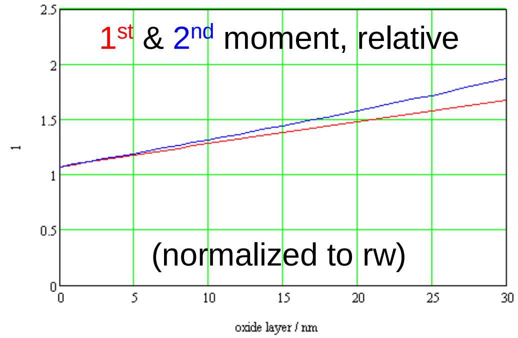
$$\varepsilon_x \approx \frac{1.5 \cdot \mu\mathrm{m}}{\gamma}$$

$$\sigma_{w'} \approx 1.5 \cdot 10^5 \, \frac{\mathrm{V}}{\mathrm{m}^2}$$

1nC

rw+rough+oixde





$$\frac{\delta\varepsilon_x}{\varepsilon_x} = \frac{1}{\varepsilon_x}\left(\frac{\sigma_{w'}}{17.5\,\mathrm{GeV}/q_0}\right)^2 \left\{ \Lambda \right\}$$

$\approx$ 1.7 m^{-5} * 0.01 m^5

$$\frac{\delta\varepsilon_x}{\varepsilon_x} \approx 0.017$$