Wakes from Surface Effects in Round Beam Pipes

beam impedance and surface impedance

dielectric layer, roughness

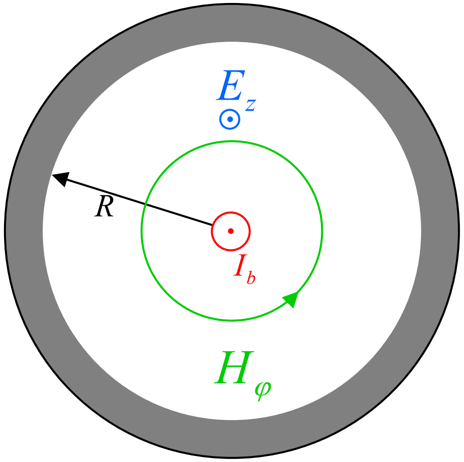
parameters

Gaussian beam

s2e beam

beam impedance and surface impedance

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



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

metallic conductor (κ):
(plane wave approximation)

$$Z_s^{(\kappa)} \approx \sqrt{\frac{j\omega\mu}{\kappa(\omega)}} \qquad \kappa(\omega) \approx \frac{\kappa_0}{1 + i\omega\tau}$$

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: $\varepsilon_r = 2$

more realistically: $\varepsilon_r = 10$ (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: $\Delta \approx 300$ nm

(~ 3 nm dielectric layer)

multiple surface effects

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

parameters

beam pipe radius 4.4 mm

material properties

$$\kappa_{al,0} = 36.6 \cdot 10^6 \frac{1}{\Omega\mathrm{m}} \quad \tau_{\mathrm{al}} = 0.71 \cdot 10^{-14}\,\mathrm{s}$$

$$\kappa_{\mathrm{cu},0} = 58 \cdot 10^6 \frac{1}{\Omega\mathrm{m}} \quad \tau_{\mathrm{cu}} = 2.46 \cdot 10^{-14}\,\mathrm{s}$$

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

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

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

$$\sigma = 3.66 \cdot 10^7 [\Omega^{-1}\mathrm{m}^{-1}]$$

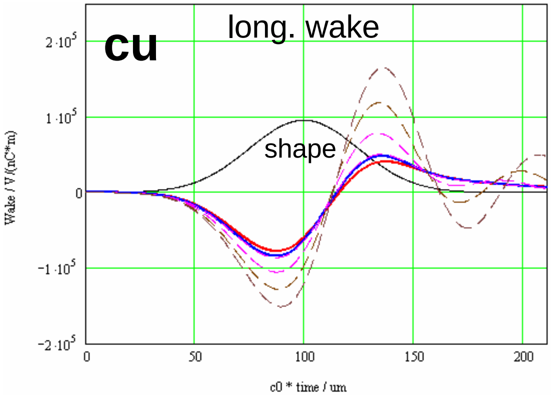
$$\tau = 7.1 \cdot 10^{-15} [\mathrm{sec}]$$

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

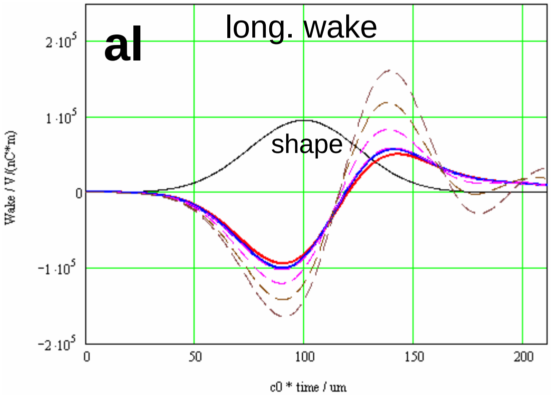
$$\Delta_{oxid} = 5 [\mathrm{nm}] \qquad \varepsilon_{\mathrm{r,oxide}} = 2$$

Elliptical chamber length = 5122 mm

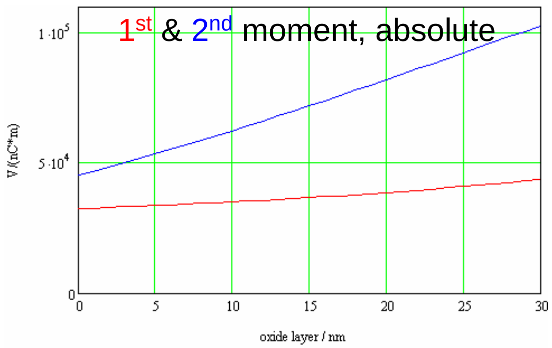
Gaussian beam



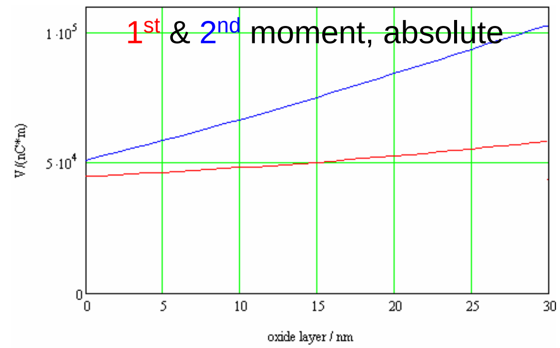
rw+rough+30nm ox
rw+rough+20nm ox
rw+rough+10nm ox
rw+rough+ 1nm ox
rw+rough (300nm)
rw

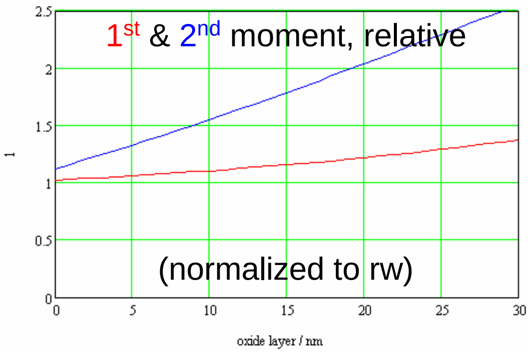


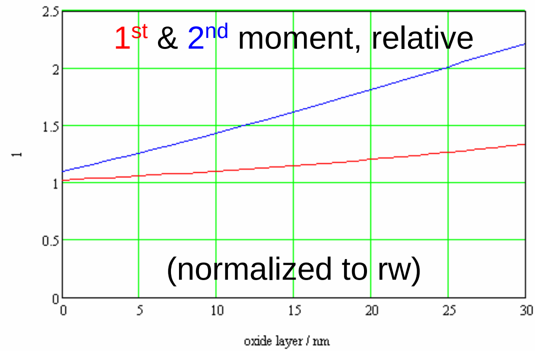
rw+rough+oixde



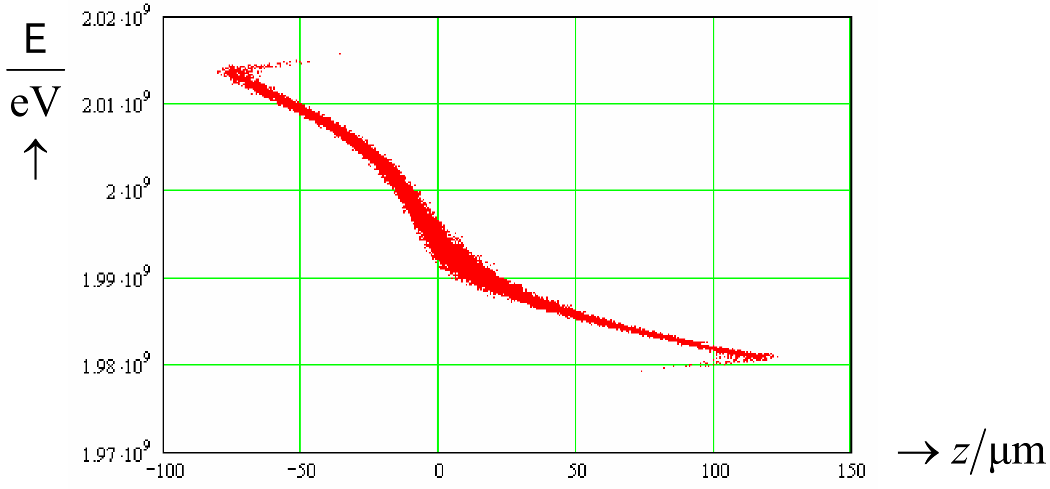
rw+rough+oixde

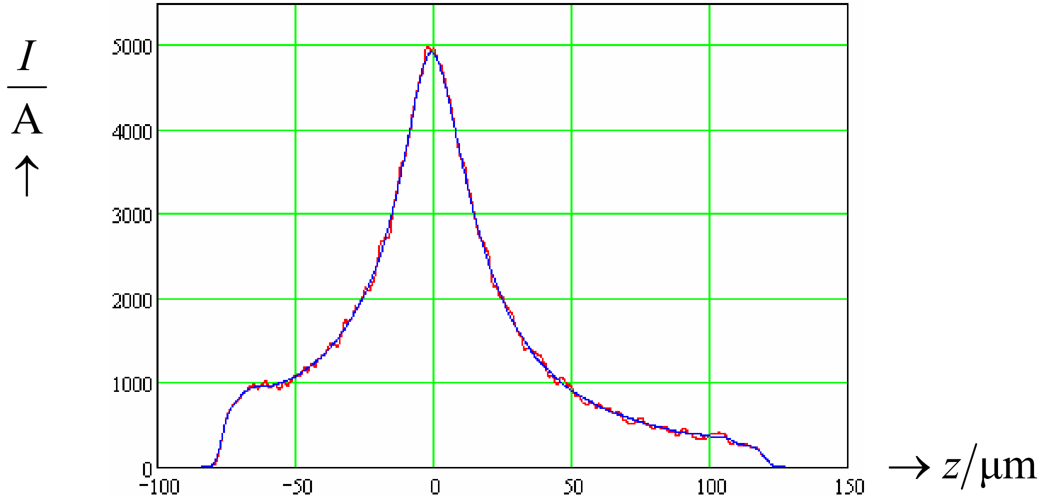




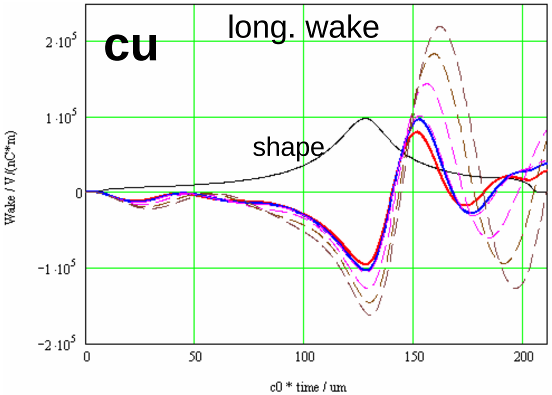


bunch shape from the "official" start to end simulation (December 2005)

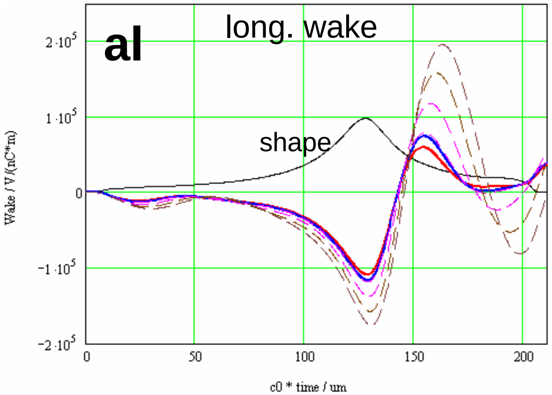




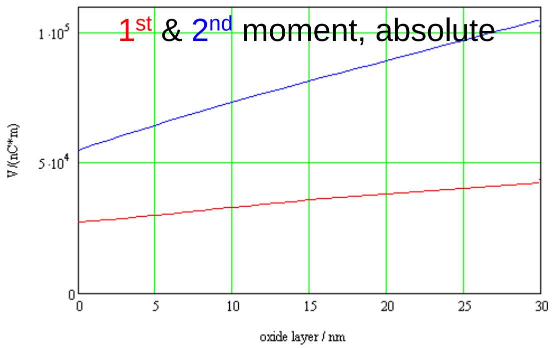
s2e beam

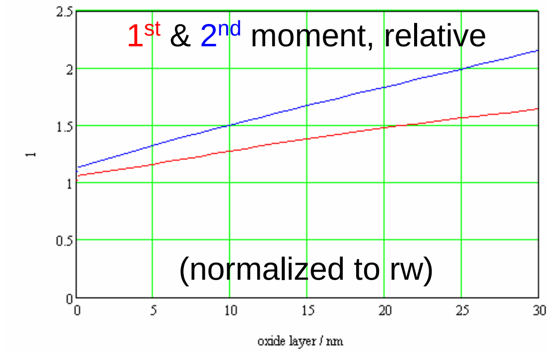


rw+rough+30nm ox
rw+rough+20nm ox
rw+rough+10nm ox
rw+rough+ 1nm ox
rw+rough (300nm)
rw

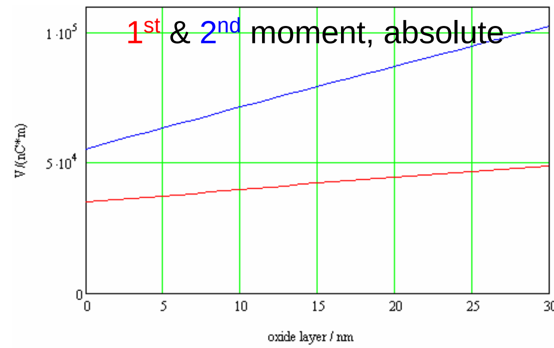


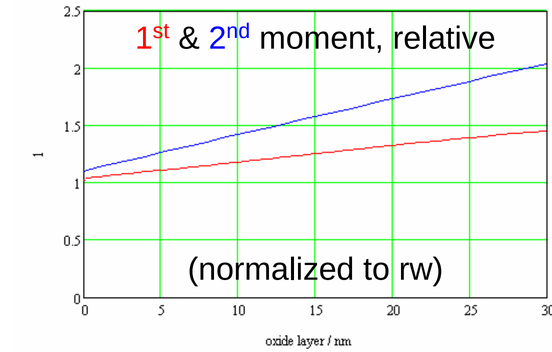
rw+rough+oixde



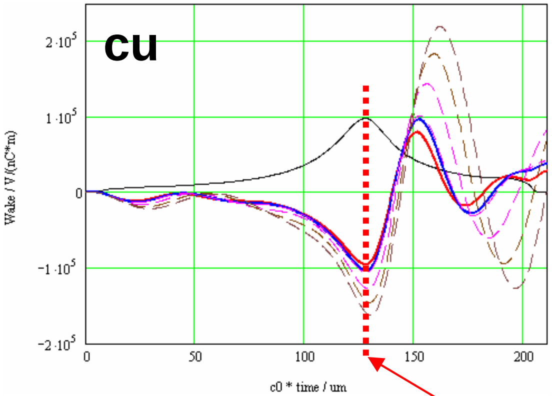


rw+rough+oixde

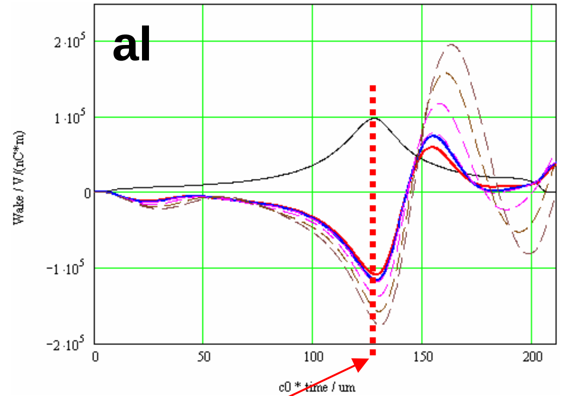




s2e beam – dE vs. current

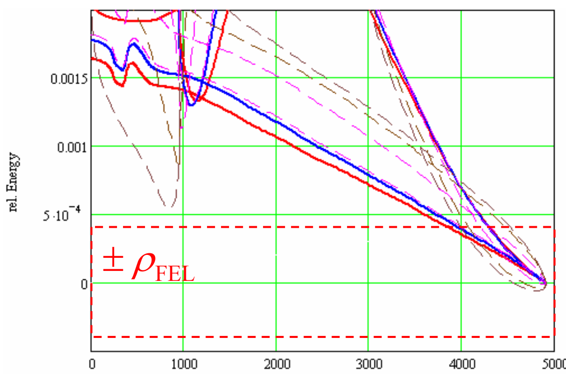


rw+rough+30nm ox
rw+rough+20nm ox
rw+rough+10nm ox
rw+rough+ 1nm ox
rw+rough (300nm)
rw



energy loss (in undulator) compensated by **tapering** for this working point !

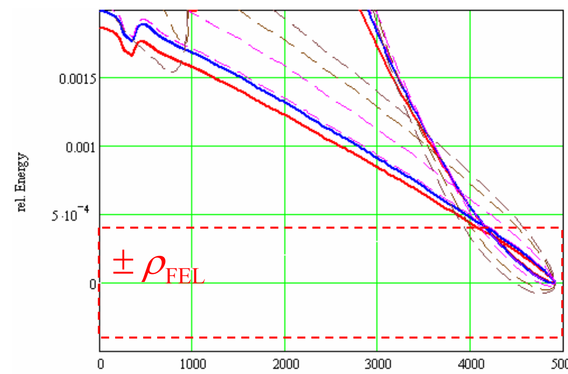
wake-wake(Imax) ×1nC×300m / 17.5 GV



current / A

$\sigma_{FEL} \approx 4\times10^{-4}$ (FEL parameter)

wake-wake(Imax) ×1nC×300m / 17.5 GV



current / A

→ surface effects might increase FEL bandwidth significantly