OSLO WINTER SCHOOL

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Polarization radiation from bunches of correlated charged particles

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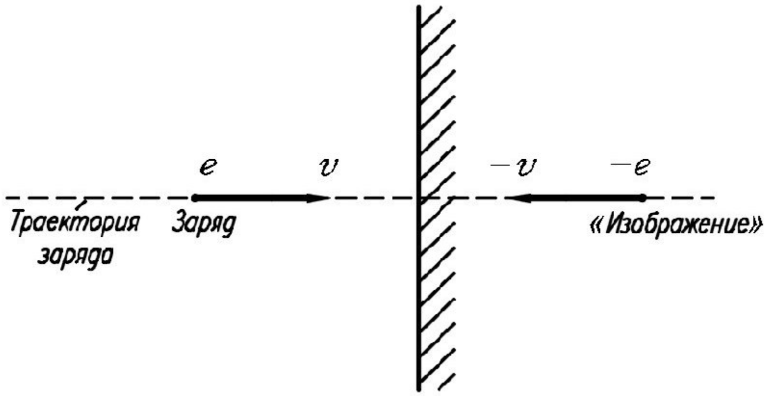
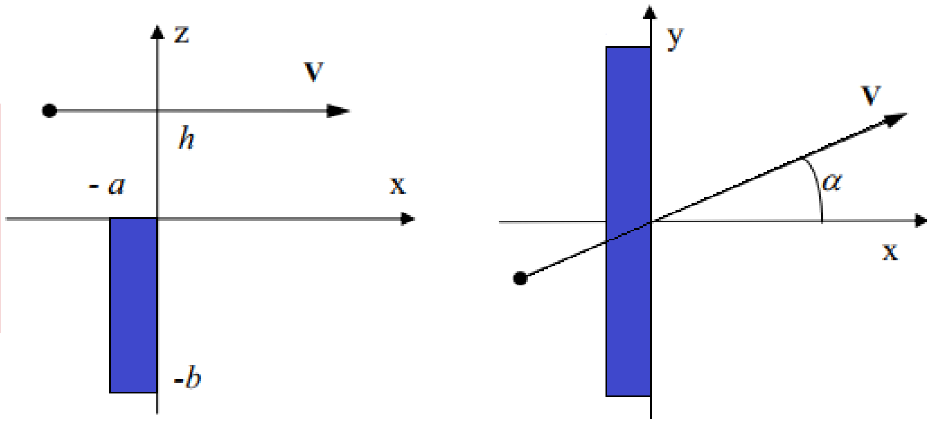
Introduction

Transition radiation



Goal: to calculate the effects of correlations in ultrashort bunches

Diffraction radiation



$$W_b^{\pm}(\omega,\vartheta)=\frac{1}{2\pi}W^{\pm}(\omega,\vartheta)F(\omega,\vartheta)$$

$$W_b^{\pm}(\omega,\vartheta)=\frac{1}{2\pi}W^{\pm}(\omega,\vartheta)\left(N+N(N-1)G_k(\omega,\vartheta)\right)$$

$$F(\omega,\vartheta)=N+N(N-1)\iint d^3r\,d^3r'\,f_2(\mathbf{r},\mathbf{r}')\exp\left\{-i\left[\varsigma\left(\boldsymbol{\rho}_m-\boldsymbol{\rho}_n\right)+\frac{\omega}{v}\left(z_m-z_n\right)\right]\right\}$$

$$f_2(\mathbf{r},\mathbf{r}')=f_1(\mathbf{r})\,f_1(\mathbf{r}')+f_0(\mathbf{r}-\mathbf{r}') \Rightarrow G_k(\omega,\vartheta)=G_1(\omega,\vartheta)+G_{cor}(\omega,\vartheta)$$

Form-factor and coherency factor for non-correlated bunch

$$G_k(\omega,\vartheta)=G_1(\omega,\vartheta)+G_{cor}(\omega,\vartheta)$$

$$f_2(\mathbf{r},\mathbf{r}')\approx f_1(\mathbf{r})\,f_1(\mathbf{r}'),$$

$$f_1(\mathbf{r})=f_\rho(\rho)\,f_z(z)$$

$$G_1(\omega,\vartheta)=\left|\int_{-\infty}^{\infty}dz\,f_z(z)e^{-i\frac{\omega}{v}z}\right|^2\left|2\pi\int_0^{\infty}d\rho\,f_\rho(\rho)\,J_0\left(\rho\frac{\omega}{c}\sin\vartheta\right)\rho\right|^2$$

Uniform distribution

$$G_1(\omega,\vartheta)=\left|\frac{\sin\left(\frac{\omega a}{2v}\right)}{\frac{\omega a}{2v}}\right|^2\left|\frac{2J_1\left(\frac{\omega}{c}b\sin\vartheta\right)}{\frac{\omega}{c}b\sin\vartheta}\right|^2$$

Gaussian distribution

$$G_1(\omega,\vartheta)=\exp\left\{-\frac{\omega^2}{2}\left(\frac{a^2}{4v^2}+\frac{b^2}{c^2}\sin^2\vartheta\right)\right\}$$

- G.M. Garibyan, Yang Shi, X-Ray Transition radiation, 1983.
- M. Ferrario, *Space Charge Effects.* Zeuthen: CAS-CERN, 2003.

Correlation function and the correlation part of the coherency factor

Uniform distribution

$$G_{cor}^{Uniform}(\omega,\vartheta)=\left(\frac{2\pi n_{e0}e^2}{T}\right)^2\left|\frac{\sin\left(\frac{a}{2}\sqrt{\kappa^2+\alpha^2}-i\frac{\omega a}{2\nu}\right)}{\left(\sqrt{\kappa^2+\alpha^2}\right)\left(\sqrt{\kappa^2+\alpha^2}-i\frac{\omega}{\nu}\right)}\right|^2 \mathrm{e}^{-a\sqrt{\kappa^2+\alpha^2}}$$

$$\frac{\pi a}{\beta}<<\lambda,\quad \pi a\sin\vartheta<<\lambda$$

и $a\leq 2r_D$

Gaussian distribution

$$G_{cor}^{Gauss}(\omega,\vartheta)=\left(\frac{4e^2}{ab^2\pi^{1/2}T}\right)^2\left|Erfc\left(\frac{b}{2r_D}\right)J_0\left(\alpha\frac{b^2}{2r_D}\right)e^{b^2/4r_D^2}\frac{\pi b^2 a/2}{\sqrt{a^2/4+b^2}}\right|^2$$

$$\frac{\pi b^2\sin\vartheta}{r_D}<<\lambda,\quad \frac{b}{2r_D}\leq 1$$

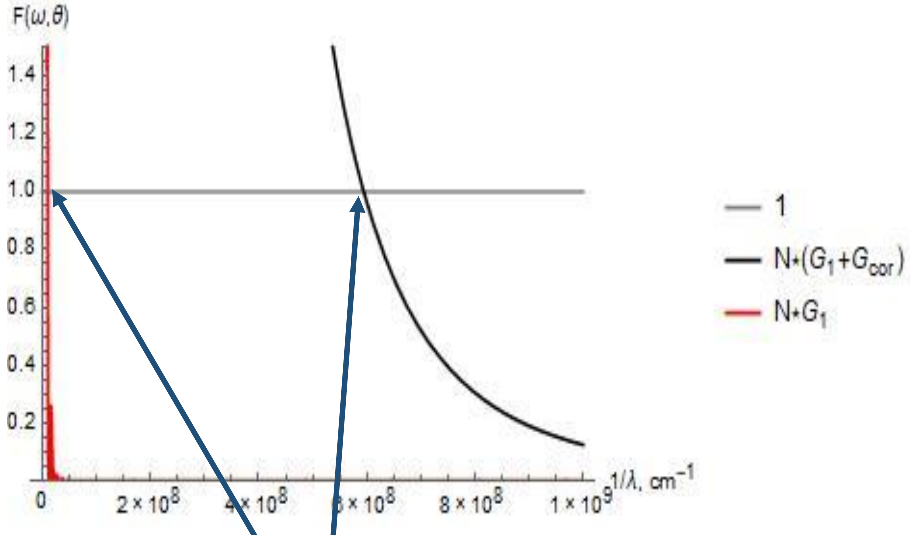
$$\alpha=\frac{\omega}{c}\sin\vartheta$$

D.K. Danilova, A.A. Tishchenko, M.N. Strikhanov. Effects of correlation in transition radiation of super-short electron bunches. NIM B, **402** (2017), 130-133

Numerical estimates

The value of the wavelength
where the coherent radiation starts
to exceed the incoherent one (λ_{coh})
with and without correlations
in the bunch

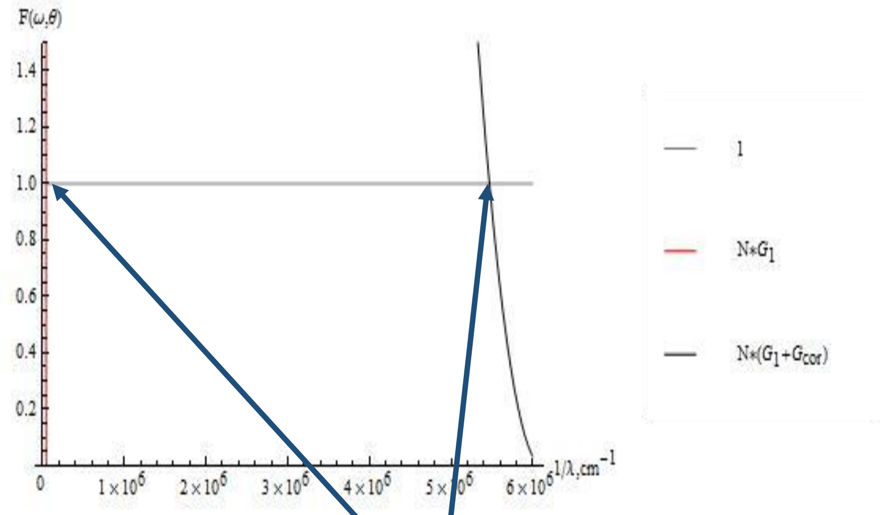
Uniform distribution



$\lambda_{cor}^{Uniform} \approx 1.7*10^{-2}$ nm

difference $\approx 10^5$

Gaussian distribution



$\lambda_{cor}^{Gauss} \approx 1.8$ nm

difference $\approx 10^3$

D.K. Danilova, A.A. Tishchenko, M.N. Strikhanov, *Coherent diffraction radiation from bunch of correlated electrons*, Proc. of RREPS-17: XII International Symposium, Hamburg, 2017, p. 107

Thank you for your attention!