Partially Coherent EM Radiation of an Electron Bunch

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Principal questions I :

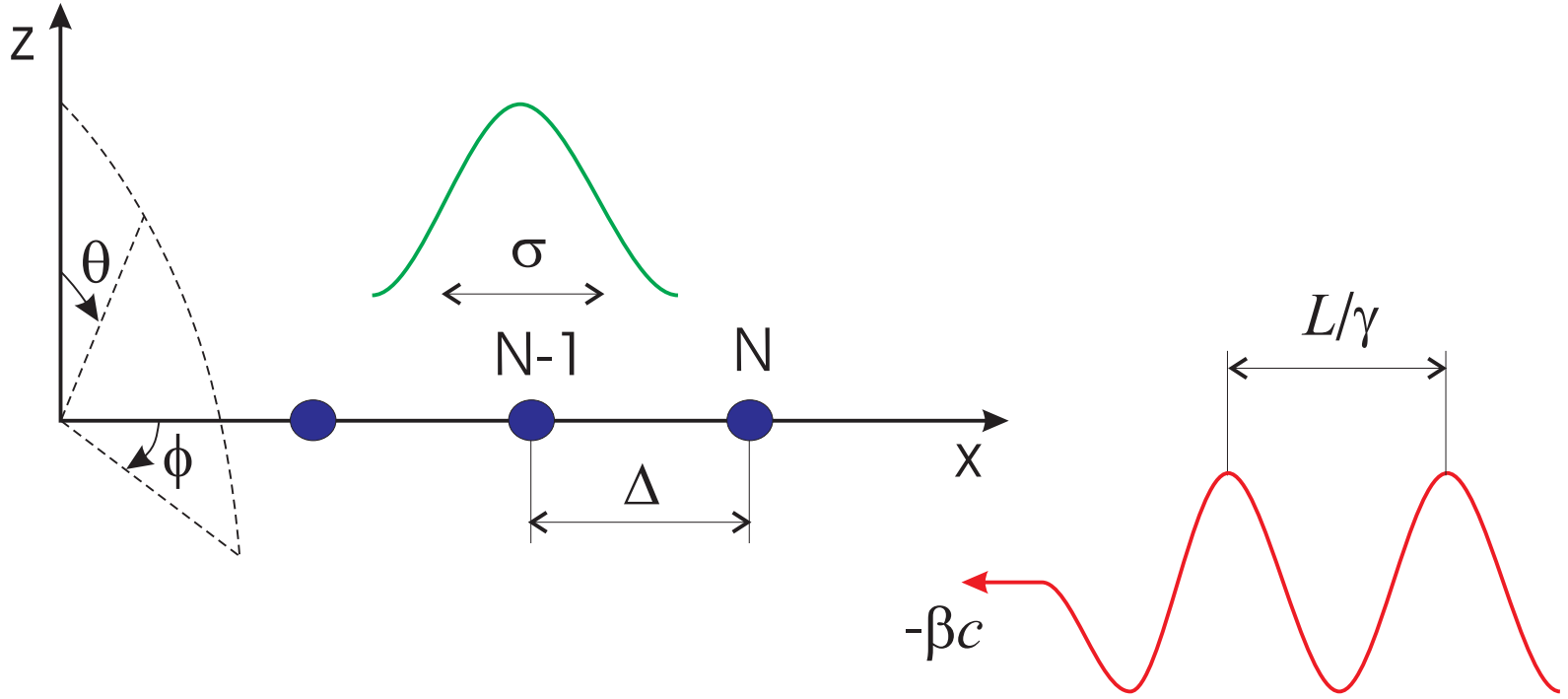
- How and when spontaneous radiation disappears in the limiting case of an uniform steady state current which can not radiate at all?
- To what extent the coherence of radiation is kept for very remote particles?
- To what extent the N^2 law is valid for a bunch which size is much smaller than the wavelength?

principal questions II :

- How is the response momentum distributed between two (or more) electrons radiating coherently a single photon?
- In application to short-wave FELs: is there a lower limit for the radiation wavelength?
- What is a spectral-angular distribution of coherent radiation of a bunched beam in an undulator serving as the second stage of a high-power FEL?

Description of the model

- Model an infinitely thin train of N electrons moving along a plane undulator approximately equidistantly with a fixed uncertainty of positions and with the same velocity βc



Calculation of the model

- **To find the coherence factor one has to calculate the sum**

$$C = \frac{1}{N}\left\langle \left| \sum_{k=1}^{N} \exp(i\psi_k) \right|^2 \right\rangle; \qquad C = 1 + A\left(\frac{1}{N} \frac{\sin^2 \alpha}{\sin^2 \alpha / N} - 1 \right)$$

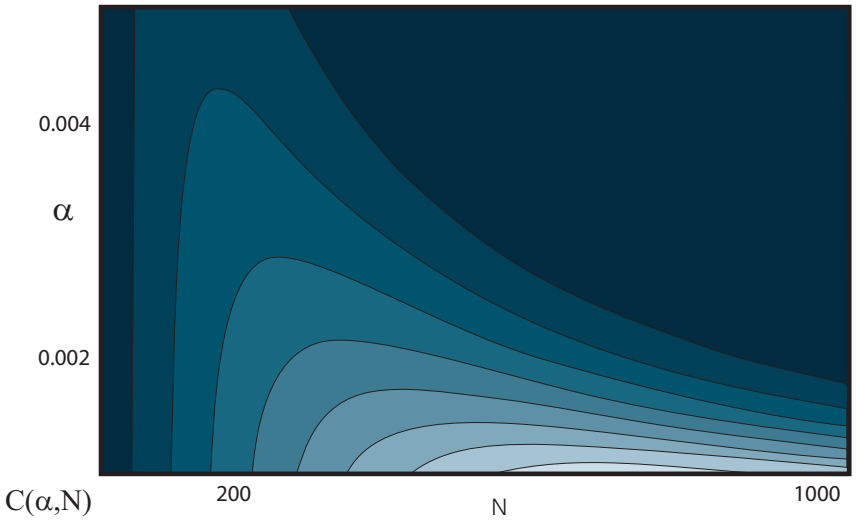
where $A = \exp\left(-\sigma^2 / 2\Delta^2\right)$ **and** $\Delta = l/N$, l **is the bunch length**

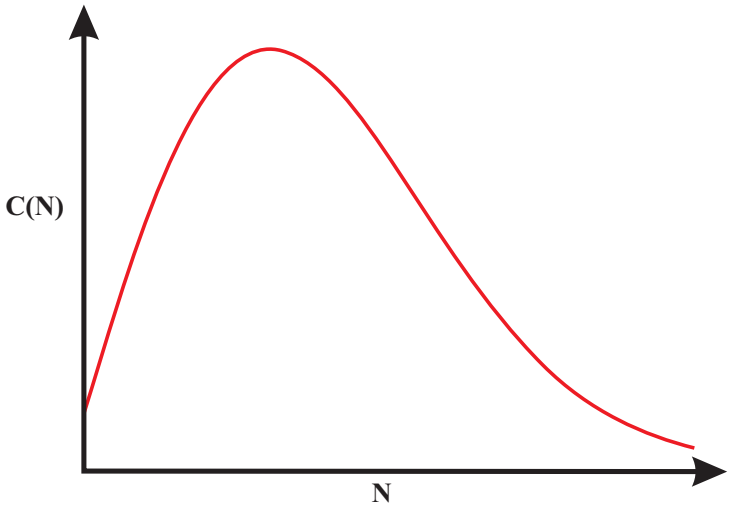
$$\alpha = \frac{2\pi\Delta}{\beta L}\gamma^2\left(1 + \beta \sin\theta \cos\varphi\right)$$

Criteria of coherence

If $\alpha << 1$

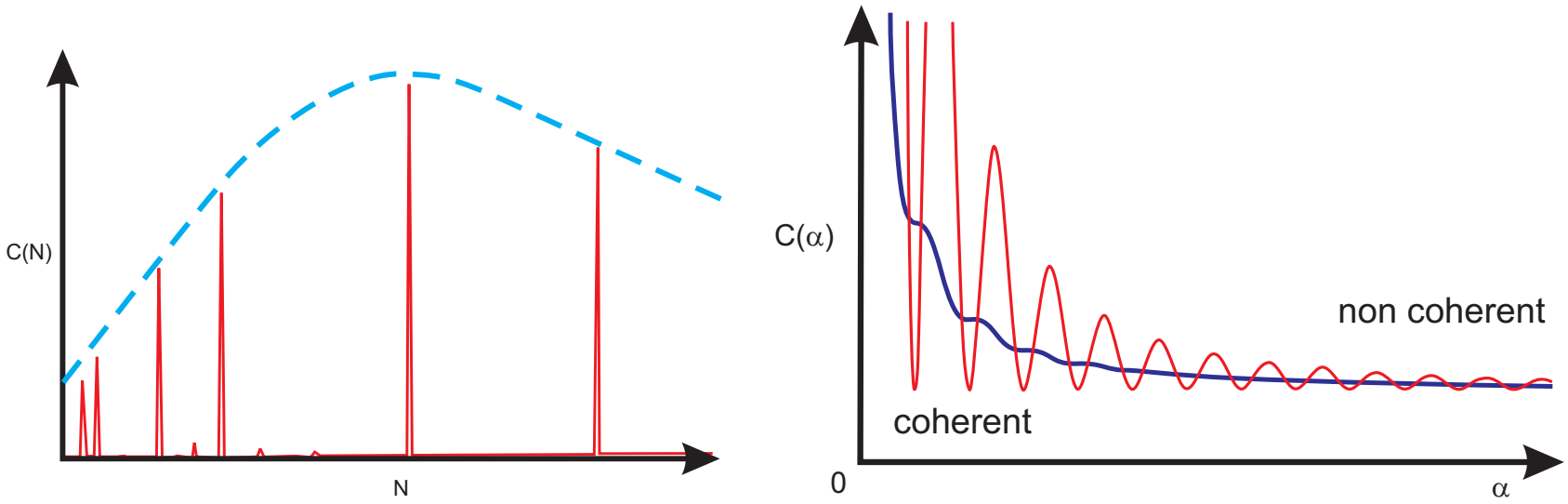
$$C = 1 + (N-1)\exp(-\sigma^2 N^2 / 2l^2)$$





Partial coherence

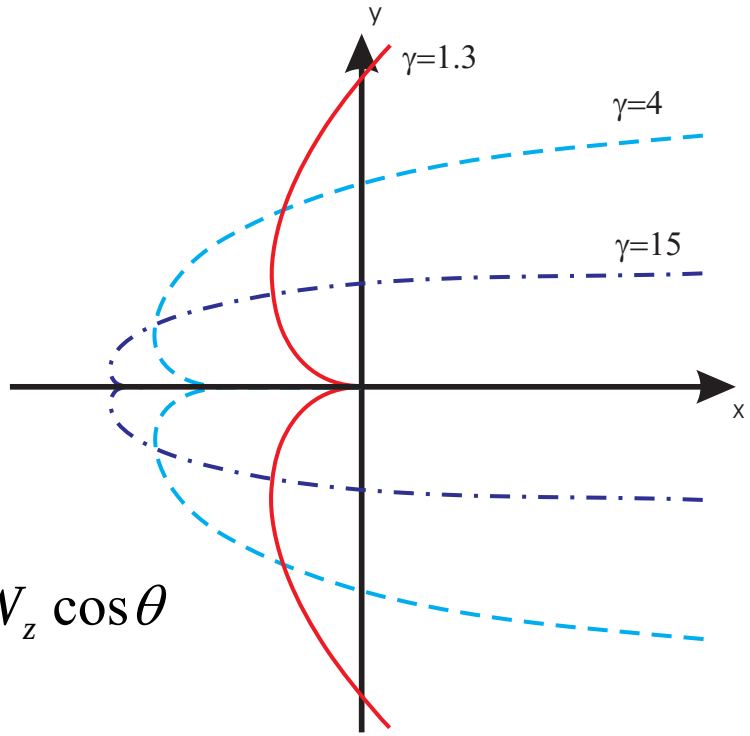
If $N \sim \alpha$



Poynting vector current lines

Poynting vector is proportional to the 4th column of Maxwellian tensor.

$$P_r \cong C(\alpha, A, N) W_r$$

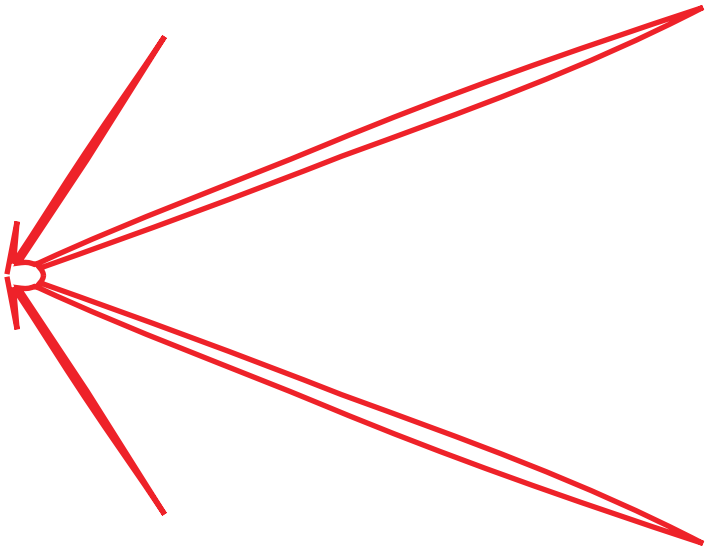


$$W_r = W_x \sin\theta\cos\varphi + W_y \sin\theta\sin\varphi + W_z \cos\theta$$

“Smearing” factor Influence

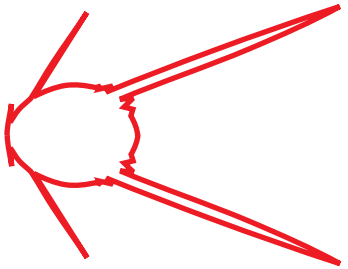
- **Coherent & freedom in particles positioning**

A=0.7



coherent

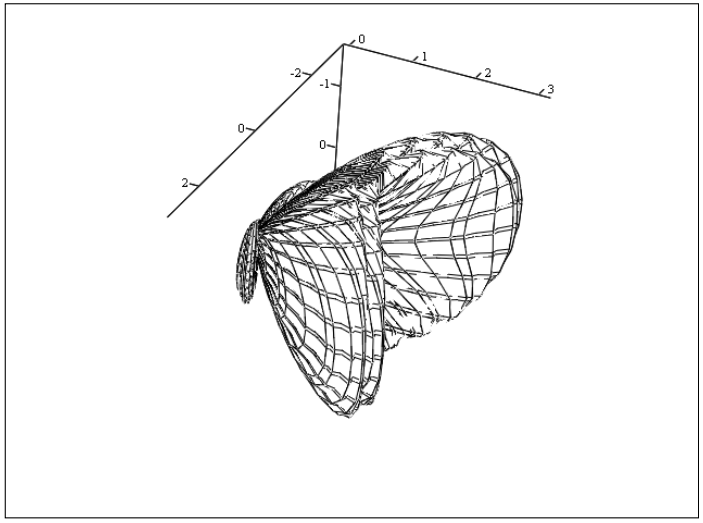
A=0.1



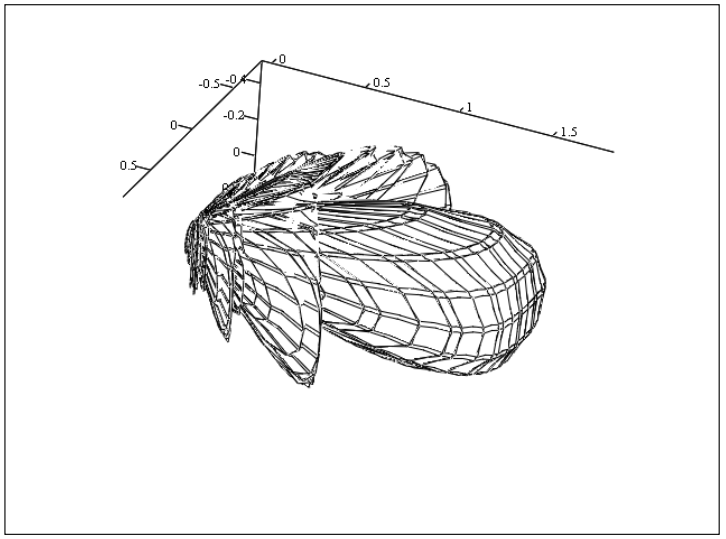
non coherent

Angular 3D distribution

- Coherent minimum (left) and maximum (right)

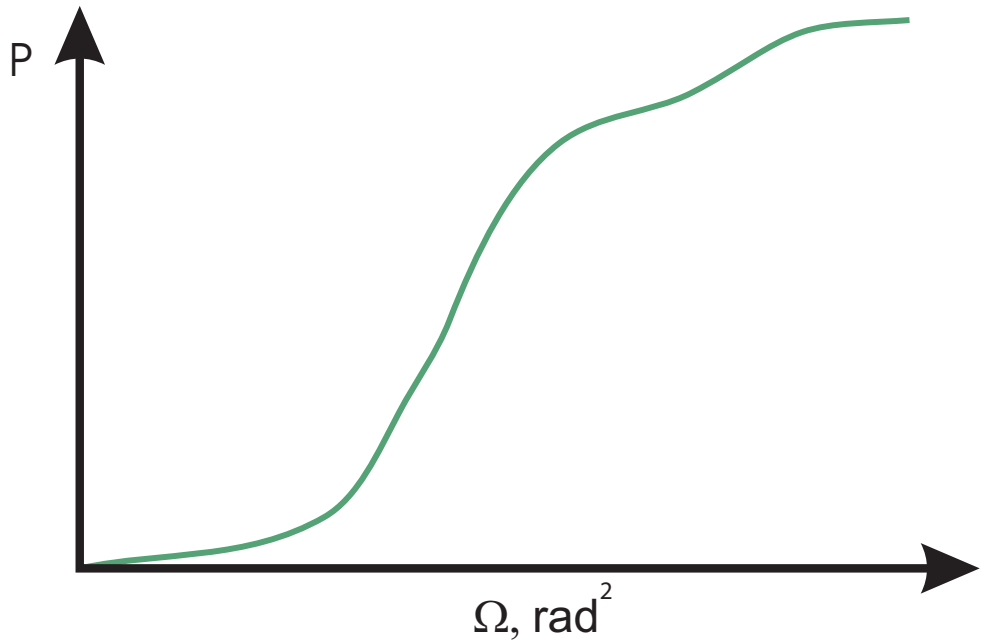


F3D



F3D

Integrated intensity in x-direction



- **Total intensity within a narrow cone of observation**

N^2 law

Point-like bunch never behaves as elementary particle of increased charge