Spectral and statistical proprieties of radiation in a quantum SASE FEL

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We have solved numerically the 1D quantum SASE model

$$\frac{\partial c_n}{\partial \bar{z}} = -i\frac{n^2}{2\bar{\rho}^{3/2}}c_n - (Ac_{n-1} - A^* c_{n+1})$$

$$\frac{\partial A}{\partial \bar{z}} + \frac{\partial A}{\partial \bar{z}_1} = \sum_{n=-\infty}^{\infty} c_n c^*_{n-1} + i\delta A$$

$$\Psi(\theta,\bar{z},z_1) = \sum_{n=-\infty}^{\infty} c_n(\bar{z},z_1)e^{in\theta}$$

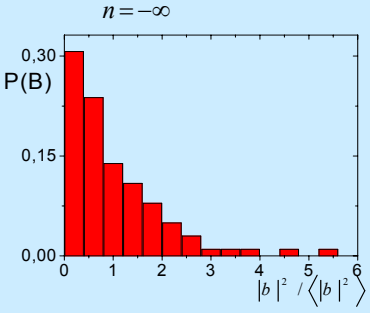
$$|A|^2 = \frac{\langle N_{ph}\rangle}{N_e}$$

$$\bar{\rho} = \left(\frac{mc\gamma_r}{\hbar k}\right)\rho,$$

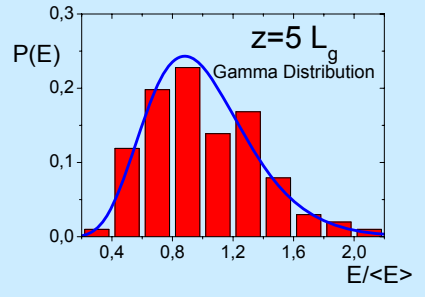
$$\bar{z} = \frac{z}{L_g}, \quad z_1 = \frac{z-vt}{L_c}, \quad \bar{\omega} = L_c(\omega-\omega_s), \quad \delta = \frac{\gamma_r-\gamma_0}{\gamma_r\rho}$$

$$L_g = \frac{\lambda_w}{4\pi\rho\sqrt{\bar{\rho}}}, \quad L_c = \frac{\lambda_r}{\lambda_w}L_g,$$

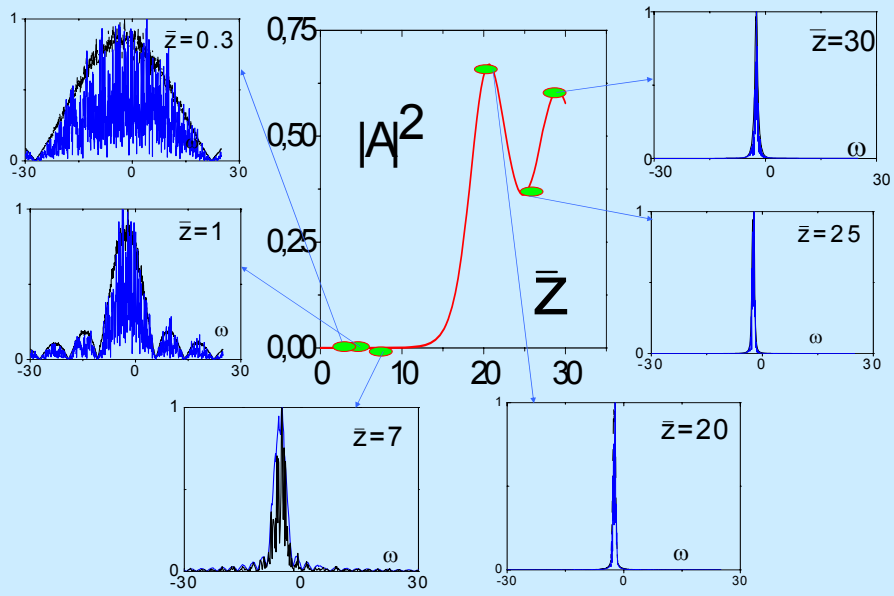
$$B = \sum_{n=-\infty}^{\infty} c_n c^*_{n-1} = |b_0|e^{\phi_0}$$



$\bar{\rho} = 0.2$



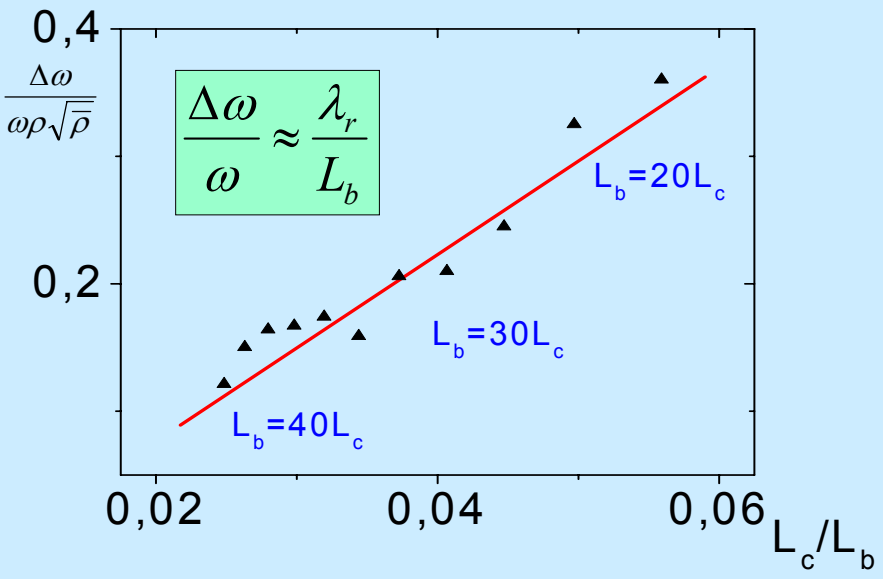
Spectral proprieties of the radiation



Single-shot spectral width

$$\sigma = \frac{\Delta\omega}{\omega\rho\sqrt{\bar{\rho}}}$$

$$\frac{\Delta\omega}{\omega} \approx \frac{\lambda_r}{L_b}$$

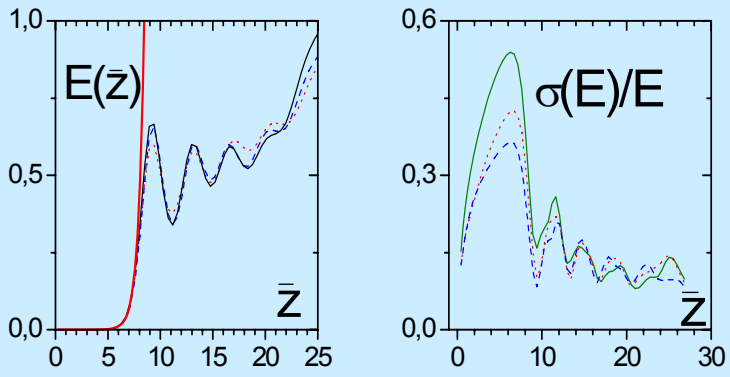


Average Energy of SASE radiation

$$E(\bar{z}) = \frac{1}{L_b}\int_0^{L_b+\bar{z}} dz_1 \left|A(\bar{z},z_1)\right|^2 \approx \frac{\sqrt{\pi}}{2N_c\sqrt{\bar{z}}}e^{2\bar{z}}$$

$\bar{\rho} = 0.2$

$N_c = N_\lambda(\lambda/L_c)$

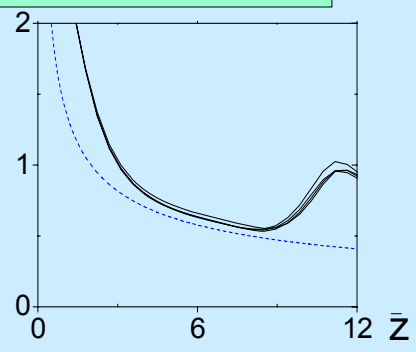


$L_b / L_c = 13, 18, 22,$

Average Spectral width

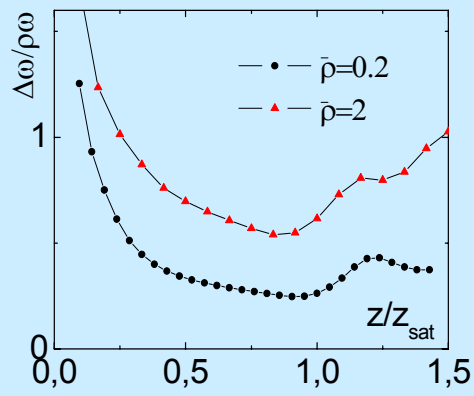
$$\sigma \equiv \frac{\Delta\omega}{\rho\sqrt{\bar{\rho}}\,\omega} \approx \sqrt{\frac{2}{\bar{z}}}$$

$\bar{\rho} = 0.2$



$L_b / L_c = 13, 18, 22, 27,$

Classical (red) and quantum (black) average spectral width



CONCLUSIONS

- **We have numerically proved that in the Quantum SASE the FEL radiation spectrum is composed by a single spike with $\Delta\omega/\omega \sim \lambda_r/L_b$, a factor 10^3 smaller that in classical SASE spectrum (composed by $N=2\pi(L_b/L_c)$ spikes).**
- **Average spectrum, energy and fluctuations have been also determined in the quantum regime.**

REFERENCE

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