Innovative X-γ ray sources based on LASER-produced plasmas

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Overview

Interaction

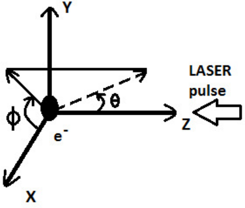

Figure: Geometrical configuration for the scattering between the LASER pulse and the electron bunch[1].

$$\xi = k_i x^i = \omega_0 (t + \frac{z}{c})$$

$$\overrightarrow{a} = \widehat{y} \; a_0 \; e^{-\frac{\xi^2}{2\omega_0^2 \tau^2}} \; \cos \xi \quad ; \quad a_0 \sim 8.5 \times 10^{-10} \sqrt{I_0 \lambda_0^2}$$

Electron dynamics

$\omega_0 \tau >> 1 \leftarrow Long \;\; Pulse$

$$
\begin{aligned}
x &= x_0 \xi \\
y &= y_0 \xi + y_1 \; a_0 \; e^{-\frac{\xi^2}{2\omega_0^2 \tau^2}} \sin \xi \\
z &= z_0 \xi + z_1 \; a_0 \; e^{-\frac{\xi^2}{2\omega_0^2 \tau^2}} \sin \xi + \frac{z_2}{2} \; a_0^2 \; e^{-\frac{\xi^2}{\omega_0^2 \tau^2}} (\xi - \frac{1}{2} \sin 2\xi)
\end{aligned}
$$

Radiation

Two variables generalized Bessel functions[2]

$$\frac{d^2N}{d\Omega d\omega} = \frac{\alpha\ \omega}{(2\pi\omega_0)^2} \left| \sum_{n,l=-\infty}^{n,l=+\infty} \int d\xi J_n(\rho_1 \frac{\omega}{\omega_0}) J_{n-2l}(\rho_2 \frac{\omega}{\omega_0}) (\widetilde{\beta_\theta}, \widetilde{\beta_\phi}) e^{i(\rho_0 \frac{\omega}{\omega_0} - n)\xi} \right|^2$$

$$\begin{aligned}
\rho_0 &= 1 - \sin\theta \frac{\omega_0}{c}(x_0 \cos\phi + y_0 \sin\phi) - \frac{\omega_0}{c}(1+\cos\theta)(z_0 + \frac{a_0^2}{2} z_2) \\
\rho_1(\xi) &= \frac{\omega_0}{c} a_0 e^{-\frac{\xi^2}{2\omega_0^2\tau^2}} (y_1 \sin\phi \sin\theta + z_1(1+\cos\theta)) \\
\rho_2(\xi) &= -\frac{\omega_0}{c} \frac{a_0^2 e^{-\frac{\xi^2}{\omega_0^2\tau^2}}}{4} z_2(1+\cos\theta)
\end{aligned}$$

Linear Thomson Backscattering Radiation

$a_0 << 1$

$$\frac{d^2N}{d\Omega d\omega} = \frac{\alpha\ \omega\ T^2}{64\gamma_0^2\pi^2}\ a_0^2\ e^{\frac{-T^2}{4\tau^2}}\ (1-4\frac{(\gamma_0\theta sin\phi - \gamma_0\theta_e sin\phi_e)^2}{(1+(\gamma_0\chi)^2)^2})sinc^2(\frac{T}{2}(\rho_0\omega-\omega_0))$$

$$Fundamental\ \ emission\ \ frequency \rightarrow \omega_f = \frac{4\gamma_0^2\omega_0}{1+\gamma_0^2\chi^2}$$

$$\chi = \sqrt{\theta^2 + \theta_e^2 - 2\theta_e\theta cos(\phi - \phi_e)}$$

Radiation from an electron bunch

$$\star\frac{d^2N}{d\Omega d\omega} = \frac{\digamma N_e\alpha}{4\pi^2}\omega a_0^2 e^{\frac{-T^2}{4\tau^2}} T^2 \int d\theta_e\ d\phi_e\ d\gamma_e\ \Theta(\theta_e)\Phi(\phi_e)\Gamma(\gamma_e)\{ (1-4\frac{(\gamma_e\theta sin\phi-\gamma_e\theta_e sin\phi_e)^2}{(1+(\gamma_e\chi)^2)^2})sinc(\frac{T}{2}(\rho_0\omega-\omega_0))\}$$

$$\star N_{ph}^{tot} = \digamma\ N_e\ \frac{1}{2}\ \alpha\ \omega_0 T a_0^2 e^{\frac{-T^2}{4\tau^2}}\ \psi^2\frac{1+\psi^2+\frac{2}{3}\psi^4-\frac{1}{4}\gamma_0^2(\theta_e^{div})^2(1+\psi^2+\frac{1}{3}\psi^4)}{(1+\psi^2)^3}$$ [3]

Transversal filling factor $\rightarrow \digamma \equiv \frac{\int dr_e R(r_e) e^{\frac{-2r_e^2}{w_0^2}}}{\int dr_e R(r_e)} = \frac{w_0^2}{w_0^2+4w_e^2}$

$\star\ \psi = \gamma_0\theta$

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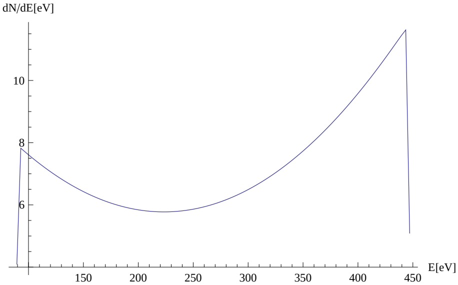
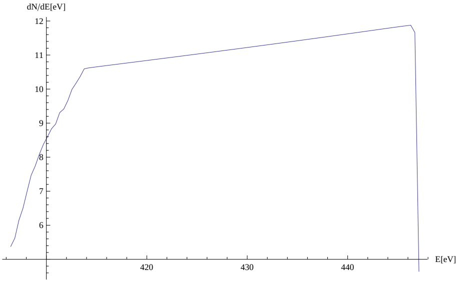
$$
\begin{aligned}
\omega_0 &= \frac{2\pi c}{\lambda} = \frac{2\pi c}{1.054\mu m} \sim 1.79 \times 10^{15} rad/s \\
\tau &= 3ns \\
w_0 &\sim 100\mu m \\
E_L &\sim 20J \\
I_0 &= 2.12 \times 10^{13} W/cm^2 \longrightarrow a_0 \sim 0.004 \\
\epsilon_n &\sim 2mm\ mrad \longrightarrow w_e \sim 2mm\ ,\ \theta_e^{max} < 1mrad \\
I_e &\sim 6A \longrightarrow N_e \sim 5 \times 10^8 \\
\tau_e &= 15ps \\
\gamma_0 &= 10, 20
\end{aligned}
$$

Emission Spectrum, maximum acceptance



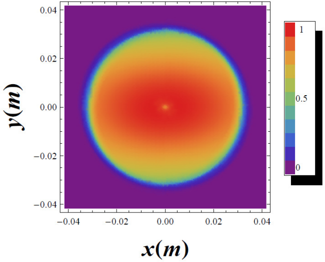
Thomson spectrum obtained by fixing the maximum acceptance semi-aperture $\theta_{max} \sim 1/\gamma_0$ ($\gamma_0 = 10$).

Emission Spectrum, 10% monochromaticity



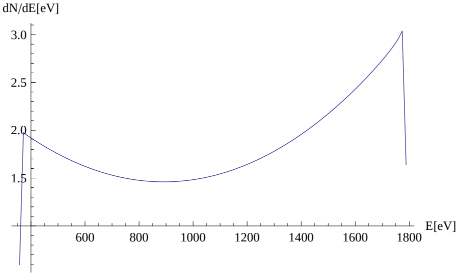
Thomson spectrum, relative to the case with $\gamma_0 = 10$, obtained by fixing the acceptance semi-aperture $\theta_{max} \sim 1/(10\sqrt{10})$ in such a way to detect just radiation near 0.45 *keV* (on-axis) with a 10% monochromaticity degree.

Radiation spot



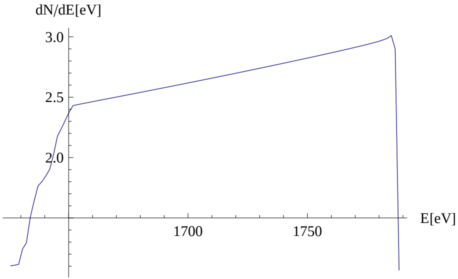
Thomson radiation spot on a screen at $1m$, relative to the case with $\gamma_0 = 10$; red stands for $\sim 1.4 \times 10^2$ photons/cm^2.

Emission Spectrum, maximum acceptance



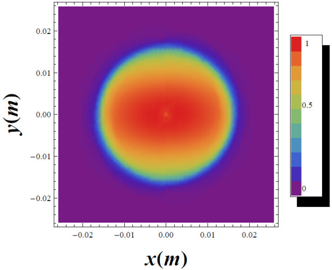
Thomson spectrum obtained by fixing the maximum acceptance semi-aperture $\theta_{max} \sim 1/\gamma_0$ ($\gamma_0 = 20$). The number of particles randomly generated for the calculation is $\sim$ 10000.

Emission Spectrum, 10% monochromaticity



Thomson spectrum, relative to the case with $\gamma_0 = 20$, obtained by fixing the acceptance semi-aperture $\theta_{max} \sim 1/(20\sqrt{20})$ in such a way to detect just radiation near 1.8 keV (on-axis) with a 10% monochromaticity degree.

Radiation spot



Thomson radiation spot on a screen at $1m$, relative to the case with $\gamma_0 = 20$; red stands for $\sim 5.6 \times 10^2$ photons/cm^2.

References

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Thank you for your time