Enhanced coherent Thomson scattering in the few-cycle regime

Ke Hu[1,*], Hui-Chun Wu[1,2]

[1]*Institute for Fusion Theory and Simulation (IFTS) and Department of Physics, Zhejiang University, Hangzhou 310027, China*
[2]*IFSA Collaborative Innovation Center, Shanghai Jiao Tong University, Shanghai 200240, China*[3]
**E-mail: ke_hu1@163.com*

Abstracts: *We study nonlinear coherent Thomson scattering of few-cycle laser pulses by relativistic electron sheets. For an electron sheet of finite thickness, the scattering efficiency is found to increase more than one order of magnitude when laser pulses approach to the single-cycle regime. This enhancement is caused by the reduction of destructive interference in the scattering process, and occurs for the sheet thicker than the wavelength of produced x-rays. The scattering amplitude in this nonadiabatic regime is calculated and agrees well with particle-in-cell simulation. These results are important for developing more intense, shorter attosecond x-ray sources.*

The advent of coherent x-ray sources, such as free electron laser, high harmonics from gas and relativistic laser-plasma processes are opening new area of nonlinear x-ray optics and attosecond science. Among these schemes, coherent Thomson scattering (CTS) from relativistic electron sheets potentially produces isolated x-ray pulses of >10GW and <10as. The electron sheet takes a relativistic velocity β_0 along the direction of the sheet plane. When a counter-propagating laser pulse is reflected by this sheet, its frequency ω_0 is upshifted by relativistic Doppler effect. The Doppler shift factor $D_{nl} \propto (1+\beta_0)/(1-\beta_0)$, so x-rays can be generated at tens of MeV. An analytic theory has been established for flat-top or long incident laser pulses.

Here, we discuss nonadiabatic effects of nonlinear CTS in the few-cycle regime, and find that the efficiency increases more than one order of magnitude within a region of laser intensities (Fig. 1a). The dramatic scattering enhancement is due to two facts. First, peak scattering amplitude rises due to the weakening of destructive interference (Fig. 1b). Second, as the pulse duration T shrinks, the lower-frequency components are reflected more efficiently, which causes the scattering pulse has a central frequency lower than $\omega_0 D_{nl}$ (Fig. 1c), and a duration larger than T/D_{nl}. Both scattering amplitude and frequency are predicted by a revised analytic model, and agree well with particle-in-cell simulation by the code JPIC. Moreover, the enhancement condition is also obtained: the electron sheet should be thicker than the wavelength of produced x-rays.

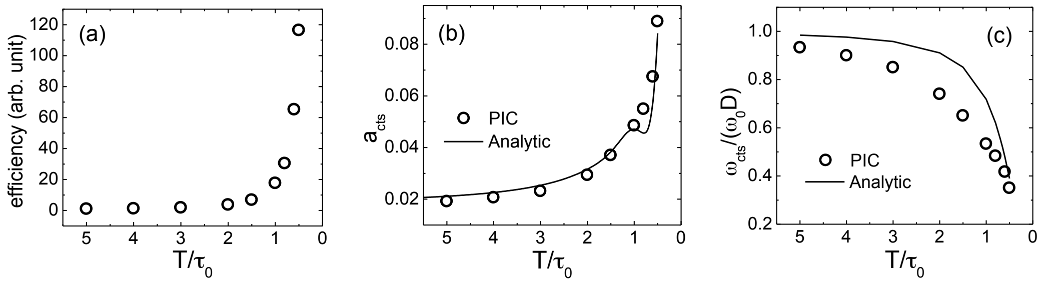

Fig. 1. Normalized efficiency (a), peak scattering amplitude (b) and central scattering frequency (c) as a function of pulse duration T/τ_0, where τ_0 is the light cycle.