Angular dispersion boost of high order laser harmonics interacting with dense plasma clusters

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***Abstract*—We propose a nanosphere array target in the plasma phase as an efficient dispersive medium for the intense XUV light which is originated from laser-plasma interactions where various high harmonic generation processes take place. The scattering process is studied with the help of numerical simulations using resonance conditions obtained from the analytical model. We show that the angular distribution of different harmonics after scattering can be good described by a simple interference, in particular for the rectangle symmetry the angular distribution corresponds to the Bragg-Wolfe diffraction theory.**

Limited size targets interacting with high-intensity coherent radiation is well-studied phenomenon of linear excited surface plasmonic oscillations. Absorption and scattering of incident light in this case good described with Mie theory predicting exist of resonance corresponding to multipole oscillations of part of the target free electrons relative to positive charged ions. Exciting of surface plasmons can lead to significant boost internal and external field on cluster eigenfrequency. In turn, this can cause enhancement of field scattered on large angles relative to the direction of incident wave.

Within the present work we consider the possibility of directed scattering of short wavelength radiation in the XUV range by scattering on suitable spherical clusters.

Similar to the work [1] we develop analytical model for a single cluster based on the Drude dielectic function of the plasma and the Mie scattering theory. To investigate the conditions under which resonant field enhancement occur the determination of the scattering coefficients is necessary in general. Since we are only interested in particle sizes which are smaller than the incident wavelength we use the limiting forms of the respective Bessel functions [2].

Such approximations allow us to estimate the resonance parameters for a target, in particular resonance electron density and radius, for pre-defined wavelength.

As we consider XUV range radiation (20-120 nm), radiuses of spherical scatters should be about few nanometers, that causes $ka \sim 1$. In first-order approximation with wavelength $\lambda_{10} = \lambda_L/10 = 83$ nm, we have $n_e \approx 5.7 \cdot 10^{23}$ cm^{-3} for $ka = 0.7$ ($a \approx 8.91$ nm) to reach efficient scattering.

With these parameters of the single cluster target we consider the resonance and non-resonance case, corresponding to the 1st and 10th harmonic. We found a good scattered field enhancement (about 5 times) in the resonance case in comparison with the non-resonance case.

Using the same resonance conditions for a single plasma cluster, we simulate diffraction by arrays of such clusters in the same cases, described by the laser and 10th harmonic, using code CELES [3].

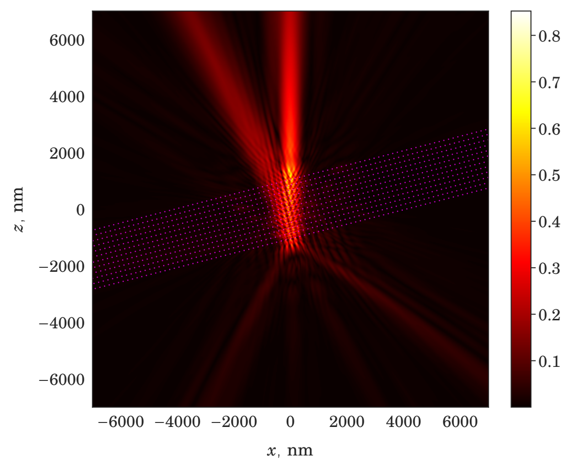

Figure 1. Scattered electric field normalized by the incident beam amplitude. The incident field represented by the gaussian beam with width $w = 300$ nm, x-polarized, propagating along positive direction of z axis; the incident angle $\theta = 14.324°$, the distance between clusters $d = 2\lambda_{10}$.

Obtained results show a significant boost of the scattered field in the resonance case for large angles, which corresponds to the Bragg-Wolfe diffraction theory [2], — the ability to control high harmonics of laser radiation (XUV range) using an ionized cluster gas.

References

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