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

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*Abstract—Periodic surface gratings or photonic crystals are excellent tools for diffracting light and to collect information about the spectral intensity, if the target structure is known, or about the diffracting object, if the light source is well defined. However, this method is less effective in the case of extreme ultraviolet (XUV) light due to the high absorption coefficient of any material in this frequency range. 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 cubic lattices 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.

We propose analytical model for a single cluster based on the Drude dielectic function of the plasma and the Mie scattering theory [1]. To investigate the conditions under which resonant ﬁeld enhancement occur the determination of the scattering coeﬃcients is necessary in general [2]. 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 [3].

Such approximations allow us to estimate the resonance parameters for a target, in particular refractive index m as well as size a, 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 ~ 1. In first-order approximation with wavelength λ10 = λL / 10 = 83 nm, we have ne = 5.7 \* 1023 cm-3 for ka = 0.7 (a = 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 consider diffraction by arrays of such clusters in the same cases, described by the laser and 10th harmonic. Simple cubic lattice with different grating constant d is considered spatial configuration of a volume grating.

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 for planar and volume gratings, --- the ability to control high harmonics of laser radiation (XUV range) using an ionized cluster gas.

REFERENCES

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