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Defects in regular nanosystems and interference spectra at reemission of electromagnetic field attosecond pulses

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Abstract. The effect of defects in nanostructured targets on interference spectra at the reemission of attosecond electromagnetic pulses has been considered. General expressions have been obtained for calculations of spectral distributions for one-, two-, and three-dimensional multiatomic nanosystems consisting of identical complex atoms with defects such as bends, vacancies, and breaks. Changes in interference spectra by a linear chain with several removed atoms (chain with breaks) and by a linear chain with a bend have been calculated as examples allowing a simple analytical representation. Generalization to two- and three-dimensional nanosystems has been developed.

Crystals and nanostructured targets are natural diffraction gratings for X-rays. The diffraction of X-rays by various periodic structures is usually described as the scattering of plane waves with infinite time duration [1]. The scattering of attosecond electromagnetic pulses from such structures has been poorly studied to date. At the same time, such processes can supplement the X-ray diffraction analysis by the capabilities of high time resolution spectroscopy, including attosecond spectroscopy and attosecond metrology [2–6]. Nevertheless, the processes of interference at the scattering of attosecond pulses from various regular targets have been studied only in a few works. The theory of the reemission of attosecond electromagnetic pulses by arbitrary multiatomic systems consisting of isolated complex atoms was developed in [7–9]. Interference effects become dominant in the rescattering spectra when targets are regular structures with a large number of atoms. In this case, the angular distributions of the incident and scattered radiations can be significantly separated by choosing the spatial structure of targets and their various combinations. The theory of the reemission of attosecond electromagnetic pulses by arbitrary regular multiatomic systems consisting of identical complex atoms was developed in [10] with allowance for chaotic thermal vibrations. However, interference processes at the reemission of attosecond electromagnetic pulses by arbitrary regular multiatomic systems containing various defects have not yet been considered.

In this work, the effect of defects in nanostructured targets on interference spectra at the reemission of attosecond electromagnetic pulses is considered. General expressions were obtained for calculations of spectral distributions for one-, two-, and three-dimensional

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multiatomic nanosystems consisting of identical complex atoms with defects such as bends, vacancies, and breaks. Changes in interference spectra by a linear chain with several removed atoms (chain with breaks) and by a linear chain with a bend have been calculated as examples allowing a simple analytical representation. Generalization to two- and three-dimensional nanosystems has been developed. The proposed approach can be directly expanded to more general types of defects. It is noteworthy that the results can pertain not only to one-dimensional and rectangular two- and three-dimensional regular nanostructures. The interference factors of various regular two- and three-dimensional nanostructures determined in [8,9] for planar and cylindrical structures can be used for models of various nanosystems (rings and nanotubes, including multilayer nanotubes and "forest" of nanotubes). In the cases under consideration, it is assumed that the duration of attosecond pulses is much smaller than the characteristic atomic time. In this work, as in [7–10], we consider of the emission of one photon by all atoms of the target in the time of action of sudden perturbation. After the action of sudden perturbation, excited atoms of the target can relax with the emission of photons belonging to the known spectra of isolated atoms. However, if sudden perturbation changes the velocities of atomic electrons, atoms can emit even during its action [11]. A classical analog of the problem in this formulation is the known example [12] of the spectrum of radiation of a free electron at a sudden change of the velocity. After sudden perturbation, atoms of the target are distributed over various excited states. In this case, they can relax with the emission of photons (in time characteristic of radiative transitions). Interference effects will obviously be absent in this case. Furthermore, reemission spectra and spectra emitted at relaxation are strictly separated in time. The reemission spectrum is emitted only in the time of action of an attosecond pulse, whereas the relaxation spectrum is emitted after the action of the attosecond pulse. Thus, the reemission spectra can be identified in the scheme of coincidences with the attosecond pulse.

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