Theory of Ellipticity of High Harmonics Generated in Noble Gases Irradiated by Two-Color Laser Fields Having Orthogonal Linear Polarizations

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Abstracts: *Here we present theoretical explanations of the observation [G. Lambert et al, Nature Comm., 6:6167 (2015)] of elliptically-polarized high harmonics as a result of interaction of two-color laser beams having orthogonal linear polarizations in a noble gas. Numerical calculations based on the non-perturbative light-atom interaction theory reproduce well the experimental data. In addition, the degree of polarization is analyzed for different harmonic orders and found to be high. Through a simplified theoretical model it is shown that the degree of harmonic ellipticity depends mainly on the population of atomic states sublevels with different angular momentum projections.*

Recently, several techniques demonstrated the production of elliptically-polarized high harmonics [1-3], thus increasing the number of possible applications of the HHG for the investigation of polarization sensitive phenomena, such as the X-ray magnetic circular dichroism (XMCD). One of these techniques is based on a two-color laser field in the cross-polarized configuration [3]. Within this scheme, the study of the XMCD in Ni (around 67 eV) brought the proof that the harmonics were highly elliptically polarized and with a non negligible degree of polarization, but up to now no real evaluation of this latter was done. Also, the origin of the observed phenomena was not clear.

For that, we developed a numerical model of the single atom, based on the non-perturbative theory [4], and which takes into account the dynamics of not only the ground states by also of the finite number of excited states. To make a reliable comparison with the experimentally measured spectra, the transmission effects and the material dispersion have been taken into account for calculating the phase-matching effects for the harmonics. The numerical model was preliminarily tested at the demonstration of some typical behavior of the HHG in standard conditions: the generation of elliptically polarized harmonics by elliptically polarized laser radiation and the generation of linearly polarized harmonics in a two-color linearly polarized relatively weak laser field [5].

First, in this report, we show that our numerical results represent nicely the experimentally measured polarization characteristics of the harmonics spectra previously observed [3]. In addition, the degree of polarization of the spatial and temporal behavior of harmonics was evaluated and was demonstrated to be high. Finally, the origin of the high value of harmonics' ellipticity was studied analytically, and leads to the conclusion that this phenomenon results from the population of sublevels with different projections of the orbital quantum numbers of the atomic states.

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