Petahertz-Bandwidth Amplifier for the XUV/X-Ray Attosecond Pulses on the Basis of the IR-Field-Dressed Plasma-Based X-Ray Laser

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High-order harmonic generation (HHG) of infrared (IR)/optical laser fields in gases led to the formation of the attosecond pulses of the extreme ultraviolet (XUV)/X-ray radiation and opened the way for the experimental study and control over the electronic processes in atoms, molecules, and solids at their intrinsic time scales. However, the HHG process is quite inefficient, whereas amplification of the attosecond pulses is a formidable problem since none of the existing amplifiers can support the corresponding petahertz bandwidth. We discuss a possible solution of this problem, that is, the possibility of amplifying an attosecond pulse train based on modulation of a plasma-based X-ray laser with a replica of the IR field used for HHG.

Plasma-based X-ray lasers are capable of producing relatively high-energy picosecond pulses in the XUV/X-ray range in a compact setup. The production of shorter (femto- or attosecond) pulses is hindered by the narrow band of the gain line of an active medium. However, as we have shown in [1], under the action of a strong IR field, which induces a sub-laser-cycle Stark shift of the energy levels of the active medium, the gain of an X-ray laser is redistributed from the inverted transition frequency to a set of equidistant sidebands in petahertz amplification bandwidth, which opens up the possibility of amplifying pulses of attosecond duration.

In this talk, we discuss the possibilities for the attosecond pulse amplification in different wavelength ranges from tens of nanometers to the "water window" range (2.3–4.4 nm) in either collisional (Ne- and Ni-like) or recombination (H-like) plasma-based X-ray lasers. In particular, we have shown the possibility of achieving a high gain on the order of a few tens in intensity for circularly polarized pulses and even higher gain on the order of a hundred for linearly polarized pulses. The possibility of increasing the ellipticity during the amplification is also shown [2]. Besides, it is shown that the use of the second harmonic of the fundamental frequency IR field for the modulation of a hydrogen-like X-ray laser makes it possible to significantly increase the amplification efficiency of the attosecond XUV/X-ray pulses of linear polarization [3].

References

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