# Amplification of elliptically or circularly polarized sub-femtosecond XUV pulses in optically dressed neon-like plasma-based X-ray laser

Ilias Khairulin[1,*], Vladimir Antonov[1,2], Mikhail Ryabikin[1,2] and Olga Kocharovskaya[3]

[1]Institute of Applied Physics of the Russian Academy of Sciences,
46 Ulyanov Street, Nizhny Novgorod 603950, Russia
[2]Prokhorov General Physics Institute of the Russian Academy of Sciences,
38 Vavilov Street, Moscow 119991, Russia
[4]Department of Physics and Astronomy, Texas A&M University,
College Station, 578 University Drive, Texas 77843-4242, USA

*email: khairulinir@ipfran.ru

In recent years, considerable attention has been paid to the generation of elliptically and circularly polarized high-order harmonics (HHs) of optical and infrared (IR) laser radiation. Recent advances in attosecond physics have led to the creation of compact sources of coherent short-pulse XUV and soft X-ray radiation based on high-order harmonic generation (HHG). The HHG sources have a number of apparent advantages such as high coherence, ultrashort pulse production capability, compactness, relative cheapness, etc. At the same time, the harmonic radiation typically has a low power, especially in the case of elliptical polarization, which motivates a search for the ways to amplify it.

Recently, the method has been proposed, in which attosecond pulse trains formed by a set of linearly (*z*-) polarized HHs are amplified in a hydrogen-like active medium of a plasma-based X-ray laser dressed by a replica of an IR field of the fundamental frequency with the same linear polarization [1]. Due to the sub-laser-cycle linear Stark shift of the excited energy levels of the resonant ions under the action of the IR field, the gain spectrum of the hydrogen-like active medium for *z*-polarized component of the X-ray field is redistributed to a set of sidebands whose frequencies coincide with the frequencies of HHs. However, the gain spectrum for the orthogonal (*y*-) polarization component of the X-ray field remains localized at the single resonance frequency, which prevents the amplification of elliptically or circularly polarized pulse trains.

In this work, we generalize the method [1] for a neon-like active medium of a plasma-based X-ray laser. We find that in the case of neon-like ions, a linearly polarized laser field induces the gain redistribution to the multiple sidebands both for *z*- and *y*- polarization components of the resonant XUV field. With the proper choice of the laser intensity and wavelength, the frequencies of the induced gain lines for *z*- and *y*- polarization components of the XUV field coincide with each other. We show the possibility to amplify a train of sub-femtosecond pulses with the circular or elliptical polarization, composed of HHs of the modulating IR field, in the active medium of a neon-like plasma-based X-ray laser. We also show the possibility to control the ellipticity of HHs and, in particular, to increase the ellipticity of a sub-femtosecond pulse train by an order of magnitude along with its amplification. Finally, we propose an experimental implementation in an active medium of a plasma X-ray laser based on neon-like $Ti^{12+}$ ions irradiated by an IR laser field with a wavelength of 3.9 μm.

[1] V. A. Antonov, K. Ch. Han, T. R. Akhmedzhanov, M. Scully, O. Kocharovskaya, *Phys. Rev. Lett.*, **2019**, 123, 243903.