# Attosecond Perspective of Plasma-Based X-Ray Lasers

V A Antonov[1], I R Khairulin[1], and M Yu Ryabikin[1,2]

[1] *Nonlinear Dynamics and Optics Division, Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov Street, Nizhny Novgorod, Russia. Contact Phone: +7(831) 436-47-33*

[2] *Faculty of Radiophysics, Lobachevsky State University of Nizhny Novgorod, 23 Gagarin Avenue, Nizhny Novgorod, Russia. Contact Phone: +7(831) 462-32-61*

Contact Email: antonov@appl.sci-nnov.ru

Plasma-based soft X-ray lasers (SXRLs) are capable of producing highly coherent energetic radiation in the extreme ultraviolet (XUV) and soft X-ray ranges [1]. However, the picosecond duration of the produced pulses prevents from using them for study of the ultrafast femto- and attosecond processes. Furthermore, the emitted radiation is unpolarized, which hinders the study of anisotropic and chiral media. Partly, these limitations are lifted by using a SXRL as an amplifier of high-harmonic (HH) radiation of an optical laser field [2,3]. However, narrow gain bandwidth of SXRLs prevents from joint amplification of the harmonics of different orders and stretches the envelope of the amplified harmonic to sub-picosecond duration.

In this contribution, we discuss our recent results, showing the possibility to enrich the gain spectrum of a SXRL with multiple equidistant induced gain lines (and thus to drastically broaden the gain bandwidth) by irradiating the active medium with a strong optical laser field. As was first shown in [4] for the hydrogen-like active medium, the optical/IR field produces deep Stark shifts of the upper lasing energy levels of the SXRL, which follow the oscillations of the laser field strength. This results in frequency modulation of the inverted transition of the SXRL on sub-laser-cycle time scale and redistribution of the gain to the set of sidebands, separated from the resonance by multiples of the modulating field frequency. This opens up the possibility to use a SXRL for the amplification of attosecond pulses produced via high-harmonic generation driven by a replica of the modulating field. In this case, under the optimal conditions, the shape and duration of the amplified pulses are nearly preserved.

Further we show that the use of an optically modulated neon-like or nickel-like SXRL makes it possible to amplify a set of HHs with arbitrary elliptical polarization [5]. This is due to the fact that in neon- or nickel-like active medium, the action of a linearly polarized modulating field results in the gain redistribution to the sidebands for both polarization components of the HH field, parallel and orthogonal to the polarization of the modulating field. We discuss the possibility to amplify a train of sub-femtosecond pulses, constituted by circularly polarized HHs, with approximate preservation of their polarization state, as well as the possibility to increase the ellipticity of harmonics during their amplification.

Finally, we discuss the possibility to transform (with energy increase) the polarization state of a train of sub-femtosecond pulses from linear into circular in optically dressed neon-like SXRL. Such transformation relies on (i) the anisotropy of the active medium, induced by the linearly polarized modulating optical field, and (ii) the resonant dispersion of the active medium [6].

## References

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