Recent Progress on Laser-Driven Soft X-Ray Lasers at LOA

A Kabacinski[1], F Tissandier[1], J Gautier[1], M Kozlova[1], J-P Goddet[1], A Tafzi[1], E Oliva[2], F Tuitje[3], T Helk[3], C Spielmann[3], M Zürch[4], and S Sebban[1]

[1] *LOA, ENSTA, École Polytechnique, CNRS, Palaiseau, France*
[2] *Universidad Politecnica de Madrid, Madrid, Spain*
[3] *Abbe Center of Photonics, Jena, Germany*
[4] *Department of Chemistry, University of California, Berkeley CA, USA*
Contact Email: adeline.kabacinski@ensta-paris.fr

We report here recent work on an optical-field ionized EUV laser at 32.8 nm, which is seeded by an external high order harmonic source allowing to improve the spatial properties of the EUV laser while exploiting the energetic qualities of the plasma amplifier (up to 14 μJ were measured in the ASE regime for a 20 mm long amplifier).

The gain lifetime of the EUV laser amplifier strongly depends on the depletion rate of the lasing ion population. Indeed, electron collisions with the lasing ions contribute to build up a population inversion but also lead to the overionization of this ion, and therefore to an anticipated interruption of the gain. When increasing the plasma density from 3×10^{18} cm^{-3} up to 1.2×10^{20} cm^{-3}, the gain duration monotonically decreases from 7 ps to unprecedented shortness of 450 fs FWHM [1]. The EUV pulse duration being dictated by the duration of the gain, we recently implemented a single shot diagnostic allowing to measure the temporal profile of the EUV laser and observed a reduction of the pulse duration with respect to the electronic density down to 900 fs FWHM at 7.6×10^{19} cm^{-3}.

Recently, we employed ptychographic coherent diffraction imaging [2] for characterizing the EUV laser beam in amplitude and phase with high fidelity. By observing the diffraction patterns produced by the illumination of a sample, one can reconstruct the incident complex-valued wavefront in the sample plane. Backpropagation of the field up to the source allows determining source properties, therefore revealing an inner sight of the ionization mechanisms and in particular inhomogeneities in the plasma resulting from the required strong optical pump field.

More newly, we demonstrated second harmonic generation (SHG) on a table-top XUV source for the first time by observing SHG at the Ti $M_{2,3}$-edge with a high harmonic seeded soft X-ray laser[3].

References

[1] A Depresseux, E Oliva, J Gautier, F Tissandier, J Nejdl, M Kozlova, G Maynard, J P Goddet, A Tafzi, A Lifschitz, H T Kim, S Jacquemot, V Malka, K Ta Phuoc, C Thaury, P Rousseau, G Iaquaniello, T Lefrou, A Flacco, B Vodungbo, G Lambert, A Rousse, P Zeitoun and S Sebban, Nat. Photonics **9**, 817 (2015)

[2] F Tuitje, P Martínez Gil, T Helk, J Gautier, F Tissandier, J-P Goddet, A Guggenmos, U Kleineberg, S Sebban, E Oliva, C Spielmann and M Zürch, Light Sci. Appl. **9**, 187 (2020)

[3] T Helk, E Berger, S Jamnuch, L Hoffmann, A Kabacinski, J Gautier, F Tissandier, J-P Goddet, H-T Chang, J Oh, C Das Pemmaraju, T A Pascal, S Sebban, C Spielmann and M Zuerch, Science Advances **7**, eabe2265 (2021)