LASERLAB-EUROPE

The Integrated Initiative of European Laser Research Infrastructures III

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Work package 32
Innovative radiation sources at the extremes (INREX)

Deliverable D32.12
Realize ultra-intense lasers at nanometre wavelengths

Lead Beneficiary: GSI

Contributing partners: CNRS-LOA, CNRS-ISMO, CNRS-LUMAT, IST, PALS, MUT

Due date: M42

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Project webpage: www.laserlab-europe.eu

Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

1 Introduction

The task **"Realize ultra-intense lasers at nanometre wavelengths"**: was described as: Short wavelength lasers will be developed using either the so-called "collisional excitation" or "recombination" schemes. Although widely studied for more than a decade, collisional schemes are the most promising as compact soft x-ray lasers and for reaching ultra-high intensities by seeding using an HHG source, while enlarging the spectral bandwidth of the plasma amplifier. The wavelength scaling with Z ($\lambda \propto$ $[Z\text{-}1]^{-2}$ or $[Z\text{-}3]^{-2}$), has more potential than those based on collisional excitation scheme ($\lambda \propto$ $[Z\text{-}10]^{-1}$ or $[Z\text{-}28]^{-1}$). Moreover, numerical simulations predict that the efficiency of recombination pumping is enhanced when the duration of the driving laser pulse is shortened. Numerical and experimental studies will be undertaken to achieve nm-scale soft x-ray lasers.

2 Objectives

The main objective was the optimization of plasma XRL towards higher output energy and beam quality. For this i) HHG as a seeding source with relatively narrow bandwidth, adapted to the gain profile of the XRL will be developed, and ii) an XRL set-up with two subsequent gain zones with different, increasing, beam diameter will be realized iii) strategies to enlarge the spectral bandwidth so as to support sub-picosecond amplification will be explored. Recombination scheme will be further studied on high Z elements both experimentally and theoretically.

3 Work performed / results / description

In order to reach the task objectives, teams from the participating partners worked on different aspects of the seeding and the amplification process in plasma XRL's. One aspect was the adaptation and optimization of the seeding sources to the required properties. This was pursued at different laboratories with different tools. In collaboration with INFLPR, CNRS-LOA and CNRS-ISMO a seeded soft x-ray laser was implemented at the LASERIX facility by CNRS-LUMAT as early as 2013, employing HHG with < 50 fs laser pulses. At GSI-PHELIX a specific development was aiming at tailoring the HHG wavelength and bandwidth by using much longer laser pulses, and higher density gas targets.

To improve the gas density modulation a new dual gas multi-jet gas puff target was developed at MUT. Schematic of the nozzle and the electromagnetic valve system to produce the target is shown in Fig. 1.

a b

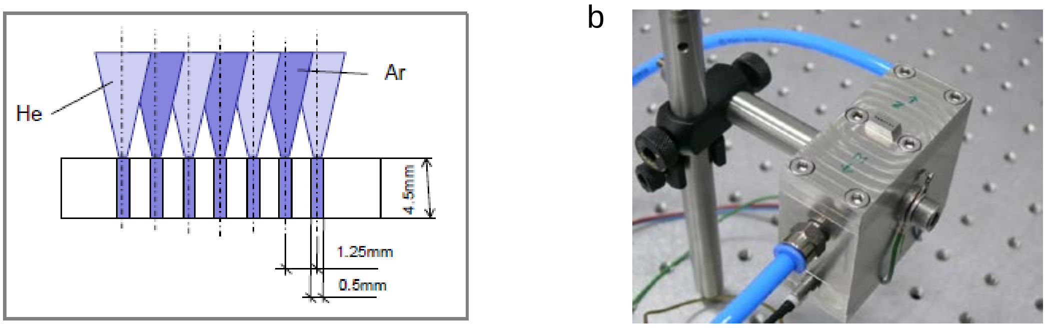

Fig. 1. Schematic of the nozzle to produce a multi-jet gas puff target (a) and the electromagnetic valve system to produce the target (b).

The new target has been studied and characterized using EUV radiography technique.

The multi-jet gas target constructed at MUT was used in joint experiments on high-order harmonics generation performed at PALS. The targets in a form of a 9-mm-long gas sheet with modulated gas density produced using 5-, 7-, and 9-orifice nozzles were irradiated with 40fs/1mJ laser pulses form a Ti:Sapphire laser. The experimental results were compared with numerical simulations performed at Cluj, Romania. The final aim at PALS is a combination of a HHG-seeded transient pumped XRL and the QSS laser pumped by PALS, which could provide a much higher number of photons per pulse. In addition to the efforts on the seeding pulse, together with CNRS-ISMO the bandwidth of the gain profile was studied.

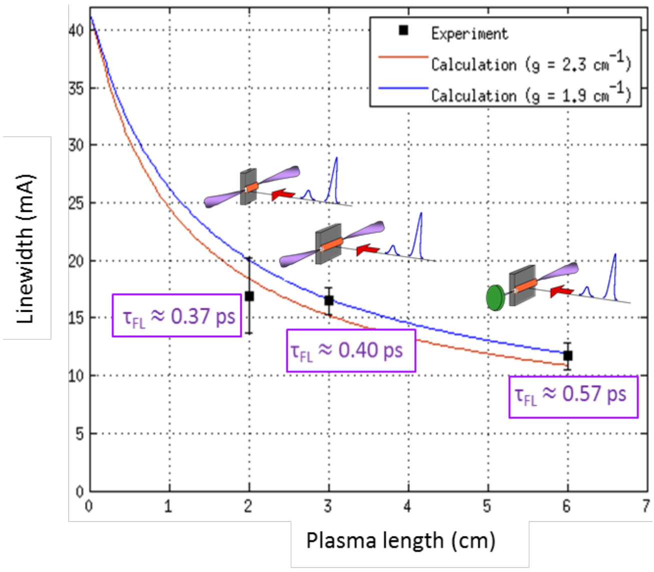

Fig. 2: Bandwidth measurement of the QSS plasma XRL at PALS (Cooperationg PALS/CNRS-ISMO)

To improve the amplification step at transient pumped lasers, a large variety of tailored pump pulses was investigated at the LASERIX facility with dramatic effects on amplifying plasma properties and seeding showing encouraging prospects for large gain region, low refraction operations or high density gain region embedded in an electron density valley for seed beam guiding. Similar schemes of transient pumping, implying multiple, ns- and ps-pulses, were realized at GSI.

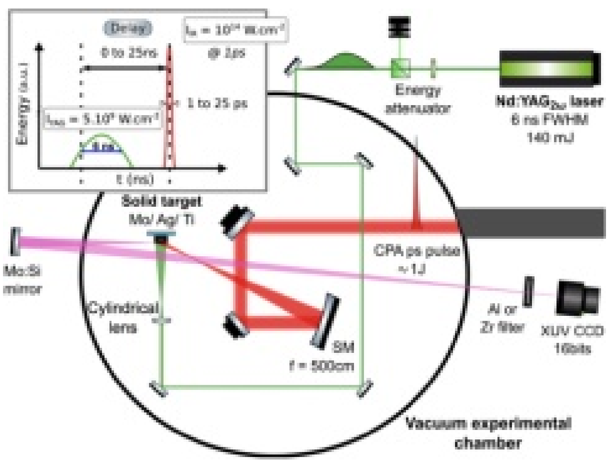

Fig. 3: Q-switched laser-assisted grazing incidence pumping set-up at LASERIX (QAGRIP)

Olivier Delmas et al., Optics Letters, 39 p6102 (2014)

Using these schemes, efficient seeding of the plasma XRL's was demonstrated. At GSI, in cooperation with ENSTA, INFLPR, IST, and LULI seeding by an additional plasma XRL stage was studied. Both stages were pumped by a combination of a ns-prepulse and two ps-pulses. The brilliance was enhanced by more than 2 orders of magnitude. At LASERIX seeding by HHG was shown to benefit strongly by the new pumping scheme.

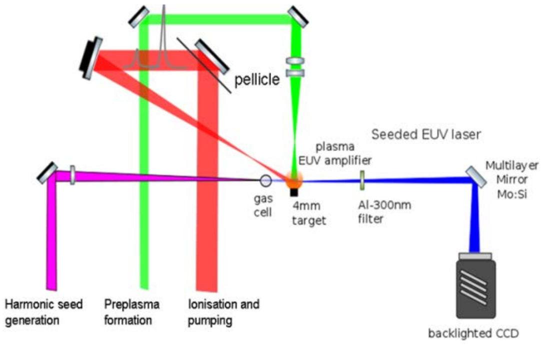

Fig. 4a Set-up for HHG seeding (LASERIX

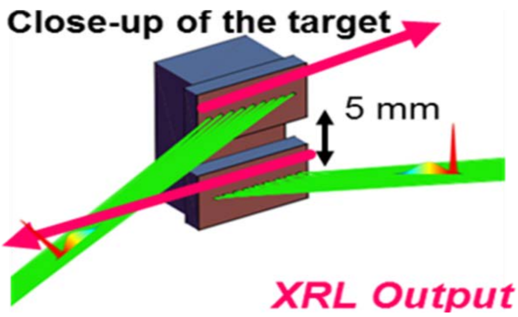

Fig. 4b :Compact double-stage XRL at GSI, Journal of Physics B 48 (2015),144009

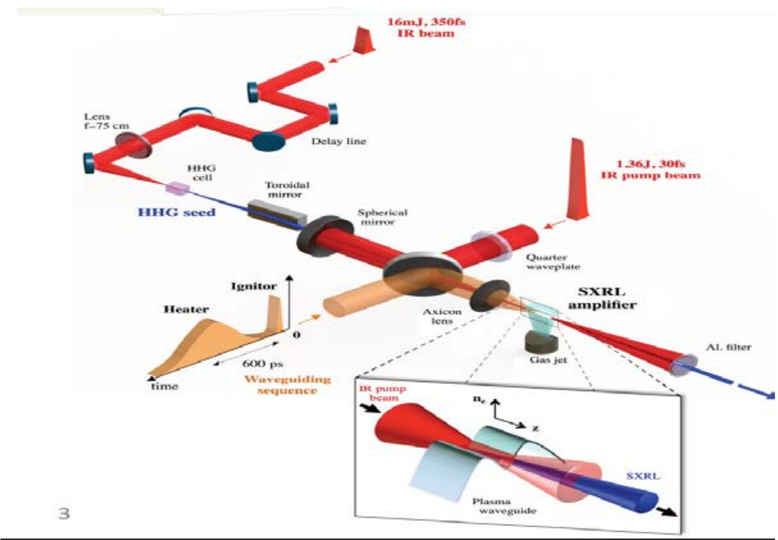

Fig 5. SXRL beam at 32,5 nm.

OFI Plasma amplifier with high density elongated KR gas jet,. Waveguide generated by ignitor and heater pulse, and pumped by intense circular polarized pulse

HH seed from Low density Ar gas cell, imaged into the amplifier with toroidal mirror.

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4 Publications

Depresseux et al. Nature Photonics 2015, doi 10.1038/nphoton.2015.225(2015)

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Double-stage soft x-ray laser pumped by multiple pulses applied in grazing incidence
B Ecker · B Aurand · D C Hochhaus · P Neumayer · B Zielbauer · E Oliva · L Li · T T T Le · Q Jin · H Zhao · K Cassou · S Daboussi · O Guilbaud · S Kazamias · D Ros · Philippe Zeitoun · T Kuehl ·
Journal of Physics B Atomic Molecular and Optical Physics 48 (2015):144009. DOI:10.1088/0953-4075/48/14/144009

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High-brilliance double-stage soft x-ray laser pumped by multiple pulses applied in grazing incidence
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Laser Driven Secondary Sources for Spectroscopy, Plasma Diagnostics and Other Applications
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