PhD position

Saptio – temporal study of an ultra-fast x-ray source produced by laser plasma in ultra-relativistic regime.

Abstract :
The aim of the PhD is to study and develop a hard Kα x-ray source source produced by the interaction of an ultra-intense laser (10 TW - 25 fs) operating at a high repetition rate (100 Hz) with a solid target for X-ray. In particular, the PhD student will study laser matter-interaction regimes that have so far not been explored to produce Kα X-ray (I> 10^{18}W/cm^2) and will carry out pump (optical) and probe (X) experiments to characterize the x-ray pulse duration (<1ps) and to study ultra-fast laser mater interaction.

Starting date : October 1 – 2020 for 3 years.
Location: LP3 laboratory, Campus de Luminy –case 917, 13288 Marseille Cedex 9 – France
Web-site : http://www.lp3.univ-mrs.fr/
Contact : Marc Sentis (DR CNRS) Sentis@LP3.univ-mrs.fr and Amélie Ferre (MCF AMU) Ferre@LP3.univ-amu.fr
Founding : 1350 €/month for 3 years after selection of candidates based on an application form (April 2020) and an oral audition (May 2020).

Introduction and context of the PhD:
Over the past ten years, new x-ray sources with a very short pulse duration (<10^{-12}s) have been developed thanks to technological advances in high-power ultra-fast laser sources. The emergence of these X sources opens new horizons for ultra-fast and x-ray sciences. Applications are numerous and varied (solid and surface physics, plasma physics, femto-chemistry, biology, health, etc.). At LP3 laboratory, a hard Kα x-ray source is generated by the interaction of an intense femtosecond laser pulse (I_{las}> 10^{16} W / cm^2) with a solid target. Kα x-ray emission is induced by the produced hot electrons due to the laser energy absorption by the plasma formed during the interaction. Therefore, Kα spectral lines radiation is governed by the energy distribution of the hot electron population accelerated by the laser electric field and/or the laser-induced plasma field. This x-ray source is carried out at LP3 as part of the ASUR Platform (http://www.lp3.univ-mrs.fr/spip.php?rubrique9)..

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Picture of ASUR Plateform

Short description of PhD work:

Research done at LP3 laboratory for several years led to deliver a very power full and unique Kα x-ray source at 17.4 KeV produced by the interaction of a femtosecond laser pulse with a massive molybdenum target. It delivers up to 10^{11} photons/s/sr with a x-ray source size varying from 6 to 60 µm depending on the laser intensity and the temporal contrast of the laser pulse [1,2]. This size is of the order of x1.5 to x10 times the size of the laser focal spot. The physical phenomena which can explain this widening of the source are quite numerous such as the energy and the trajectory of the energetic electrons generated in the plasma and scattered in the solid target, the presence of a induced electrostatic field and magnetic field, the spatial distribution of the laser beam, ... Another important characteristic of these source is its time duration. It is also more longer than the time duration of the laser pulse for physical phenomena quite similar to those mentioned above. Time duration of the pulse and size of the source are a very important parameters for achieving high peak brightness required to develop many applications. Still today, du to the complexity of such experimental characterization, very little data has been published.

A large part of the work will therefore consist in identifying and studying the physical phenomena leading to a widening of the size and a lengthening of the pulse duration of the x-ray source. The study in the relativistic optics regime (I> 10^{18} W / cm^2) with very high temporal contrast laser pulses (~ 10^{10}) [3] will be emphasisi because still very little explored for such sources.

For the experimental study the PhD student will be able to play with the parameters of the laser pulse (spatial and temporal distribution, temporal contrast) and on the nature, thickness, surface structure of the solid target. Several diagnostics will have to be implemented in order to be able to characterize the x-ray emission, the temperature of the hot electrons, the thickness of the pre-plasma, etc. Some of these diagnotics are already implemented on the LP3 Kα experimental setup, like x-ray spectroscopy or measuring the size of the x-ray source by the well known "knife edge" technic. The latter will be improved because it does not allow up to known, for example, to determine the spatial and spectral distribution of the x-ray source. As already mentioned, the measurement of the duration of an x-ray pulse is a delicate point to solve for such ultra-fast Kα sources. Indeed the most efficient existing direct measurement technic using a streak camera, allows direct measurement only of durations greater than ~ 500 fs. An indirect method consists in detecting an ultra-fast phase transition induced by a femtosecond laser beam of a material by x-ray diffraction. This pump (optical) and probe (x-ray) method will be developed during the thesis to characterize the duration pulse (<1 ps) of the x-ray source using crystalline materials such as Germanium, (Ge), Bismuth (Bi) or Indium Antimonide (InSb) known to present ultra-fast solid-liquid phase transitions (~ 300 to 400 fs).

During his/her PhD, he/she will exploit and enhance the results by participating in: i) phase contrast imaging work where the smallest source size is sought to obtain a quality image and ii) work on static and dynamic phase transition induced by ultra fast laser radiation of material.

[1] AZAMOUM Y., TCHEREMISKINE V., CLADY R., FERRÉ A., CHARMASSON L., UTÉZA O. and SENTIS M. - Impact of the pulse contrast ratio on molybdenum Kα generation by ultrahigh intensity femtosecond laser solid interaction - **Scientific Reports 8**, 4119, 2018.

[2] CLADY R., AZAMOUM Y., CHARMASSON L., FERRÉ A., UTÉZA O. and SENTIS M. - 22 W average power multiterawatt femtosecond laser chain enabling 10^{19} W/cm^2 at 100 Hz - **Applied Physics B** 124, 89, 2018.

[3] AZAMOUM Y., CLADY R., FERRÉ A., GAMBARI M., UTÉZA O. and SENTIS M. - High photon flux Kα Mo x-ray source driven by a multi-TW femtosecond laser at 100 Hz - **Optics Letters** 43(15), 3574-3577, 2018.

Keywords : Ultrafast phenomena, laser-mater interaction, instrumentation.

Scientific skills : Physics, Optics, laser-matter interaction, material sciences and characterizations.

Personal skills : Experimental skills are mandatory, autonomy, curiosity, rigourus, good writting

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