3-year fully-funded PhD position

EUV emission of femtosecond laser-induced nano-plasmas

FEMTO-ST / Optics Department

Besancon, France

Keywords : laser-matter interaction, femtosecond laser pulses, beam shaping, plasmas, ultrafast science, spectroscopy

The Research:

The advancement of Extreme Ultraviolet (EUV) lithography relies on compact, high-brightness sources of EUV radiation. Currently, these sources are large-scale and complex, often requiring extensive installations with multiple CO2 lasers focused onto a single micro-sphere of frozen water. This bulkiness presents a significant limitation, and the emission has no directional control.

This PhD thesis will build on a decade of research into novel laser-matter interaction schemes using spatio-temporally shaped pulses in our group [1] for laser materials processing applications. When appropriately focused inside transparent solids, for instance using Bessel beams, femtosecond laser pulses can be absorbed via nonlinear ionization in extremely confined nano-plasmas with very high energy densities, which lead to the generation of Warm Dense Matter [2]. The confinement within nanoscale plasmas has been recently assessed by ultrafast pump-probe experiments [3,4].

Here, this thesis will explore the EUV emission of nano-plasma rods, generated through the irradiation of solid dielectrics with high-intensity shaped femtosecond laser pulses. Advanced Particle-In-Cell simulations from our group show that a fraction of the free-electrons in the plasma are highly accelerated, from eV to several keV around the critical plasma surface at which field amplification takes place [4,5]. This suggests that the laser-solid interaction will yield EUV emissions in a highly confined and controllable new scheme.

The initial phase of the research is to develop a setup capable of recording EUV emissions from laser-induced nanoplasmas. All the necessary equipment is already available within our laboratory. In a second step, the PhD student will focus on identifying the key plasma control parameters that influence brightness, aiming for optimal spatial and temporal control. Finally, spatial shaping of the laser pulse will be employed to engineer the spatial profile of the emission pattern, allowing for greater directionality and luminosity.

The successful implementation of this project is expected to result in applications towards more compact and efficient EUV sources, with enhanced luminosity and directional control. This could lead to significant advancements in EUV lithography. This will also offer new insights into the laser-matter interaction mechanisms for laser material processing applications.

Research environment:

FEMTO-ST is one of the largest institutes of CNRS in France with more than 750 staff members. Within the Optics Department (85 people), the OPTO group is a large group of more than 30 academics, postdocs and PhD students on different areas of photonics (quantum engineering, artificial intelligence, ultrafast photonics: see group website). offering a rich and multicultural environment

The research of the PhD topic will be realized within the team led by François Courvoisier. The team expertise on ultrafast laser-matter interaction, beam shaping, laser materials processing is internationally recognized by more than 70 invited talks at international conferences and an important track-record of funded European project proposals. Our PhD students and postdocs quickly find attractive positions in academia and industry.

The research will take place in a new science building that provides access to a wide range of basic and technological sciences facilities, including numerous laboratories dedicated to photonics, 1300 m2 of clean room, and high-performance computing. The experimental system has its dedicated workspace.

Besancon is in the East of France, 2 hours 15 minutes from Paris by train and near the foothills of the Jura mountains, close to excellent hiking and mountain bike trails, ski stations and rock-climbing formations. It is consistently rated as having one of the highest qualities of life in France and has a vibrant university atmosphere.

References

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[2] Nanoscale confinement of energy deposition in glass by double ultrafast Bessel pulses
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[3] In-situ diagnostic of femtosecond laser probe pulses for high resolution ultrafast imaging
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[4] Femtosecond laser-induced sub-wavelength plasma inside dielectrics: I. Field enhancement, Kazem Ardaneh, Remi Meyer, Mostafa Hassan, Remo Giust, Benoit Morel, Arnaud Couairon, Guy Bonnaud, and Francois Courvoisier,
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[5] K. Ardaneh, R. Giust, P.-J. Charpin, B. Morel and F. Courvoisier " Electron heating and radiation in high aspect ratio sub-micron plasma generated by an ultrafast Bessel pulse within a solid dielectric ",
The European Physical Journal Special Topics, **232**, 2247–2252 (2023).
https://doi.org/10.1140/epjs/s11734-022-00751-y

Applicant's profile

Excellent scientist, open-minded physicist. The applicant must demonstrate a track-record of previous experimental work (at least significant lab courses). English-speaking is mandatory as our group is highly international. The candidate will join an enthusiastic team with diverse profiles in physics and photonics. Scientific honesty, curiosity and willingness to learn are key values in our group.

Funding

Starting date : Oct. 1st 2024

Monthly Gross Salary : 2 100€

Application deadline: June 1st (first interviews will start before)

Contact

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To apply

To be eligible, the application must contain the following documents:

- CV
- Cover letter
- At least 1 reference letter