Stage de master de physique / Physics Master Internship

Proposition de stage/ Internship proposal (1 page max)

Date de la proposition : 15/10/2021

Responsable du stage / *internship supervisor*:

Nom / *name*:	TIGNON	Prénom/ *first name* :	Jérôme
Tél :	06 16 92 86 63	Fax :	
Courriel / *mail*:	jerome.tignon@ens.fr		

Nom du Laboratoire / *laboratory name*: Laboratoire de Physique de l'ENS (LPENS)

Code d'identification : UMR 8023 Organisme : ENS/CNRS/Sorbonne Univ./Univ.Paris

Site Internet / *web site*: https://www.lpens.ens.psl.eu/

Adresse / *address:* LPENS, Ecole Normale Supérieure, 24 rue Lhomond, 75005 Paris

Lieu du stage / *internship place*: LPENS

Titre du stage / *internship title*: Tera-Hertz generation from femtosecond-laser induced microplasma

Résumé / *summary*

The tera-Hertz (1 THz = 10^{12} Hz) frequency range is located in the far-infrared region of the electromagnetic spectrum, between microwaves and mid-infrared. It is known to potentially offer a huge number of interesting applications ranging from medicine, security imaging, astronomy, spectroscopy, to fundamental physics for the study of meV excitations (since 1 THz ~ 4 meV) in a wide variety of systems, such as semiconductor nanostructures, novel 2D materials or THz quantum optics. Despite this potential, the THz range remains largely unexplored due to the high cost or dimensions of the conventional THz sources (e.g the synchrotron accelerator or the free electron laser), or their limited performance (e.g. compact electronic sources or known semiconductor photonic devices). That is why this range of the electromagnetic spectrum is still called the "THz gap".

In this context, time-domain THz techniques [1], such as time-resolved or time-domain spectroscopy are becoming widely used to study the dynamics of excitations in a very wide variety of systems and materials, on the femtosecond time-scale. These techniques revolutionized the physics of THz ultrafast spectroscopy. They rely on the use of powerful femtosecond near-IR laser sources that excite solid state THz emitters, typically nonlinear crystals or photoconductive antennas. Such systems proved being very successful table-top optical setups, but with limited THz spectral coverage and very limited power.

It was later demonstrated that the spectral range of THz time-domain spectroscopy techniques can be significantly improved by using gas plasmas produced by highly energetic and focused femtosecond laser pulses. In such setups, mJ near-IR pulses produced by kHz repetition rate femtosecond laser amplifiers are used, resulting in optical-to-THz conversion efficiencies in the range 10^{-6} range. The conversion efficiency can be further improved by using ultrafast laser field composed by the fundamental and its second harmonic (two-color plasma approach) [2]. Nevertheless, both approaches still rely on using complex and expensive kHz amplifiers. Moreover, the low kHz pulse repetition rate given by those laser systems intrinsically limits the signal-to-noise ratio (SNR).

Our approach at LPENS consists in producing instead a clever micrometer-size (two-color) plasmas that can be generated using a more flexible MHz and only micro-J femtosecond laser. Those systems are much more affordable and the higher repetition rate allows to envision acceptable SNRs. This requires developing an optical experimental setup for focusing femtosecond pulses on very small micro-meter sized volume without losing the temporal compression of the laser field. The project is being developed in close collaboration with OIST (Japan ; https://groups.oist.jp/fsu) and should open important perspective in condensed matter physics [3] and quantum physics.

Techniques ou méthodes utilisées / *Specific techniques or methods*

- Femtosecond lasers
- Optics, nonlinear optics and ultra-fast spectroscopy
- Condensed matter and/or quantum physics

Références / *References*

[1] M. Nuss, D. Auston, F. Capasso, Phys. Rev. Lett. **58**, 2355 (1987).

[2] D.J. Cook, R.M. Hochstrasser, Opt. Lett. **25**, 1210 (2000) ; I. Thiele et al., Phys. Rev. A. **96**, 053814 (2017).

[3] J. Madéo, et al. "Directly visualizing the momentum-forbidden dark excitons and their dynamics in atomically thin semiconductors." Science **370**, 1199-1204 (2020).

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : OUI**

Si oui, financement de thèse envisagé/ *financial support for the PhD***: Ecole Doctorale**