ÉCOLE DOCTORALE
des SCIENCES PHYSIQUES et de L'INGÉNIEUR

Université de Bordeaux – Bâtiment A1
351 cours de la Libération – 33405 TALENCE CEDEX
 05 40 00 65 26
E-mail : edoc.spi@u-bordeaux1.fr

Thématique : Lasers, Matière, Nanosciences[1]

Année universitaire 2014-2015

DIRECTEUR DE THÈSE [2] : SKUPIN, Stefan, Habilitation (HDR) expected on March 10 2014
E-mail : skupin@celia.u-bordeaux1.fr

CODIRECTEUR DE THÈSE [2] :
E-mail :

LABORATOIRE D'ACCUEIL : CELIA, UMR 5107

Adresse : 351, Cours de la Liberation

33405 Talence cedex

Téléphone : 05.40.00.33.65

TITRE DU SUJET DE THÈSE : Advanced numerical modeling of ultrashort highly nonlinear pulse propagation

FINANCEMENT DEMANDÉ [3] :

- Si contrat doctoral UB, préciser s'il s'agit d'un support : *(case à cocher)*

☒ **UB sollicitée dans le cadre de l'appel à projets (AAP) 2014**

☐ **UB hors AAP 2014**

☐ **Région Aquitaine** si cofinancement, en préciser l'origine :

☐ **IdEx**

☐ **LabEx**

COLLABORATIONS SCIENTIFIQUES :
CEA DAM, Universidad Complutense Madrid, Max-Born-Institut Berlin, University of Porto

RELATIONS INDUSTRIELLES : Jenoptik AG

DESCRIPTIF DU SUJET DE THÈSE : *(1 page maximum)*

Context : High intense ultrashort pulses propagating in bulk media undergo so-called filamentation. This is a process where narrow transverse structures (filaments) are formed with more than 10% of the energy localized in the near-axis area. Filamentation is attributed to an initial increase of the light intensity, termed as self-focusing, which in turn is originated from the Kerr response of the medium. In non-structured systems the self-focusing is saturated by the defocusing action of the electron plasma created by photoionization of the medium. Similar results, but on smaller length scales, are known for propagation in dense media like water or silica, where material damage due to photoionization can be observed. Filamentation is a very complex spatio-temporal problem where the inner high-intensity part of the filament strongly interplays with the low-intensity ambiance. The understanding of the complex dynamics is crucial for potential applications such as frequency conversion and supercontinuum generation, pulse compression, remote sensing, lightning control, etc.

On the other hand, structured materials, such as photonic lattices or gas-filled hollow photonic fibers filled allowing tailored dispersion and diffraction properties, can also strongly influence the propagation dynamics of ultrashort pulses. In particular, the control over spatial properties of the light pulses via specially designed waveguides or even exploitation of plasmonic field enhancement in nano-structures offers additional degrees of freedom on the route towards tunable novel ultrashort light sources.

State-of-the-art numerical models are not fully capable of describing all physics involved correctly, in particular they rely on so-called envelope approximations, at least in the description of ionization processes. Modeling the physics on sub-cycle time-scales of the laser pulses is one of the standing goals in the field of ultrashort nonlinear pulse propagation.

Objectives : In this project nonlinear laser pulse propagation in bulk and structured material will be modeled numerically. The first major task is to derive a vectorial forward wave equation which allows for the description of ultrashort pulses as well as tightly focused beams far beyond paraxiality. As an important propagation medium we will consider noble gases, e.g., argon, where linear and nonlinear material properties are well known. In a second step, the presence of photonic lattices and hollow fibers will be also considered. The crucial point here will be to incorporate an accurate description of linear and nonlinear dispersion as well as ionization processes, but under the constraint of low computational costs.

An improved numerical modeling of high-intense laser propagation will enable us to look right into the complex laser matter interaction, a point of view that is not accessible for experimental diagnostics. In particular, we will be able to study frequency conversion processes over large spectral bandwidths. One goal here will be the generation of ultrashort pulses in the UV region of the spectrum. Another interesting effect to study is THz generation from plasma bubbles created by a tightly focused single cycle laser pulse in bulk media or in photonic hollow fibers filled with gases, which could lead to the design of highly controllable and/or compact THz sources. Moreover, THz generation can be used as a tool for pulse characterization, e.g., as a simple diagnostic for the carrier envelope phase.

In the case of structured media it is important to study localization and motion effects in photonic lattices and gas-filled fibers filled in great detail. Here, an accurate description of the material dispersion will be a key ingredient for a correct description of the pulse dynamics. Then, additional spatial degrees of freedom will be exploited, with the ultimate goal to control the pulse spatio-temporal dynamics in the high-intensity ultrashort-pulse regime.

Requirements : We are looking for a highly motivated postgraduate student with solid background in theoretical optics and atomic physics. Good experience in programming (c, fortran) is required, as well as some knowledge about parallel coding using MPI or OpenMP. Any experience with CUDA, HMPP or OpenACC is highly welcome.