Research Topic for the ParisTech/CSC PhD Program

Field : Physics, Optics

Subfield: femtosecond laser, laser-matter interaction, plasmas

Title: Laser-plasma interaction using single-cycle laser pulses

ParisTech School: ENSTA

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Short description of possible research topics for a PhD:
In our group, we are trying to generate the shortest electron beams ever produced in the laboratory, i.e. electron pulses of a few femtoseconds only. Such electron pulses could have a huge impact because they can be used to probe matter on the atomic scale and with unprecedented temporal resolution. *They could be used to literally see atoms move in a molecule for example, or in the crystal lattice of a solid.* In order to create short electron pulses, we rely on the interaction of a very intense laser with a gas. When the femtosecond laser is focused into the gas, it creates a plasma, i.e. a fully ionized gas. We use the interaction between the laser and the plasma to accelerate electrons in very short distances, thereby creating miniature particle accelerators. The specificity of our research comes from the fact that we use a unique laser in which the laser pulses are composed of a single optical cycle, i.e. they have a duration of only 3.5 fs! This unique instrument allows us to accelerate electrons to almost the speed of light and the electron pulse has femtosecond duration. The student will study the physics of laser-plasma interaction in this new regime. He (she) will study the influence of many experimental parameters: the carrier envelope phase, the type of gas, the gas jets… The goal will be to understand the interaction physics in the single cycle regime and use that knowledge to optimize the electron source. Once the electron source is fully operational, the student will use the electron to visualize the motion of atoms in material, in ultrafast electron diffraction experiments. The work will essentially be experimental: development of an experimental set-up, data collection, data analysis and interpretation. Theory and simulations will be used to model and interpret the experimental results.

Required background of the student:
Strong background in general physics. Knowledge in one or several of the following will be appreciated: plasma physics, nonlinear physics, optics and lasers. The work will be essentially experimental and we are seeking a candidate who is highly motivated by cutting-edge experiments. A taste for theory will also be appreciated.

A list of 5(max.) representative publications of the group:
- "High-charge relativistic electron bunches from a kHz laser-plasma accelerator"; D. Gustas et al., Phys. Rev. Acc. & Beams **21**, 013401 (2018)
- "Relativistic electron beams driven by kHz single-cycle light pulses"; D. Guénot et al., Nature Photonics 11, 293 (2017)
- "Capturing structural dynamics in crystalline silicone using chirped electrons from a laser wakefield accelerator"; Z. He et al., Sci. Rep. 6, 36224 (2016)
- "Vacuum laser acceleration of relativistic electrons using plasma mirror injectors"; M. Thévenet, et al., Nature Physics 12, 355 (2016)