Extreme-light physics at the Apollon laser: new challenges & opportunities for laser-plasma interaction

Mickael Grech[1,*]

[1] *Laboratoire pour l'Utilisation des Lasers Intenses, CNRS, Sorbonne Université, CEA, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France*

* mickael.grech@polytechnique.edu

The Apollon laser [1,2] is now operational at the 1PW level (22J in 22fs, after compression). An ongoing upgrade will allow to reach the multi-PW level in the months to come, and the first experiments are about to start. Apollon and similar (multi-PW class) laser systems in Europe and Asia will soon allow to reach unprecedented on-target intensities, well beyond 10^{21} W/cm^2 and potentially up to 10^{24} W/cm^2. Under such extreme light conditions, the laser-plasma interaction is not only relativistic, it is also strongly impacted by quantum electrodynamic (QED) effects [3]. Among these effects are high-energy (γ) photon emission and its back-reaction on the emitting electron dynamics, as well as electron-positron pair production in either the strong laser-field or the Coulomb field of highly-charged ions. These new processes will not only strongly modify the dynamics of the laser-plasma interaction, they will provide new opportunities in terms of radiation and particle sources, as well as pose new challenges in terms of their experimental detection.

To support this formidable experimental undertaking, new theoretical and numerical tools need to be developed, that allow to model new processes at the edge of relativistic plasma physics and QED. In this talk, I present recent code developments [4] and advances we have made - on both the simulation & theory sides - in treating QED processes of outmost importance for the forthcoming experiments on the Apollon laser. A particular emphasis is put on γ-photon [5,6] and electron-positron pair production [7,8] in strong electromagnetic fields.

[1] Papadopoulos et al., *High-contrast 10-fs OPCPA-based Front-End for the Apollon-10PW laser*, Advanced Solid State Lasers 2015, Oct 2015, Berlin, Germany
[2] Cros et al., Nucl. Inst. Meth. Phys. Res. A **740**, 27 (2014)
[3] Di Piazza et al., Rev. Mod. Phys. **84**, 1177 (2012)
[4] Derouillat et al., Comp. Phys. Comm. **222**, 351 (2018) ; https://smileipic.github.io/Smilei
[5] Niel et al., Phys. Rev. E **97**, 043209 (2018)
[6] Niel et al., Plasma Phys. Control. Fusion **60**, 094002 (2018)
[7] Lobet et al., Phys. Rev. Accel. Beams **20**, 043401 (2017)
[8] Mercuri-Baron et al., New J. Phys. **23**, 085006 (2021)