Simulation of Strong-Field Ionization in PIC Codes for Triggering QED Cascades

A A Mironov[1], E G Gelfer[2], S V Popruzhenko[3,4], M Grech[5], and C Riconda[6]

[1] *Center for Theoretical Physics (CPHT), CNRS, École Polytechnique, Palaiseau, France*
[2] *Extreme Light Infrastructure ERIC, Dolní Břežany, Czech Republic*
[3] *Theoretical department, Prokhorov General Physics Institute of RAS, Moscow, Russia*
[4] *Theoretical Physics, National Research Nuclear University MEPhI, Moscow, Russia*
[5] *LULI, CNRS, CEA, Sorbonne Université, École Polytechnique, Institut Polytechnique de Paris, Palaiseau, France*
[6] *LULI, Sorbonne Université, CNRS, CEA, École Polytechnique, Institut Polytechnique de Paris, Paris, France*
Contact Email: mironov.hep@gmail.com

Testing strong-field QED effects like the onset of avalanche-type cascades in interactions of ultra-high intensity lasers with matter requires the injection of electrons in the focal area, which is a non-trivial problem. Strong-field ionization of heavy atoms, such as noble gases Ar, Kr, or Xe, is a highly non-linear process known to be suitable for such purposes [1]. The threshold intensity needed for ionizing deep electronic shells can exceed 10^{23-24} W/cm^2. For this reason, this process is not only suitable for electron injection but is also suggested for gauging the peak laser intensity [2].

In this talk, we will first discuss the problems arising in simulations of strong-field ionization in PIC codes. Such codes rely on rates derived within the strong-field approach [3, 4], however, the PIC method imposes some additional constraints. In particular, it is common to treat ionization as sequential (namely, electrons are extracted one by one in the order of the orbitals they populate) and neglect the dependence on the magnetic quantum number by setting it to zero [5]. We will discuss the validity of this hypothesis in the case of dilute gas target and show that the ionization process can be non-sequential for high-order subshells (p, d, etc) and that taking this into account increases the accuracy of the model. We suggest a refined approach that resolves these issues and improves the PIC simulation accuracy on these grounds [6].

As an application, we test noble gases for triggering avalanche-type QED cascades with SMILEI PIC simulations. We focus on the parameter range of a promising project of the NSF OPAL laser facility designed in Rochester, which suggests bringing two 25-petawatt tightly focused laser pulses to the interaction point. According to our results, avalanche-type cascades are accessible under realistic geometries of the laser setup, and ionization of krypton is suitable for triggering cascades [7].

References

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