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Field ionization in PIC codes and application to laser-accelerated ions

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It is now well known that the interaction between a relativistic laser pulse and a thin foil generates high energy ions through the "Target Normal Sheath Acceleration" mechanism[1]. A hot electron cloud, generated during the irradiation of the target with the laser pulse, travels across the target and creates on the non-irradiated surface an electrostatic field strong enough to ionize hydrocarbon pollutants and accelerate ions up to MeV energy. Because of their largest charge over mass ratio, protons are the most efficiently accelerated ion species and have therefore attracted most theoretical and experimental attention. However, some experimental measurements have reported acceleration of highly charged ions such as carbon ions. To study the laser-acceleration of partially ionized ions, we have developed a field ionization model in the Particle-In-Cell (PIC) code CALDER. This model is based on the quasi-static approximation of the ADK theory[2], which describes the ionization of an atomic system by an electrostatic field. Multiple field ionizations are accounted for using a Monte Carlo technique.

We will first present this field ionization model and its implementation in the CALDER code. The numerical schemes considered to evaluate the photo-ionization probabilities and the energy conservation will be detailed during the presentation. Second, some numerical results about the highly charged carbon ions accelerated from a foil-laser interaction will be presented. Particularly, we will show that, in agreement with experimental measurements, the C^{4+} ions are the main accelerated particles for laser intensities in the 10^{18}-10^{19} W/cm^2 range, and that carbon ions up to C^{6+} can be accelerated with foils as thin as 200 nm.

[1] S.C. Wilks *et al*, Phys. Plasmas, 8, 542 (2001)
[2] M.V. Ammosov *et al*, Soviet. Physics, JETP, 64, 6, 1191 (1986)