Particle-in-cell simulations of laser-plasma interactions at solid densities and relativistic intensities: the role of atomic processes

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A direct study of intense laser-solid interactions is still of great challenges, because of the many coupled hysical mechanisms, such as direct laser heating, ionization dynamics, collision among charged particles, and electrostatic or electromagnetic instabilities, to name just a few. Here, we present a full particle-in-cell simulation (PIC) framework, which enables us to calculate laser-solid interactions in a "first principle" way covering almost "all" the coupled physical mechanisms [1-2]. Apart from the mechanisms above, the numerical self-heating of PIC simulations, which usually appears in solid-density plasmas, is also well controlled by the proposed "layered-density" method. This method can be easily implemented into the state-of-the-art PIC codes.

The electron heating/acceleration at relativistically intense laser-solid interactions in the presence of large scale pre-formed plasmas [3-5] is re-investigated by this PIC code. Results indicate that collisional damping (even though it is very week) can significantly influence the electron heating/acceleration in front of the target. Furthermore, the Bremsstrahlung radiation will be enhanced by 2~3 times when the solid is dramatically heated and ionized. For the considered case, where laser is of intensity 1020 W/cm2 and pre-plasma in front of the solid target is of scale-length 10 μm, collision damping coupled with ionization dynamics and Bremsstrahlung radiations is shown to lower the "cut-off" electron energy by 25%. In addition, the resistive electromagnetic fields due to Ohmic-heating also play a non-ignorable role and must be included in real laser-solid interactions.

References

[1] D. Wu, X. T. He, W. Yu, and S. Fritzsche, Phys. Rev. E 95, 023208 (2017).
[2] D. Wu, X. T. He, W. Yu, and S. Fritzsche, Phys. Rev. E 95, 023207 (2017).
[3] D. Wu, S. I. Krasheninnikov, S. X. Luan, and W. Yu, Phys. Plasmas 23, 123116 (2016).
[4] D. Wu, S. I. Krasheninnikov, S. X. Luan, and W. Yu, Nucl. Fusion 57, 016007 (2017).
[5] D. Wu, S. X. Luan, J. W. Wang, W. Yu, J. X. Gong, L. H. Cao, C. Y. Zheng and X T He, Plasma Phys. Control. Fusion 59, 065004 (2017).