Proton acceleration using laser irradiation of microstructured targets

Imran Khan, Vikrant Saxena
Department of Physics, Indian Institute of Technology Delhi
e-mail (speaker): vsaxena@physics.iitd.ac.in

Acceleration of protons/ions to multi tens of MeV or even higher energies using laser irradiation of solid targets has recently attracted a strong interest from laser-plasma researchers across the globe. Based on the target and the laser pulse parameters there are basically two class of acceleration mechanisms which are responsible for the acceleration of protons as well as ions from the target. For thick (> few 10s of microns) targets and linearly polarized lasers, the target normal sheath acceleration (TNSA) mechanism is dominant. In TNSA a significant fraction of hot electrons, generated as a result of laser irradiation of the front surface of the target, traverse through the target and exit from its rear side thus giving rise to a sheath electric field at the rear target surface. This electric field is responsible for the acceleration of protons and ions. For thin (~ few 10s of nm) foils irradiated by high intensity high contrast laser pulses the acceleration happens primarily via radiation pressure based mechanisms.

We explore, via two dimensional particle-in-cell (PIC) simulations, the TNSA based acceleration of protons when a high intensity laser pulse irradiates a hydrocarbon target having a micron size groove on its front (laser facing) surface. The effect of the groove's geometry as well as its dimensions on the protons' energy spectra have been investigated in detail.

It is observed in our simulations that the laser pulse while traveling along the groove pulls out the electrons from its walls and accelerates them towards the rear side, as in the surface-plasmon based acceleration mechanism reported earlier. These electrons give rise to a sheath field on the rear side as in the regular TNSA mechanism, however, the sheath field in the case of a grooved target is much stronger as compared to a flat target. Moreover, we found that a groove with rectangular shape (in the 2-D plane) is more effective for enhancing the proton energy cutoff than the one having a triangular or a circular shape. The optimal width of the groove is found to be of the same order as the waist of the laser pulse. Furthermore, a misalignment in the laser pulse with respect to the horizontal target axis as well as a small pre-plasma inside the groove are found to adversely affect the proton acceleration.

References

[1] R. Snavley et al., Phys. Rev. Lett., 85, 2945 (2000).
[2] S. Wilks et al., Phys. Plasmas, 8, 542-549 (2001).
[3] A Macchi, Phys. Plasmas, 25, 031906 (2018).
[4] J. Sharma et al., New J. Phys., 24, 073023 (2022).
[5] I.Khan,V. Saxena, Phys. Plasmas, 30, 063102 (2023).