Laser absorption and ion acceleration under tight-focusing conditions

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There is a constant effort to explore laser matter interaction at ultra-high laser intensities where novel physical processes like radiation damping of electrons and radiation pressure acceleration of ions can be observed. One of the most promising techniques to enhance the focused laser intensities is to use ellipsoidal plasma mirrors to tightly focus a laser beam. This technique has been successfully employed to obtain sub-\(\mu\)m spot size \cite{1} in which case one may expect an order of magnitude increase in focused intensity in comparison with a typical spot size of about 3-4 \(\mu\)m obtained using f/3 off axis parabolic mirror. Not only the higher intensity, but also an extremely strong radial ponderomotive force and a strong longitudinal electric field component affect the trajectories of electrons in the focal spot area. They have a significant effect on the absorption process and parameters of hot electrons and in turn on ion acceleration from the surface of a thin foil targets in the TNSA process.

These processes are studied here using 2D Particle-in-Cell simulations with the code EPOCH \cite{2} in the laser intensity range of \(10^{20} – 10^{22}\) W/cm\(^2\). The tight focusing is implemented using the approach \cite{3} and it varies between 4\(\lambda\) and 0.5\(\lambda\). It is found that the absorption process is significantly more efficient in the case of a smaller spot size producing relatively higher number of hot electrons, whereas the maximum energy is still given by the laser pulse intensity. The signatures of \(j \times B\) heating producing electron bunches twice per laser period are less significant with tight focusing and the angular distribution of hot electrons is wider. At higher laser intensities, the increased in laser absorption is not so significant as the laser pulse partially self-focuses due to the hole boring process.

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References

