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Ion acceleration using a flattop laser beam

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The relativistic interaction of laser pulses, intensities in excess of 1018 W/cm2, with solid targets has been studied in many experiments aiming for different application. One of the prominent applications is laser-driven ion acceleration which is of particular interest for Helmholtz Association and for applications driven by upcoming FAIR facilities.
One of the well accepted mechanisms for the ion acceleration is Target Normal Sheath Acceleration (TNSA) mechanism which has been explored extensively since its discovery about 15 years ago.
According to the TNSA model, the shape of the accelerated ions strongly depends on the structure of the hot electron sheath which itself follows the laser beam shape. Since Gaussian laser beam produces Gaussian hot electron sheath, the accelerated ions have nonuniform shape which propagate in all directions that are not suitable for most applications.
Instead one approach for having smooth and uniform ion acceleration population is considering a flattop laser beam. In a series of numerical simulations, using EPOCH code3, we have shown the validity and applicability of such approach. EPOCH is a plasma physics code which uses MPI parallelized, explicit, second-order, relativistic Particle in Cell (PIC) method for simulating laser plasma problems.
It is well known that the PIC codes, such as EPOCH, are prone to a phenomenon known as selfheating which is a stochastic heating, possibly after an initial thermalization stage, leads to linear
heating of the plasma. To minimize the numerical heating effect we initially run several simulations to find the optimum values for the number of particles per cell parameter and also the temperature of each species, such as proton or carbon.
During the simulations we used a plastic layer with the thickness of 10 μm as target which consists of carbon and proton. To have more realistic simulations we also considered an exponential raising part for the ion density to include the effect of preplasma.
The extensive numerical analyses show a smooth and uniform hot electron sheath with maximum angle of divergence in the range [-20°, 20°] degree. Maximum energy of ions estimated to be about 14 MeV. The angle of divergence of accelerated ions predicted to be in the range [-1°, 1°] degree which are promising results for having a uniform ion acceleration.

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