Optimization study for laser-triggered ion acceleration from thin targets

V.Yu. Bychenkov\textsuperscript{1,2}, A.V. Brantov\textsuperscript{1,2}, E.A. Govras\textsuperscript{1,2}

\textsuperscript{1} Lebedev Physics Institute, Russian Academy of Science, Moscow, Russia
\textsuperscript{2} Center for Fundamental and Applied Research, VNIIA, ROSATOM, Moscow, Russia

The high contrast of the advanced lasers of today enabled effective acceleration of ions from ultra-thin foils which are semi-transparent to laser light. In this regime a high-intensity laser pulse expels electrons from the irradiated area of the foil in forward direction that cause ion acceleration from the entire target volume through the mechanism somewhat between TNSA and Coulomb explosion – the directed Coulomb explosion \cite{1}.

It is known that target thickness should be properly matched to the laser intensity \cite{2} to get maximum ion energy. Although the optimal target thickness can be estimated in the order of magnitude \cite{2} the 3D PIC simulations are needed to correctly quantify it for different laser intensities. It is also a timely problem for the 3D PIC simulations to consider how spot size and pulse duration contribute to optimization of target thickness. Such optimization should be based on systematic study of laser light absorption (i.e. laser to electron energy conversion efficiency) in semi-transparent targets that is still missed. We fill a gap in this study and quantify how all parameters of the pulse affect laser energy conversion to the hot electrons and finally define effectiveness of high-energy ion production.

Here we present the results of 3D optimization study with PIC code Mandor for acceleration of ions from thin targets triggered by femtosecond laser pulses. The dependence of maximum ion energies which are for a volumetric heating of the targets with optimum thicknesses versus laser intensity shows very universal scaling $e_{\text{max}} \propto I^{0.7}$ for wide intensity range and different pulse durations and spot sizes of practical interest. More sharp dependence of maximum ion energy as compared to popular scaling $e_{\text{max}} \propto \sqrt{I}$ is a result of absorption increase with laser intensity. The correspondence between PIC simulations and recent theory is found \cite{3}.

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References

