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# Investigation of magnetic inhibition effect on ion acceleration at high laser intensities

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Laser-driven ion acceleration has been the focus of much research activity for several decades because of its potential to provide compact energetic ion sources with unique beam properties. An important requirement for several of these applications is an increase in the energy per nucleon up to hundreds of MeV and beyond, which is also the major challenge facing current laser-driven ion sources.

However, a degraded scaling of the maximum proton energy with increasing laser intensity that is observed in both the PIC simulations and experimental results. The irradiation of a target with high laser intensity can lead to self-generation of an intense magnetic field (B-field) on the target surface. It has therefore been suggested that the sheath-driven acceleration of high-energy protons would be significantly hampered by the magnetization effect of this self-generated B-field at high enough laser intensities[1], but this theory is controversial.

In order to study the effect of the self-generated magnetic field, we resort to particle-in-cell (PIC) simulations. An external B-field $B_{ex}$ is adopted to provide an artificial modification of the magnetization effect. To compare the magnetization effect at different B-field strengths, we perform simulations with three different external B-fields, $B_{ex}=mB_s$ ($B_s$ is the self-generated B-fields), with m=−1, 0, and 4, referred to as cases I, II, and III, respectively. These external B-fields are applied such that the dynamics of the energetic particles escape into the vacuum region at the rear side of the target can be modified. In case I, the charged particles at the rear side experience a modified B-field, $B_m=B_{ex}+B_s=0$ such that the Lorentz force on the charged particles is exactly zero, i.e., the magnetization effect vanishes completely. Case II is the normal TNSA case. In case III, $B_m=5B_s$, leading to an enhancement of the magnetization effect by a factor of 5.

The energy spectra of the accelerated protons for the three cases at t=100$T_0$ are shown in Fig. 1(a). We can see that there is very little difference in the maximum energies of the protons between cases I and II, suggesting that the magnetization effect indeed plays a rather limited role in the high-energy proton acceleration, especially for the highest-energy protons. Hence the magnetization effect alone cannot explain the degraded scaling of the maximum proton energy with increasing laser intensity.

We proposed that the degraded scaling of proton energy at high laser intensities can be explained by the decrease in acceleration time caused by the increased sheath fields at high laser intensities rather than by the magnetic inhibitory effect, because of the longer growth time scale of the latter[2], as shown in Fig. 1(b). This understanding of the magnetization effect may pave the way to the generation of high-energy protons by sheath-driven acceleration at high laser intensities.

References

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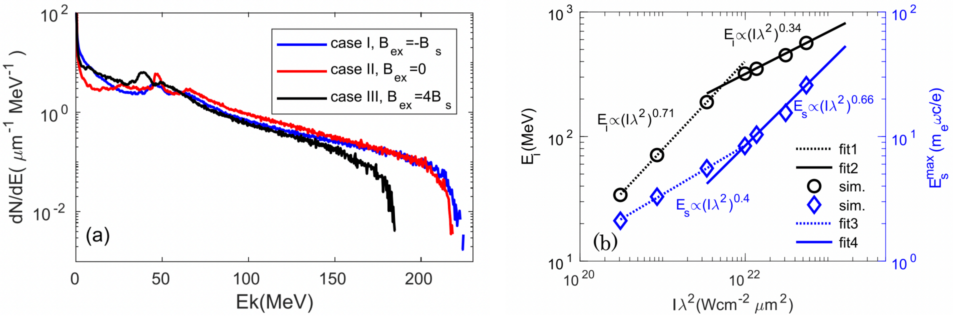


**Figure 1.** (a) Proton energy spectra for cases I (blue), II (red), and III (black) at t=100$T_0$ ($T_0$ is the laser period). (b) Maximum proton energy $E_i^{max}$ and maximum sheath field strength $E_s^{max}$ as functions of the peak laser intensity.