Magnetic reconnection and electron acceleration driven by ultra-intense Fs lasers

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Magnetic reconnection (MR) occurs widely in fast energy release processes such as in solar flares, coronal mass ejections, interaction of solar and magnetosphere, certain explosive astrophysical events, and fusion plasma instabilities. Moreover, the relativistic magnetic reconnection may play an important role for energy conversion in relativistic objects, for example, hard x-ray and higher energy spectrum bursts in solar flares, pulsars, gamma-ray bursts, and active galactic nuclei.

Three-dimensional fast magnetic reconnection driven by two ultraintense femtosecond laser pulses is investigated by relativistic particle-in-cell simulation, where the two paralleled incident laser beams are shot into a near-critical plasma layer to form a magnetic reconnection configuration in self-generated magnetic fields. Fig. 1 presents at t = 35T₀ when the laser pulses have not yet reached most of the right half of the simulation box, two magnetic flux tubes have already clearly shaped shown in Fig. 1(a). Then, a fully developed 3D magnetic reconnection configuration is formed at t = 50T₀ [Fig. 1(b)] with the two flux tubes reconnecting into one in the outer region. Meanwhile, the reconnection rate is found to be faster than that found in previous two-dimensional Hall magnetohydrodynamic simulations and electrostatic turbulence contribution to the reconnection electric field plays an essential role as shown in Fig.1(d)¹.

\[ E_z = \frac{1}{\varepsilon}(j \times B)_z + \frac{1}{\varepsilon}(\nabla \cdot P_e)_z \]

\[ + \frac{m_e}{e^3} \left( \nabla \left( \frac{j}{n_e} \right) \right) + \frac{m_e}{(n_e)^2} \frac{\partial j_z}{\partial t} \]

\[ + \frac{1}{(n_e)} \delta n_e \delta E_z + \frac{1}{e(n_e)} \delta j \times \delta B_z. \]

In Fig.2, pickup ring of energetic electrons found in relativistic magnetic reconnection (MR) driven by two relativistic intense femtosecond laser pulses. And In the field line diffusion region, electrons are accelerated to multi-MeV with a flatter power-law spectrum due to MR⁴.

In recent simulations, three-dimensional asymmetric magnetic reconnection (AMR) driven by ultraintense femtosecond (fs) lasers is investigated⁵. The reconnection rate is found to be only one-third of that in the previous symmetric reconnection PIC simulations. And, magnetic X- and velocity stagnation points are not colocated, with the X-point at the lower field side and the stagnation point at the higher field side. Then, the hosing instability triggered by AMR and the merging of two parallel currents resulting in the tilt of the electron beam generated by the weak laser are also investigated.

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References