Magnetic reconnection in the high-energy-density and relativistic regime

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Magnetic reconnection (MR), breaking and reorganizing the topology of magnetic field dramatically, is a fundamental process observed in many space, laboratory and astrophysical plasmas. In this talk, I report recent theoretical investigations [1-4] on MR in the high-energy-density and relativistic regime for high-β (β>1) and relativistic plasmas. For MR in the high-β regime, comparing 2D and 3D PIC simulation results for the interactions of colliding laser-produced plasma bubbles with induced anti-parallel and parallel poloidal magnetic fields, we find that many of the previously-observed characteristics [1, 4], such as the quadrupole magnetic field, plasma heating and even the out-of-plane electric field, can be induced by the mere plasma bubble collision, which do not necessarily indicate MR occurrence in the high-β regime. The Lorentz-invariant scalar quantity $D_e = \gamma_e \vec{\boldsymbol{J}} \cdot (\vec{\boldsymbol{E}} + \vec{v}_e \times \vec{\boldsymbol{B}})$ in the electron dissipation region is proposed as the key sign of MR occurrence in this regime. For MR in the relativistic regime, though the topology of magnetic field depends on the relativistic observer, we prove that the x-point of MR is conserved as well as o-point. Therefore, the reconnection physics still survive in the relativistic regime. In the global view, we propose two global Lorentz invariants $\int (c^2B^2 - E^2)d^3x$ and $\int (E \cdot B)^2 d^3x$ to be more reasonable for the description of the energy dissipation and the fields activity in multi-reconnection circumstances. Based on this, relativistic reconnection [3] in the extreme near-Schwinger magnetic environment has also been investigated. We find that the MR dynamics are strongly coupled with and heavily influenced by the QED effects. In turn, gamma-ray emission and pair creation have a strong relevance with the MR configurations, i.e., X- and O- points.

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