Shocks in astrophysics and laser plasma interactions

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In collisionless shocks the interaction of charged particles and electromagnetic fields dominates over collisional effects. Such shocks occur in many different fields of physics. In the context of space and astrophysics they have been investigated since many decades, being a good candidate for explaining the origin of energetic cosmic rays. In fusion, shock waves are used for efficient compression of the target material and recently, collisionless shocks are discussed for acceleration of ions for medical physical applications.

The physical conditions are the key quantities for a controlled application, such that the shock is stable and directed with efficient energy transfer. In this context, plasma instabilities are important as mediators of the shock but also as undesired side effects.

This tutorial addresses these aspects for electromagnetic shocks as well as for electrostatic shocks. Electromagnetic shocks are of importance mainly in astrophysical environments. They are mediated by the Weibel or filamentation instability and accelerate charged particles via Fermi acceleration.

Electrostatic shocks can be produced in the laboratory with the powerful state-of-the-art laser systems. They are characterized by a strong electrostatic field, which leads to electron trapping. Ions are efficiently accelerated by reflection from the electrostatic potential. An overview will be given over the shock formation and particle acceleration mechanisms in theory and simulations.