Summary of the thesis

Recent studies on laser-matter interaction have been demonstrated the possibility to expel all the electrons, leaving an ion cloud which can expand due to the Coulomb explosion phenomenon. The PhD thesis investigates the phenomenon of pure Coulomb explosion in different geometries, with homogeneous or heterogeneous targets. In case of the presence of two species, the dynamic of both fast and slow ions is considered. Firstly, the expansion of spherical nanoclusters is considered from a theoretical point of view; starting from a homogeneous target we demonstrate numerically how the shape of the energy spectrum is poor of quality, with a considerable energy spread around the peak. Consequently, an analytical model to study the expansion of composite cluster is proposed, connecting the rise of shock shells with a narrow behavior of the kinetic energy spectrum of the fast species. The existence of a limit value on one of the mixture parameters is retrieved and rigorously demonstrated to determine the presence of overtakings between fast ions. In this case, the theoretical model is no longer valid, and a numerical method is developed to study the spherical explosion, the so-called shell method. The problem is essentially one dimensional, computational particles are in the shape of spherical shells and by using the Gauss's formula, the electric field is readily evaluated. Different results are presented in case of spherical clusters made by two ion species, varying the charge-to-mass ratio and the composition of the mixture. Then, cylindrical targets are considered, firstly using gridless particle techniques and then introducing an in-house two-dimensional PIC code. Numerical methods without a computational grid are useful in situations, in which the physical domain occupied by the particles increases rapidly in time (as for plasma expansion and explosion). In this framework, in general situations one could employ a set of computational particles and directly calculate the electric field acting on each of them, as the sum of the contribution of the other particles. This requires an extremely high computational effort unless the problem under exam presents some symmetry. The three-dimensional Soft-Spheres method was developed to this purpose, it is an N-body technique useful if a hypothesis on the symmetry of the system cannot be made. Whenever an axial symmetry is present, as in cylindrical targets, the EXPICYL PIC code can be used to simulate the expansion. EXPICYL is a two-dimensional PIC code without a fixed computational domain to follow expansion phenomena correctly. Finally, another tool was developed by the group: the ring method. This is a gridless N-body method and here the particles are modeled as thin circular rings, which are characterized by their radii and their axial coordinates. In this case, the evolution of the force acting on each particle necessarily requires the calculation of the sum of contributions due to the other particles. All the details of the numerical methods are explained, combined with the validation of the codes in reference cases for which the analytic solution is available. In case of heteronuclear spherical targets, the interesting result obtained is the presence of a critical value around which the energy spectrum becomes quite monoenergetic, dependent only on the charge of the ions and not on their masses. But the peak energy of the spectrum remains in the order of magnitude of tens of keV, not useful for applications as hadrontherapy. On the contrary, in case of double-layer targets very interesting results were found, in particular in terms of energy reached by the light ions, around hundreds of MeV, as requested by medical applications.