HYBRIDE VERFAHREN ZUR SIMULATION DER WECHSELWIRKUNG RELATIVISTISCHER KURZPULS-LASER MIT HOCHDICHTEN PLASMEN

ABSTRACT

In this thesis an efficient numerical algorithm for the simulations of relativistic short pulse laser interaction with high density plasmas is presented.

The most popular methods to describe laser plasma interactions are particle-in-cell (PIC) codes because they provide the most detailled description of plasmas. But they are not efficient for high density plasmas because in this case they have to use very small time steps and a high number of particles is needed which leads to high computational effort. To handle these applications one can use a fluid description of the plasma and treat it hydrodynamically, whereby one looses physical properties, or combine both models. In this thesis a new hybrid model is presented, which combines the hydrodynamic description of the high density plasma and the kinetic description of low density plasmas. The main goal of this thesis is the development of new numerical methods to simulate relativistic short pulse laser interaction with high density plasmas, which are described by this model.

First the physical model and the particle-in-cell code VLPL (Virtual Laser Plasma Laboratory) is explained. Then the problem is considered in one dimension and an efficient one-dimensional implicit code H-VLPL (Hybrid Virtual Laser Plasma Laboratory) is presented, which is unconditionally stable independent of the density. The numerical dispersion relation of the scheme is derived and finally it is applied on some well-known physical examples. But the efficiency drops if the code is extended to three dimensions, because linear systems arsing from a three-dimensional discretization have to be solved.

Therefore a new approach based on exponential integrators is presented in the second part of the thesis. First the approach is considered in one dimension to understand the problems arising. The stability of the spacial and time discretization is showed and the numerical dispersion relation is derived. Numerical examples show that the numerical scheme is of order two independent of the density. Further the problem is considered in two and three dimensions and a new parallel 3D C++ Code H-VLPL is presented, which is developed in collaboration with the institut of theoretical physics and gives the opportunity to simulate plasmas of arbitrary density. Comparisons to the code VLPL show that H-VLPL describes the basic physical properties correctly, though with much less computational effort. Finally also the 3D Code is applied to some well-known physical examples.