Nonlinear stimulated Raman scattering in laser fusion plasmas

Didier Bénisti, Olivier Morice, Laurent Gremillet, Mikael Tacu, Christphe Rousseaux, Arnaud Debayle,

CEA, DAM, DIF F-91297 Arpajon, France and Université Paris-Saclay, CEA, LMCE, 91680 Bruyères-le-Châtel, France
didier.benisti@cea.fr

Stimulated Raman scattering (SRS) is one of the numerous effects that may hamper the propagation of laser beams inside a plasma. It is one major deleterious effects for laser fusion, because it induces the reflection of the incoming laser power, which breaks the implosion symmetry of the Deuterium-Tritium (DT) target and reduces the energy available for fusion. Moreover, hot electrons that may preheat the target result from SRS. Both the reflection of the incoming laser power and the production of hot electrons are mediated by the electron plasma wave (EPW) that results from SRS. Consequently, a quantitative modeling of SRS requires an accurate description of the growth and nonlinear propagation of the EPW. This is a particularly difficult problem because it requires, at least, a nonlinear kinetic description of the plasma, i.e., a nonlinear resolution of the Vlasov-Maxwell system.

We provide a theoretical resolution of Vlasov equation by matching the results from two different kinds of perturbative techniques. This allows us to accurately calculate the scalar and vector potentials of the EPW, its nonlinear frequency shift and the nonlinear counterpart of its Landau damping rate. We also derive the maximum amplitude beyond which a nearly monochromatic EPW cannot exist (the so-called wavebreaking limit), the latter result being complemented by a theoretical description of the unstable growth of sidebands. Moreover, our theoretical resolution of Vlasov equation allows us to express Maxwell equations in term of coupled wave equations. These equations express a balance in the number of photons and plasmons (the number of quanta for the EPW), which is the very mechanism for SRS.

A novel numerical method, dubbed Rays In Cell (RIC), is introduced to solve these coupled equations. An example of a RIC simulation of the wavefront bowing resulting from the nonlinear frequency shift, and of the EPW wavebreaking is shown. Although a RIC simulation is about 10 millions times faster than a kinetic simulation, it is still too slow to simulate a fusion experiment. This led un introduce a simplified model that has been implemented in a hydro-radiative code to simulate an actual experiment. A very good agreement is found between the numerical and experimental results. This is the first time that such a good agreement has ever been found.

Références

1. M. Tacu and D. Bénisti, *Phys. Plasmas*, **28**, 052109, (2022).
2. D. Bénisti, D. F. G. Minenna, M. Tacu, A. Debayle, and L. Gremillet, *Phys. Plasmas*, **29**, 052109, (2022).