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Explicit high-order symplectic integrators of coupled Schrödinger equations for pump-probe systems

Xiaobao Jia[1], Qing Jia[1], Jianyuan Xiao[1], Jian Zheng[1, 2]
[1] Department of Plasma Physics and Fusion Engineering and CAS Key Laboratory of Geospace Environment, University of Science and Technology of China
[2] Collaborative Innovation Ceter of IFSA, Shanghai Jiao Tong University
e-mail (speaker): jxb2020@mail.ustc.edu.cn

Two-beam coupling within the field of nonlinear optics, which transfers energy from one light beam to the other, also called as Crossed-Beam Energy Transfer (CBET), has received considerable attention in in inertial confinement fusion (ICF) and plasma optics. In direct-drive ICF, CBET decreases the energy coupling efficiency of the laser and may cause the irradiation asymmetry, while in plasma optics, it is usable as a tool to manipulate one light with another hence has many applications, such as short amplifier [1], plasma-based combiner [2] and polarization control [3].

In this work, we model the two-beam coupling with coupled Schrödinger equations (CSEs) deduced from the coupled-wave equations in a slowly varying enveloped approximation. We find that the CSEs constitute a Hamiltonian system, which preserves its intrinsic properties after the application of symplectic integrators. Then, we propose an arbitrary high-order explicit symplectic algorithm resorting to the Hamiltonian splitting method and develop a matching code BEAM of second-order accuracy [4]. We apply the BEAM code to demonstrate the physics of the CBET and Brillouin short pulse amplification, which shows good agreement with particle-in-cell (PIC) simulation but a much lower computational cost.

Figure 1 illustrates the intensity distribution of lasers after 3900 laser periods obtained from BEAM code and PIC code EPOCH [5]. Both Fig. 1(a) and Fig. 1(b) demonstrate the energy transfers from the pump light to the probe light and the transferred energy is quantitatively comparable.

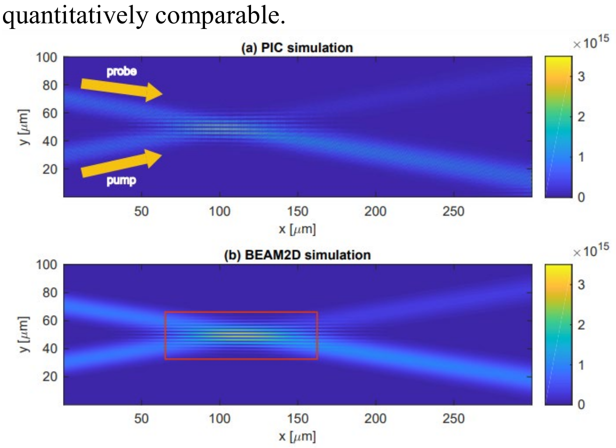

Fig 1. Intensities of laser beams in CBET obtained from (a) EPOCH and (b) BEAM2D.

Figure 2 plots the intensity of the probe pulse during Brillouin amplification which characterized by the multiple-peak structure and the narrowing of peaks. The probe pulse has been amplified by a factor of about 50 in a $500/\omega_1$ time, which is quantitatively consistent with the PIC simulation results of FIG. 2 in Ref. [6].

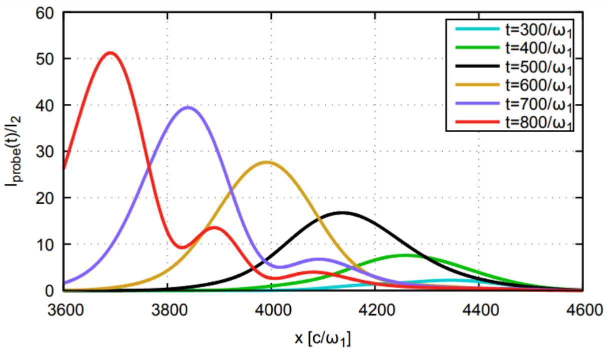

Fig 2. The amplification of the probe pulse in a $500/\omega_1$ time.

The significance and originality of this work is that it provides an efficient conservative and fast numerical algorithm or solution idea for simulating long time and large scale nonlinear optical interactions described by the coupled-wave equations.

References

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