TB-IV5

세 파동의 상호작용에 의한 패턴 형성 및 솔리톤의 전산모사

Simulation of Pattern Formation and Solitions in Three-Wave Interactions

이해준, 김진철*, 김광훈, 김종욱, 김창범, 석희용
한국전기연구원 플라즈마가속기 연구단, *포항공과대학교 물리학과
leehj@keri.re.kr

The nonlinear three-wave interaction is an interesting topic having various applications in nonlinear optics, hydrodynamics, acoustic waves, and plasma physics. The resonant interaction between two laser pulses and a plasma wave plays important roles in plasma heating, laser reflection in the inertial confinement fusion (ICF), plasma wakefield generation, and ultra-intense laser pulse amplification(1) and pulse compression(2) using stimulated Raman backscattering (RBS). In this study we describe the evolution of three-wave resonant interaction in time and one spatial dimension between two counter-propagating laser pulses and an electron plasma wave, and investigate nonlinear behaviors of them. The governing equation can be derived from the relativistic equation of motion and Maxwell's equation with resonant condition $\omega_0 - \omega_1 = \omega_p$ and $k_f = k_0 + k_1$ as

$$\begin{aligned}
\frac{\partial a_0}{\partial t} - v_{g0}\frac{\partial a_0}{\partial x} &= K\frac{\omega_p}{\omega_0} a_1 f\,, \\
\frac{\partial a_1}{\partial t} + v_{g1}\frac{\partial a_1}{\partial x} &= -K\frac{\omega_p}{\omega_1} a_0 f^*\,, \\
\frac{\partial f}{\partial t} - v_{g2}\frac{\partial f}{\partial x} + \Gamma f + i\frac{3}{8}\omega_p |f|^2 f &= -K a_0 a_1^*\,.
\end{aligned}$$

Here, ω_s, k_s, and v_{gs} are the angular frequency, the wave number, and the group velocity of the pump (s=0) and the seed (s=1) pulses respectively, and $a_s = eA_s/mc$ is the normalized vector potential. $f = eE_x/mc\omega_p$ is the normalized longitudinal electric field, $K \equiv ck_f/4$, and Γ is the damping rate caused by landau damping and electron collisions. The $|f|^2$ term reflects the effect of relativistic mismatch, which is minor for the cases studied here. In this study, we assumed v_{g2} and Γ are zero and neglected the relativistic detuning term.

Spatiotemporal intermittency and transition to turbulence in this system were investigated for a strong long pulse(3), but not for a short seed pulse. Usually, the seed pulse gains energy from the pump by stimulated RBS and is amplified to generate strong nonlinear behaviors. Figure 1 shows the spatiotemporal evolution of the pump pulses for different a_0 when the pump pulse is equal or larger than the seed pulse ($a_0 \geq a_1$). When $a_0 = 0.01$ it shows regular motion, but oscillating solitions and self-organized patterns are shown for $a_0=0.03$ and $a_0=0.05$. The pattern formation has a strong relation with the ratio of the nonlinear bounce frequency, $\omega_B\equiv2\omega_1(a_0a_1)^{1/2}$, to the plasma frequency. As ω_B increases, the nonlinear term becomes dominant and self-organized patterns occur in the plasma wave and the transmitted pump. For the case of a strong seed $(a_1>a_0)$, a different tendency in pattern formation is observed as shown in Fig. 2. The self-modulation of the seed pulse is regular when the pump amplitude is very small, but it shows stochastic behaviors as the pump amplitude increases because of more effective seed amplification.

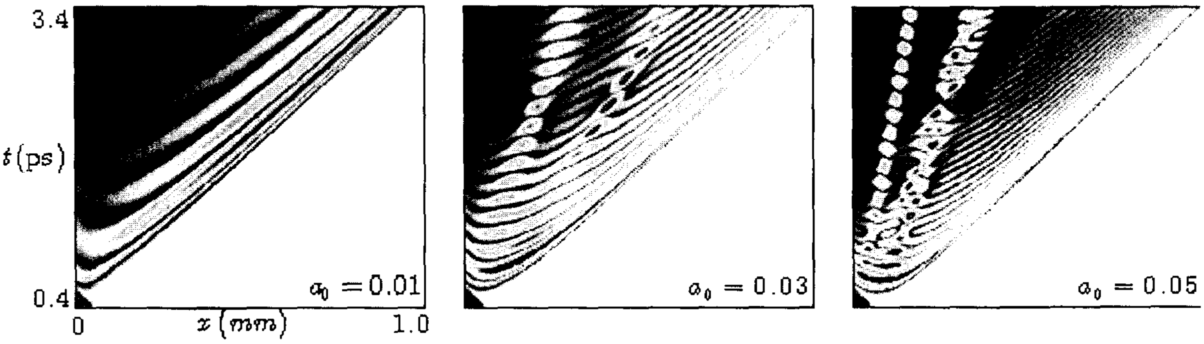

FIG 1. Spatiotemporal evolution of the pump pulses for various a_0. $\omega_p/\omega_0=0.1$, $a_1=0.01$, and the pulse duration $\tau_L=0.2$ ps are fixed. The pump propagates to the left, and the seed to the right.

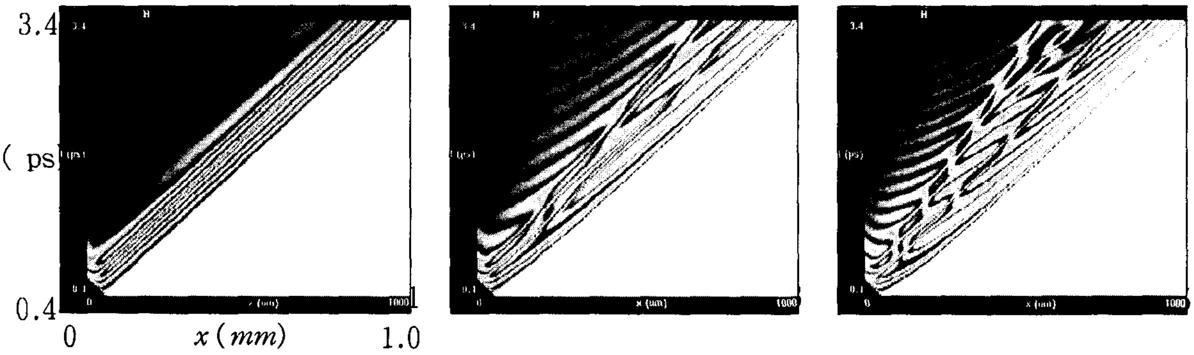

FIG 2. Spatiotemporal evolution of the pump for various a_0 with a larger seed, $a_1=0.1$. $\omega_p/\omega_0=0.03$, and $\tau_L=0.2$ ps. The pump propagates to the left, and the seed to the right.

This work is supported by the Creative Research Initiatives of the Korean Ministry of Science and Technology.

References

1. G. Shvets and N. J. Fisch, Phys. Rev. Lett. **81**(22), 4879 (1998).
2. V. M. Malkin, G. Shvets, and N. J. Fisch, Phys. Rev. Lett. **82**(22), 4448 (1999).
3. M. M. Škorić, M. S. Jovanovic, and M. R. Rajkovic, Phys. Rev. E **53**(4), 4056 (1996).