§ 7. Electron Parametric Instabilities of Intense Laser Light in an Underdense Plasma

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Inertial confinement fusion represents one of the most challenging goals in current energy research. Since fusion pellets are surrounded by large regions of coronal plasma, a general issue in laser fusion that has been of interest in past decades is the growth of instabilities in underdense plasma regions. The study of parametric instabilities is of vital importance. Most of these instabilities represent resonant decay of intense laser light $(\omega_0, \mathbf{k}_0)$ into a scattered electromagnetic (EM) wave $(\omega_s, \mathbf{k}_s)$ and an electrostatic (ES) wave $(\omega_{es}, \mathbf{k}_{es})$, [1].

To investigate the growth of instabilities in an underdense plasma a number of simulations were carried out by using an EM relativistic particle-in-cell code (1d3v EM PIC). The simulation model was as follows. A plasma layer (length L) driven by an intense laser wave (laser strength β) was placed into a long vacuum region. For EM waves as well as for energetic particles that can reach boundaries of the simulation system additional damping regions at the system ends were introduced.

As is well known, the stimulated Raman scattering (SRS) instability plays an important role in underdense plasmas below quarter critical density ($n < 0.25n_{cr}$). This SRS instability restriction can be shifted to higher plasma densities in the case of propagation of large amplitude EM waves. However, we have observations of strong electron parametric instability that involves an electron acoustic ($\omega < \omega_p$) ES wave (SEAS instability) [2]. This novel instability, absent from a standard theory of laser-plasma parametric instabilities, has main contribution for plasma densities that are overcritical for the SRS instability ($n > 0.25n_{cr}$+ relativistic shift). To illustrate, Fig. 1 shows propagation of laser light and generation of large amplitude ES waves ($k_{es} \approx k_0 \Rightarrow k_s \approx 0$). The generated ES wave can efficiently accelerate electrons.

Furthermore, there are simulation evidences that the SRS instability can assist (mediate) the SEAS instability excitation. Near the threshold intensity for the SEAS instability ($\beta \sim 0.3$) high electron temperature may be essential for the instability growth. As an illustration of the SEAS instability in this case, in Fig. 2 we show spectra of the scattered light $\omega_s \approx 0.7\omega_0$ (see EM spectrum) and electron acoustic ES wave $\omega_{es} \approx 0.3\omega_0$ ($\omega_{es} = \omega_0 - \omega_s \approx \omega_0 - \omega_p < \omega_p \approx 0.7$).

The obtained results are possibly important to future inertial fusion experiments.

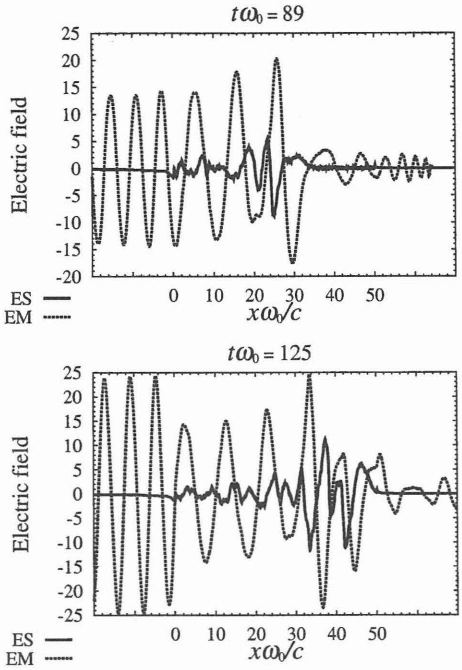

Fig. 1. Snapshots of EM and ES fields versus position for plasma layer ($n = 0.7n_{cr}$, $L = 50c/\omega_0$, $T = 500$eV, $\beta = 0.5$) at $t\omega_0 = 89$ (top) and $t\omega_0 = 125$ (bottom).

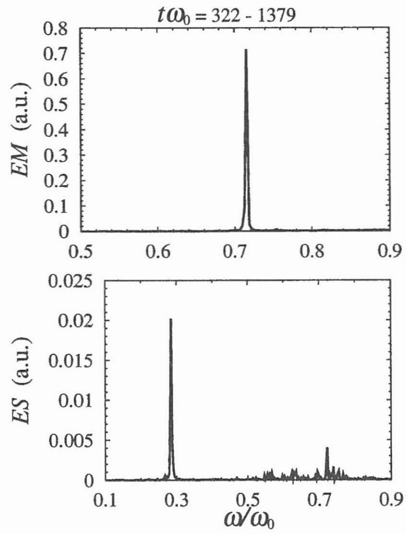

Fig. 2. Spectrum of EM (top) and ES (bottom) waves in the plasma layer ($n = 0.6n_{cr}$, $L = 40c/\omega_0$, $\beta = 0.3$) for time interval $t\omega_0 = 322 - 1379$. The initial electron thermal velocity is $v_t/c = 0.28$.

References

1) Mima, K. and Nishikawa, K.: in *Basic Plasma Physics II*, edited by A. A. Galeev and R. N. Sudan, (North-Holland, Amsterdam 1984), p. 451.

2) Nikolić, Lj., et al.: Phys. Rev. **E66** (2002) 036404.