§ 6. Large Amplitude Electromagnetic Relativistic Soliton in Ultraintense Laser Underdense Plasma Interaction

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Relativistic solitons are E.M.(electromagnetic) structures self-trapped by locally modified plasma refractive index through the relativistic electron mass increase and the electron density redistribution by the ponderomotive force of intense laser pulse. Recently the research of solitons has received much attention. In this report we present here, standing, left- and right-accelerated large amplitude localized relativistic E.M. solitons, induced by intense laser pulse propagation in long underdense, homogeneous plasma after multiple interaction processes, were observed by means of particle simulations. In our simulations, one-dimensional E.M. relativistic 1d3v PIC code is used. The length of simulation system in the x direction is $2700c/\omega_0$, the plasma length is $900c/\omega_0$ (c and ω_0 are the speed and frequency of laser pulse). In the left and right side of plasma two vacuum regions are present, the ions are kept immobile as a neutralizing background. The density of plasma is 0.032 times as the critical density of laser pulse, temperature is 350eV. The normalized amplitude of the incident laser pulse is $\beta = eE_0/m_e\omega_0 c$ and it is linearly-polarized in the y direction.

When laser pulse enter the plasma, in the first stage Stimulated Raman Scattering occurs, after that, complex nonlinear dynamic processes follows, such as the electron heating, reflected spectral broadening, cascading process. These processes transfer the incident laser energy to higher order scattering modes. In the laser pulse $\beta = 0.3$ case, a localized, non-propagating electron density cavity is created. As shown in fig.1, an E.M. field is trapped and oscillates coherently inside the density cavity, that is, a large amplitude standing relativistic E.M. soliton comes into form.

For large laser pulse amplitude with $\beta = 0.4$ (fig.2) and $\beta = 0.5$, the observed large amplitude localized E.M. solitons are accelerated towards the left plasma-vacuum interface where the laser pulse is entered. When soliton arrives at the plasma-vacuum interface, it radiates its energy away in the form of low-frequency E.M. wave due to the interaction with the plasma boundary, as a result, one can observe a very high reflectivity which is larger than that of Simulated Raman Scattering process during the soliton radiation.

As we further increase the laser pulse amplitude to $\beta = 0.6$ (fig.3) and $\beta = 0.7$, large amplitude localized right-accelerated solitons are observed. As the soliton approaches the plasma vacuum interface, it radiates its energy away in the form of low-frequency E.M. wave due to the interaction with the plasma boundary, and a very high transmittivity during the solitary wave radiation can be observed.

From our simulation we found that the acceleration of solitons depend upon the intensity of the incident laser pulse in a uniform underdense plasma. The frequency of E.M. wave trapped inside the solitons is about half unperturbed plasma frequency. The electric field of solitons has half of one cycle structure in space, magnetic field, and corresponding electrostatic field have one cycle structure.

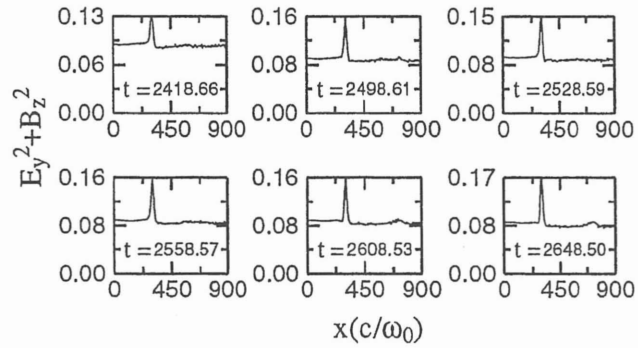

Fig.1. The energy density of E.M field inside the soliton for the case with $\beta = 0.3$

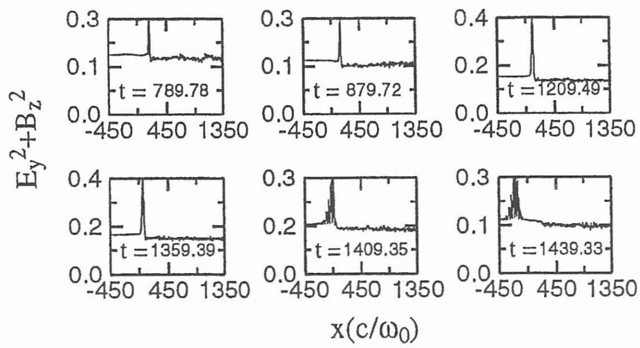

Fig.2. The energy density of E.M field inside the soliton for the case with $\beta = 0.4$.

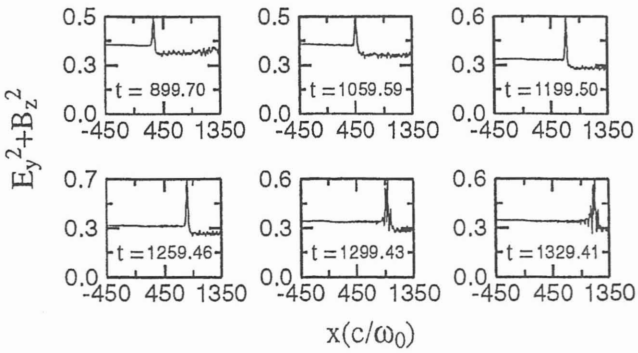

Fig.3. The energy density of E.M field inside the soliton for the case with $\beta = 0.6$