Transient setting of relativistic ponderomotive nonlinearity and filamentation of ultra-short laser pulses in plasmas

R. P. Sharma[1] and Narender Kumar[*2]

[1] *Centre for Energy Studies, IIT Delhi, New Delhi-110016, India, e-mail: rpsharma @ces.iitd.ernet.in*

[2] *Sri Venkateswara College, University of Delhi, New Delhi-110021, India, e-mail: narenderk@svc.ac.in*

We study the setting up of relativistic ponderomotive nonlinearity when the laser frequency is much larger than the electron plasma frequency (viz. under dense plasma far away from critical density region). Brandi *et al.* [1] have studied the relativistic ponderomotive nonlinearity when the laser frequency is more than the electron plasma frequency (but near the electron plasma frequency only). Therefore, their approach cannot be applied to the present case. Using the two fluid approach, the nonlinear dynamics of the plasma oscillations under the combined effects of relativistic mass variation and ponderomotive force of laser beam has been derived. We present the numerical simulation for the coupled system of equations governing the dynamics of laser and plasma oscillations in a collisionless plasma, when the coupling arises through relativistic ponderomotive non-linearity

The pump beam has been perturbed by a periodic perturbation that leads to the nonlinear evolution of the laser beam. The simulation results show quite complex localized structures that grow with time. The filamentation of laser beam has been found to vary appreciably with varying perturbation number. It was observed that the frequency spectra of the plasma oscillations have several harmonics peaks at terahertz frequencies when the electron plasma frequency is in terahertz range and laser frequency is around 10^{15} sec^{-1}. We also presents the semi analytical model that uses the results obtained through numerical simulation for describing the effect of the nonlinear evolution of the laser beam on the localization pattern and varying number density. As the beam propagates in the plasma it encounters nonlinearity due to which the beam width parameter decreases and the beam suffers self-focusing, during the course of time this decrease becomes so prominent that the natural diffraction starts playing its role thereby leading to defocusing of the beam. Again as time passes the nonlinear converging terms starts dominating the diffraction term and beam starts to focus, in this way there is a mutual competition between the diverging diffraction term and the converging term that is a combination of both the relativistic ponderomotive nonlinearity as well the contribution from density modes resulting in oscillatory self-focusing of the beam.

1. H. S. Brandi, C. Manus, G. Mainfray, T. Lehnere and G. Bonnaud, "Relativistic and ponderomotive self-focusing of a laser beam in a radially inhomogeneous plasma. I. Paraxial approximation" *Physics of Fluids B: Plasma Physics* 5, 3539 (1993); doi: 10.1063/1.860828.