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On Wave Breaking of Relativistically Intense Longitudinal Space Charge Waves in Plasma

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Spatio-temporal evolution of large amplitude relativistically intense longitudinal space charge waves in plasma is a fascinating field of research. It is not only a topic of fundamental academic interest to nonlinear plasma theory but also serves as a useful paradigm to illustrate the underlying physics of many plasma based phenomenon in the laboratory and astrophysical scenarios where large amplitude space charge waves are excited. A space charge wave is said to be relativistically intense when the energy gained by an oscillating particle over a distance of one wavelength becomes of the order or more than its rest mass energy. The amplitude of these nonlinear plasma waves is limited by a phenomenon called wave breaking, which may be induced by several physical processes [1, 2]. In this talk, along with a brief overview of the subject, current understanding of wave breaking of relativistically intense space charge waves will be presented. Its application to the rapidly developing field of plasma based particle acceleration schemes will also be touched upon. In the present study, we restrict ourselves to relativistic space charge waves excited in a cold unmagnetized plasma.

In the first part of the talk, we will present the spatio-temporal evolution of relativistically intense longitudinal plasma waves which are supported by electron motion only *viz.* the Akhiezer-Polovin wave [3]. To investigate these waves, they were excited using a 1-D sheet code [4] (Dawson sheet model) and also, using fluid simulation, in the wake of an electron beam propagating with relativistic speeds through a cold plasma [5]. The second case is of relevance to particle acceleration schemes. It is shown that Akhiezer-Polovin wave does not break unless longitudinally perturbed. When longitudinally perturbed, these waves are found to break via the process of phase mixing at an amplitude which is well below the well-known Akhiezer-Polovin limit [4, 5]. The wave-breaking time has been analytically estimated and is found to scale inversely with the energy density of the wave [5, 6, 7]. These results have been verified using both Dawson sheet simulation and fluid simulation [Fig. 1].

In the second part of the talk, we will discuss the spatio-temporal evolution of relativistically intense longitudinal plasma waves which are supported by both electron and ion motion *viz.* the Khachatryan wave [9]. To investigate these waves, they were excited using fluid simulation, in the wake of an electron beam propagating with relativistic speeds through a cold plasma, a configuration of relevance to particle acceleration schemes. Again it is found that, as a result of longitudinal perturbation, Khachatryan mode breaks via the process of phase mixing at an amplitude which is well below the limit derived by Khachatryan [9, 10]. In this case also, the wave breaking time is found to scale inversely with energy density of the wave [Fig. 2].

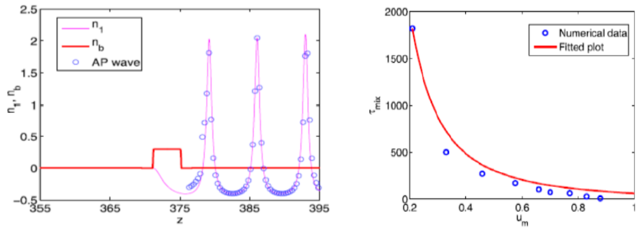

Fig.1 : Akhiezer-Polovin Mode and its breaking

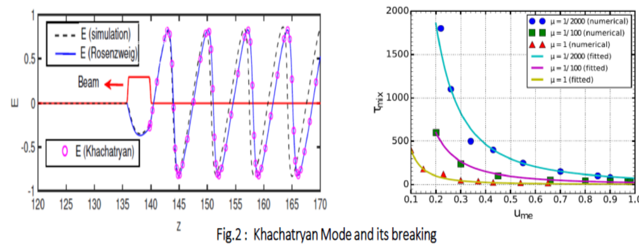

Fig.2 : Khachatryan Mode and its breaking

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