Using a traveling wave tube to analyze nonlinear effects in plasmas

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Traveling wave tubes [1] (TWTs) are electron devices in which an electron beam interacts with electromagnetic waves in a vacuum environment. Industrial TWTs range from 2 to 30 cm in length and are mostly used as signal amplifiers for space telecommunication and other wireless communications [2].

On the other hand, some meters long TWTs are especially useful to experimentally mimic beam-plasma systems [3,4]. Such a comparison is possible because both the TWT and beam-plasma instabilities are described by the same equations. The TWT is much less noisy than any plasma since the interaction between electrons and waves occurs in vacuum. Another advantage is that the waves propagate through an intrinsically linear medium. Therefore, in the TWT we are able to properly identify the effects due to the beam and waves dynamics.

At PIIM Laboratory, we use a 4 meters long TWT to study wave-particle interactions in plasmas [5]. This TWT is long enough for strong nonlinear effects to take place, such as beam modulation and wave growth and saturation. For low values of beam current, we obtain that the wave growth coefficient and saturation amplitude follow the predictions of the linear theory. For high beam currents, nonlinear space charge effects become important and these parameters deviate from the linear predictions. We also observe trapping oscillations after the wave saturates [5]. The beam electrons form bunches that move back and forth in the wave potential, making its amplitude oscillate along the TWT.

The TWT at PIIM Laboratory was recently upgraded [5,6], and this upgraded version provides accurate experimental data with an excellent agreement with the theoretical model. Therefore, it enables us to carry out new experiments on pulsed beams [7], the synergy between chaotic and self-consistent effects [8], and the predictions of the quasilinear theory for warm beams interacting with a broad spectrum of waves [9]. Furthermore, the results we present in this talk are currently used to benchmark the new numerical model DIMOHA [10,11,12], which describes nonlinear wave-particle interactions in periodic structures.

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