DYNAMICS DAYS SOUTH AMERICA 2010
International Conference on Chaos and Nonlinear Dynamics

INPE – National Institute for Space Research
São José dos Campos – SP – Brazil – July 26-30, 2010

THE INITIAL INHOMOGENEITY AND HALO FORMATION IN INTENSE CHARGED PARTICLE BEAMS

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keywords: Chaotic Dynamics, Collective Phenomena, Control of Chaos and applications, Fluid Dynamics, Plasma and Turbulence.

Homogeneous beams with mismatched envelopes usually evolve to an equilibrium-like state after some characteristic time during its magnetic focusing inside the confinement channel. This process is macroscopically characterized by a not negligible growth of emittance [1], which is a statistically-averaged beam quantity that involves spatial and velocity coordinates of its constituent particles. If beam is initially cold (all beam particles have velocities that can be neglected), one can assure that the increasing of emittance is unconditionally associated with increasing of particle velocities. Beam earns kinetic energy or, using jargons of the field, beam is progressively heated during magnetic focusing. Since overall energy is a constraint of beam motion, thus if kinetic energy increases (in this case from an initial zero value to some of equilibrium), effective potential energy must decrease, conserving total energy. Large non-linear resonances are responsible in to excite beam particles individually, converting potential energy stored in envelope oscillations into kinetic energy that supplies the chaotic movement of these particles [2][3].

Some similar emittance growth also occurs for initially non-homogeneous beams. Initially cold and inhomogeneous beams also direct to its equilibrium with a systematic heating of its particles [4]. Inhomogeneity leads beam fluid elements to oscillate with a frequency that is dependant of spatial position. Note the force that beam exerts over each particle is nonlinear, because its density is intrinsically non-homogeneous. Even consecutive fluid elements (those displaced initially with an infinitesimal spatial distance, that has in this way much similar oscillating frequencies), in a finite time will lose coherence and inevitably will collapse. From beam phase-space picture, this collapse will look like as particle jets, which are the forerunner instability for the beam reaches its equilibrium. If envelope mismatch is eventually present, the previous commented large resonant islands also exist to provide kinetic energy to the particles of non-homogeneous beams. However, even in the absence o envelope mismatch, heating process still occurs, inducing phase-space mixing and consequently that beam reaches its equilibrium. This is due to another physical mechanism, which it has been called of charge redistribution [3]. In the same manner particles couple with envelope oscillations, particles can also couple with charge redistribution oscillations. The main difference between both couplings is that the first one is resonant but the second one usually is not [3]. Resonant interaction is achieved in just some limit situations. But this discussion is out of scope of the current work.

Although undesired in many applications, the intrinsic spurious spatial inhomogeneity that permeates real systems is the forerunner instability which leads high-intensity charged particle beams to its equilibrium. In general, this equilibrium is reached in a particular way, by the development of a tenuous particle population around the original beam, conventionally known as the halo.

In this way, the purpose of this work is to analyze the influence of the magnitude of initial inhomogeneity over the dynamics and over the equilibrium characteristics of initially quasi-homogeneous mismatched beams. The system considered here is an initially cold, azimuthally symmetric, and quasi-homogeneous beam, focused by a constant magnetic field and encapsulated by a conducting pipe. To this end, all beam constituent particles, which are initially disposed in an equidistant form, suffer a progressive perturbation through random noise with a variable amplitude. Dynamical and equilibrium quantities are quantified as functions of the noise amplitude, which indirectly is a consistent measure of the initial beam inhomogeneity. The results have been obtained by the means of full self-consistent N-particle beam numerical simulations and seem to be an important complement to the investigations already carried out in prior works.

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