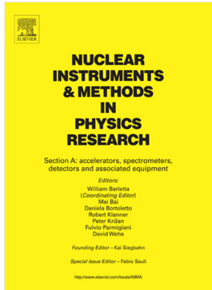

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Longitudinal Instabilities of the Experimentally Generated Laser Accelerated Ion Beam Relevant to Fast Ignition

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ABSTRACT

The advent of laser-assisted ion acceleration technology promises an alternative candidate to conventional accelerator drivers used in inertial confinement fusion. The experimental generation of quasi-monoenergetic heavier ion species i.e. carbon and aluminum, applicable to fast ignition studies has been recently reported. The propagation of these energetic ions may impact on the proper ignition phase through growing of micro-instabilities of beam-plasma system. The growth of flow-aligned instabilities is much more important for heavier ions transport in the dense plasma. Here, we have presented a general non-relativistic one-dimensional dispersion relation of cold fluid model as well as corresponding kinetic theory of incident ion beam with atomic number, Z_b enters into a fast ignition DT plasma. The longitudinal instabilities of some selected average energies of experimentally generated C^{6+} (E_C=50, 100 and 200 MeV with δE/E~10%) and Al^{11+} (E_{Al}=150 and 300 MeV with δE/E~25%) quasi-monoenergetic beams were examined and beam-plasma system stable configuration have been then derived. It has been shown that in the kinetic theory framework, carbon and aluminum ions may be completely stabilized by the combination of beam to plasma density ratio (α_b) and plasma temperature (T_p) of ignition phase parameters. Moreover, in complete stabilization, α_b parameter of aluminum beam is an order of magnitude lower than carbon.

Keywords: ion beam driver, quasi-monoenergetic, fast ignition, Nyquist criterion, beam-plasma instability
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I. INTRODUCTION

The acceleration of energetic ion beam through the interaction of intense short pulse laser-plasma system as well as its propagation in neutralized background plasma have attracted a growing interest in recent years especially in fast ignition (FI) [1-5]. In the early stages of fast ignition approach to inertial confinement fusion, laser accelerated ultra-relativistic electron beam was responsible to deliver the required ignition energy into the dense core of pre-compressed deuterium-tritium (DT) plasma [6-7]. The key challenge in electron fast ignition was relatively large beam divergence during its transport. To address this issue, some modification in target design such as re-entrant cone was then proposed [8]. These relativistic electron beam can be subject to numerous micro-instabilities during its propagation inside the plasma [9-11]. Among them, the two-stream (TS) and filamentation instabilities are beam dependent, so that they need the beam to exist. The first one is longitudinal with a wave vector aligned with the beam and the second one is transverse with a wave vector normal to the beam, but both disappear when the beam is removed. The understanding of this transport system is crucial in fast ignition scheme.

A more efficient alternative to electron ignitor beam was first reported by Roth *et al.* during successful demonstration of proton acceleration from high power lasers at Lawrence Livermore National Laboratory (LLNL) [12]. It took advantage from the so-called ‘target normal sheath acceleration’ (TNSA) mechanism where a laser beam with an intensity exceeding 10^{18} W/cm^2 is focused on μm size targets. By this way, LLNL was enabled to accelerate protons up to 60 MeV with an exponential spectrum [13]. The main challenges of the proton fast ignition (pFI) concept lies in its spectral shape, particle energy and the conversion efficiency [8, 15]. In recent years, heavy ion fast ignition has attracted more