FOCUSING AND TRANSPORTATION OF INTENSE LIGHT ION BEAM IN INERTIAL CONFINEMENT FUSION

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INTRODUCTION

The minimum requirement for the light ion beam (LIB) as the energy driver is that the instability must not grow up enough while the propagation time. The LIB will diverge by its own strong Coulomb repulsive force as it is, because the LIB is an ensemble of the charged particles. The complete charge neutralization must be required by all means. One of the way for the charge neutralization of LIB during the propagation is to fill up the reactor cavity with the inert gas of 0.1-1 Torr. The electrons in this inert gas are expected to neutralize the charge of LIB. The self-pinch propagation method has been proposed recently as a new idea. Such a propagation will be achieved by setting the ratio of the number density of background plasma to that of beam particles to be 1:10. As the current density of the beam is very intense, the self-induced magnetic field in the azimuthal direction pinches the beam itself. Because, the self-pinched plasma is not stable, the magnetic field in the axial direction to stabilize the beam is induced by the rotating motion of the beam. This magnetic field corresponds to the toroidal magnetic field in the tokamak machine. In this paper, the effects of magnetic field on the stabilization of the beam is investigated numerically as an eigenvalue problem. This is an analysis for macroscopic stabilities. The importance of the effect of electric field on the beam propagation was pointed out recently. That is, the leading- and tailing edges diverge by electric fields. These electrostatic fields are estimated on
the basis of the kinetic theory and the beam divergence is calculated in the later part of the present paper.

MACROSCOPIC STABILITY FOR ROTATING BEAM

The scheme employed here for stability analysis is of an eigenvalue problem. This scheme is applied to the LIB propagation in the background plasma which fills inside the reactor. In order to stabilize the beam propagation, the ion beam particle rotates around the propagating axis. The beam rotation enduces the magnetic field in the axial direction. The magnetic field corresponds to the "toroidal field" in tokamak. Propagating beam ions are confined in a small radius by the azimuthal magnetic field (corresponding to the poloidal magnetic field in tokamak) which is induced by the self-current of beam in the axial direction. The toroidal field is necessarily required to exist to stabilize the plasma confined by the poloidal field. The electro-magnetic fields induced around the beam are schematically shown in the following figure.

Because of the high particle energy of propagating beam, the beam particle can be considered to be collision-free. The Larmor radii of beam particles and the amplitudes of their betatron oscillations are comparable to the propagating beam radius. Thus the macroscopic description is very poor for the beam. The growth rates of disturbances depend completely on the steady solution. Thus the macroscopic treatment gives very limited information about the stability. Surely the steady solution is easily obtained in the form of a distribution function. (The Maxwellian form for the beam distribution is not preferred, because it is not confined by the magnetic field.) But the stability analysis becomes much more complex in the case of microscopic treatment because of its many independent variables, although the formalism is similar to the macroscopic one. In this paper, for simplicity we choose the macroscopic description for the beam as an example in which the eigenvalue problem is applied. The governing equation for the beam are,

\[
\frac{\partial n_b}{\partial t} + \nabla \cdot (n_b v_b) = 0 ,
\]

\[
m_b n_b \left\{ \frac{\partial v_b}{\partial t} + \frac{1}{2} \nabla v_b^2 - v_b \times (\nabla \times v_b) \right\} = -k_B \nabla (n_b T_b) + e_b n_b (E + v_b \times B) ,
\]

\[
j_b = e_b n_b v_b .
\]