Recent activity on beam dynamics study during longitudinal bunch compression by using compact beam simulators for heavy ion inertial fusion

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In heavy ion inertial fusion scenario, heavy ion beams with extreme high current are most important assignment [1]. Predictions of beam behavior are basic necessity to design the accelerator complex. Especially, a bunch compression manipulation in the final stage of accelerator complex is required to generate the beam with high current and suitable short pulse duration [2].

Recent research activities in beam dynamics during bunch compression with strong space charge effect using compact beam simulators [3-11] are introduced in this study.

In Tokyo Institute of Technology, a compact simulator of electron beam was constructed [3-5]. The compact simulator consists of an electron gun, an energy modulation gap, an induction modulator, a drift line with a solenoidal electromagnet, and a Faraday cup. Electrons emitted from the electron gun with 2.8 keV of kinetic energy come in the modulation gap. The induction modulator gives the deceleration voltage into the gap. The synthesized voltage waveform applies the kinetic energy modulation to the electron bunch with head-to-tail velocity tilt. The electron bunch is compressed during the drift transport of 2 m length. The electrons are transversely confined due to the magnetic field of several tens mT produced by the solenoid coil. Finally, the electron bunch achieves to the Faraday cup placed in the transport line. The beam current increases up to 25 times from the initial one due to the pulse compression. It is estimated that the electron bunch is changed to space-charge-dominated states.

In Kanazawa University, a compact simulator based on the Malmberg-Penning trap was demonstrated for the investigation of space-charge-dominated beam [6]. In the device, the electron cloud is transversely confined with 0.1 T of axial magnetic field generated by the solenoidal electromagnet, and is axially confined with the saddle shaped axisymmetric potential of negative barriers at both ends. After the confinement, the electron cloud is extracted from the trap region, and a phosphor screen and a CCD camera detect the density profile. By controlling the potential barriers, the energy distribution of the electrons is also measured. The axial compression is carried out by applying voltage to ring electrodes. The diameter of electron cloud is 1 mm. The length is shortened from 170 mm to 80 mm due to the axial compression. The number density of electron plasma is achieved up to 4.3×10^{13} m^{-3}.

In Nagaoka University of Technology, we study the beam dynamics in the compact electron beam simulators, theoretically and numerically [7-11]. Using the longitudinal envelope equation, the ratio between the repulsion forces due to the space charge and the emittance was estimated. The numerical simulations were carried out in the parameters of compact device. These approaches suggested that the compact simulator is able to simulate the beam dynamics around the stagnation point. A numerical code based on molecular dynamics is developed to calculate the beam dynamics in three-dimensional space. In the multi-particle simulation result, a longitudinal-transverse coupling motion is studied in the compact simulator.

References

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