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Simulation of ion cyclotron resonance heating by using particle-in-cell method in MPS-LD linear plasma device

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The construction of a steady-state linear plasma device, called Multiple Plasma Simulation Linear Device (MPS-LD)[1], is underway. One of the main objectives of MPS-LD is to simulate divertor plasma conditions, which can fill partially of the gaps in edge plasma between current tokamak devices and fusion reactors. As a divertor plasma simulator, the study of plasma transport and detachment requires to have typical scrape-off layer (SOL) /divertor plasma parameters with plasma density of 10^{18}-10^{20} m^{-3} and plasma temperature of 1-30 eV. For MPS-LD, the Helicon plasma source is designed to provide the plasma. However, the plasma temperature is only several electronvolt (eV), which is much lower than required. Therefore, the auxiliary heating is necessary to raise the temperature.

The ion cyclotron resonance heating (ICRH) method based on "beach-heating" technique has been successfully applied to some linear plasma devices[2,3], which provides an efficient ion heating and is essentially appropriate for a steady-state operation[4]. Ion heating is accomplished by launching a wave from a region of high magnetic field to a region of decreased magnetic field where the wave encounters the ion cyclotron resonance, and is expected to be absorbed by the ions via fundamental ion cyclotron damping[5]. Numerical simulation studies based on a full wave calculation by TASK/WF3D code have been carried out[4]. These works focused on the understanding of the heating effect, absorption efficiency and so on.

In this report, the ICRH will be presented for the MPS-LD experiment optimization and prediction. The particle-in-cell (PIC) method, which is relatively intuitive and can track the trajectory of charged particles, is applied for the numerical simulation. A left-handed, circularly polarized wave along the magnetic field lines is used to represent electromagnetic wave in the model, after the analysis of the cold plasma dispersion relation. The energy absorption efficiency is high when the rotation direction of electric field vector of the left-handed, circularly polarized wave is the same to the ion gyro-motion, and the frequency is consistent. This work focuses on evaluating the effects of main parameters such as wave frequency, magnetic field configuration, heating power on plasma heating to further understand the wave-plasma coupling mechanism. The results show that ICRH can significantly increase the ion temperature as shown in Fig. 1, and the heating effect near the resonance point (~2.05 m) is the best. The heating effect can be optimized by adjusting these parameters.

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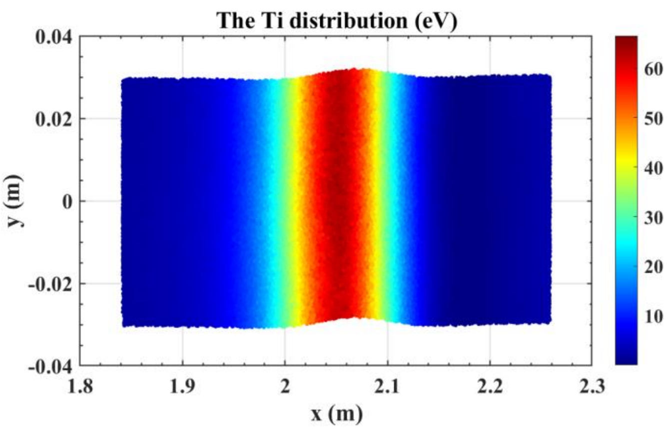

Figure 1. The T_i distribution after ion cyclotron resonance heating (ICRH) from PIC simulation.