SimulatinganIon Energy Analyzer using Particle-in-Cell technique

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1. The XPDP1 code

XPDP1 is a bounded electrostatic code used for simulating a plasma within planar electrodes. The code uses Particle-in-Cell (PIC) technique to simulate the electrons and ions, meaning that the physical volume is divided into several parallel cells. At the boundaries of the cells the charge density, current density and electromagnetic field are calculated. There are superparticles used in the simulations. A superparticle represents a homogeneous collection of a large number of real particles. This way the mass-to-charge ratio stays the same, thus minimizing the number of simulated particles. [1]

2. Ion Energy Analyzer

An Ion Energy Analyzer is a simple probe consisting of parallel grids and a collector plate behind them. The probe is used in plasma devices for obtaining ion plasma parameters.

XPDP1 was modified in order to simulate the Ion Energy Analyzer. The new version, XPDP1_rfa, includes two conductive grids with adjustable permeability. The first grid (reflector) is set to be on a floating potential and since average electron speed is much greater than average ion speed, the grid will become negatively charged according to the eq. 1.1.

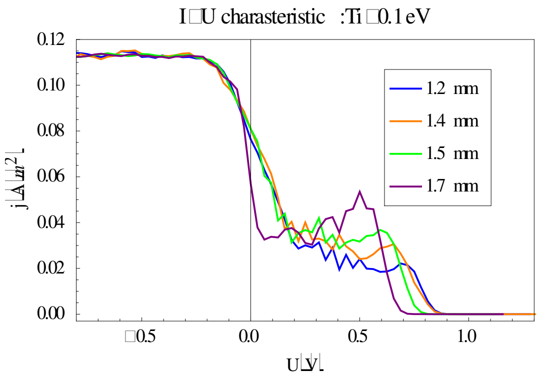
$$\Phi = \frac{k_B T_e}{e_0} \ln\left(\sqrt{\frac{2\pi m_e}{m_i}}\right) \qquad 1.1$$

The potential on the collector should be low enough to repulse the remaining high-energy electrons.

The second grid is an ion discriminator. The potential on this grid is directly driven and only the ions with high enough energy can pass through the grid. [2]

2.1. Simulations

The simulations are used for researching an impact of the analyzer on the plasma and the importance of various probe characteristics. The most important parameter is the distance between the grids. If the distance is too large, the maximum potential between the grids exceeds the potential on the discriminator grid due to the excess of the electronsin the area between the grids. This limit distance varies depending on the opacity of the grid, the initial temperature of the ions and other characteristics of the probe.



discriminator potential for different distances between the grids.

The temperature of the ions is calculated using the eq. 1.2 and U-I characteristic. The calculated temperature is then compared to the set temperature of the ions to determine the impact of the probe on a plasma.

$$I(U) = I_s exp\left(-\frac{e_0 U}{k_B T_i}\right) \qquad 1.2$$

2.2. Additional studies

In the second part of the research the secondary emission of electrons was included to the code. It can be seen from the results of the simulations that the materials for the grids must be chosen carefully, since the secondary electrons disrupt the measurements.

In addition, a third grid was included to the code to show the difference between different types of the probes.

References

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