$E\times B$-probe modeling for diagnostics of Plasma Propulsion Thruster

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Plasma propulsion thrusters (PPT) are actively used in space. However presence of multiply charged ions (MCI) at PPT plume adversely affects main thruster parameters: thrust, mass utilization and lifetime. One of the instruments to measure MCI population is $E\times B$-probe [1]. Analyzing probe spectrum we assess MCI concentration and its velocity (or energy) distribution function (IVDF/IEDF). This diagnostic has been used on different PPT [2]. However for sources with a wide spread of ions velocity (in particular HT), it is a hard to predict probe's parameters needed to resolve peaks for particles with different charges. In this work we present a model of the probe that has been created to predict probe transfer functions and methods for peak separation.

1. Introduction & theory

The interpretation of experimental data made with help of integral methods introduces inaccuracy and does not allow us to recover original IDVF due to asymmetrical broadening of the spectrum that depends on main particle velocity and blending of current peaks related to different ion species. In the work [3] the Fredholm equation for energy spectrum was used for data analysis to recover initial parameters of plasma with needed accuracy. Authors used Gaussian fitting for the raw signal for peak resolution problem. In the present work introduced the methods to determine $E\times B$-probe 's parameters. For this reason we made a program module that allows to calculate needed parameters of the probe and to decode measured spectrum.

Let's define initial Z-charged ion velocity distribution in probe's axis direction as $f(v)$ and filtration speed as $u = E/B$ where E – electric field and B – magnetic field. The probe cuts out a small part of the initial distribution function $f(v) \rightarrow f(v,\ u)$. We can declare the probe's transfer function as $g(v,\ u) = f(v,\ u)/f(v)$. The probe resolution w is determined by the speeds where $g(u,\ v)$ becomes zero. The ion current to the collector surface is defined from Fredholm integral equation as $j = Kf$ with kernel $K = Z \cdot ug(u,\ v)$. The kernel of this equation can be obtained from the probe model. Then IVDF can be reconstructed by solving inverse problem with help of regularization methods.

2. Results & conclusions

The numerical and analytical probe models were created to predict transfer functions, probe resolution and IVDF. These models show that probe's resolution (in velocity units) depend on E^2/B^3 multiplied by geometric constant. In other words common integral interpretation of IVDF is incorrect for high-speed particle fractions. The calculated ions transfer functions dependence on energy shown in fig.1. Modeled broad signal demonstrated in fig.2.

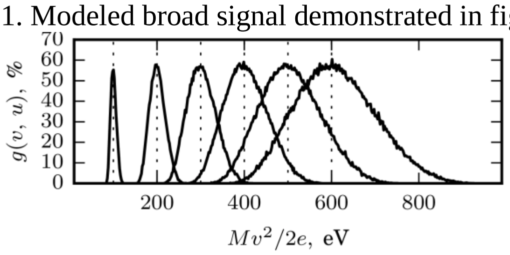

Fig.1. Transfer functions for single charged ions.

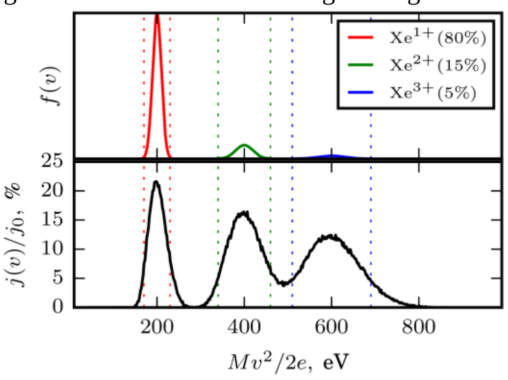

Fig 2. Simulated $E\times B$-signal for defined IEDF.

Also, the probe modification was suggested to better peaks separation. The modeling results are in a good agreement with available experiments data.

3. References

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