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Simulation study for the design of multi-needle Langmuir probe (m-NLP) instrument

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The space in-situ measurement missions extensively utilize sounding rockets and satellites to carry scientific instruments and conduct experiments along the spacecraft's trajectory. Among these missions, it is popular to employ Langmuir probes for density and temperature measurements [e.g., 1,2]. Operating classical Langmuir probes requires sweeping the bias voltages from the ion saturation region to the electron saturation region. Thus we can infer physical parameters such as ion density, electron density, and electron temperature based on the shape of the obtained current-voltage characteristics [3].

The so-called multi-needle Langmuir probe (m-NLP) instrument consists of two or more small fixed-bias cylindrical Langmuir probes compared to the Debye length. Because it does not require sweeping over different voltages, the advantage of the m-NLP system is that it can provide electron density measurements with a high sampling rate (~ kHz) [4, 5]. Many sounding rockets and satellites have included the m-NLP system for high-resolution data [e.g., 6-9]. The plan to employ the m-NLP system on the International Space station is also in progress.

A traveling object can disturb the local plasma environment and lead to a plasma wake in the downstream region. To avoid the potential measurement errors led by the formed wake has been a typical question for the design of space in-situ measurement missions. This question comprises the effect of the large-scale objects such as spacecraft and boom; and the one associated with smaller objects such as the Langmuir probes themselves. In the present study, we investigate the importance of the latter. We employ a three-dimensional unstructured Particle-in-cell code, PTetra, to study the wake formation problems in the interaction between the positively biased Debye-scale Langmuir probe and its surrounding plasma. The choices of the positively biased and Debye-scale Langmuir probe are due to the basic concept of the m-NLP instrument.

We find that the higher electric bias and the higher flow velocity can enhance the plasma. An external magnetic field will also enhance and skew the wake behind a thin cylindrical Langmuir probe. While employing the background magnetic field in the simulation system, we can observe the wing structures in the density profiles along the background magnetic field. We will also discuss how far such probes should be placed from each other to avoid plasma measurement errors [10]. Furthermore, we will also present the latest simulation results for comparison with the laboratory experiment.

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