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Diagnostics in Void of Dusty Plasmas
微粒子プラズマのボイドにおけるプラズマ診断

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The research project of fine particle (dusty, complex) plasmas had been done with cooperation for the PK-3 plus flight module between scientific teams of Germany and Russia on the International Space Station (ISS). Several Japanese scientists joined to the project for investigating a physical phenomenon of critical point in the plasmas. For further analyses of the critical point, uniformity of plasma comes to be a project to obtain large dust clouds without a void. The void, which corresponds to a region dust particle free inside the dust cloud, should be closed or removed. The balance of forces on dust particles forms the void, which is determined by potential structures of plasmas. Understandings of the mechanism for the void will be brought in diagnostics of the void with a double-probe method.

1. Introduction

The Japanese science team had been motivated in the experiments on the international space station (ISS) of dusty (complex) plasmas, which was done on with collaboration between Max-Planck-Institute for Extraterrestrial Physics (MPE, Germany) and Joint Institute for High Temperature (JIHT, Russia) in 2013.

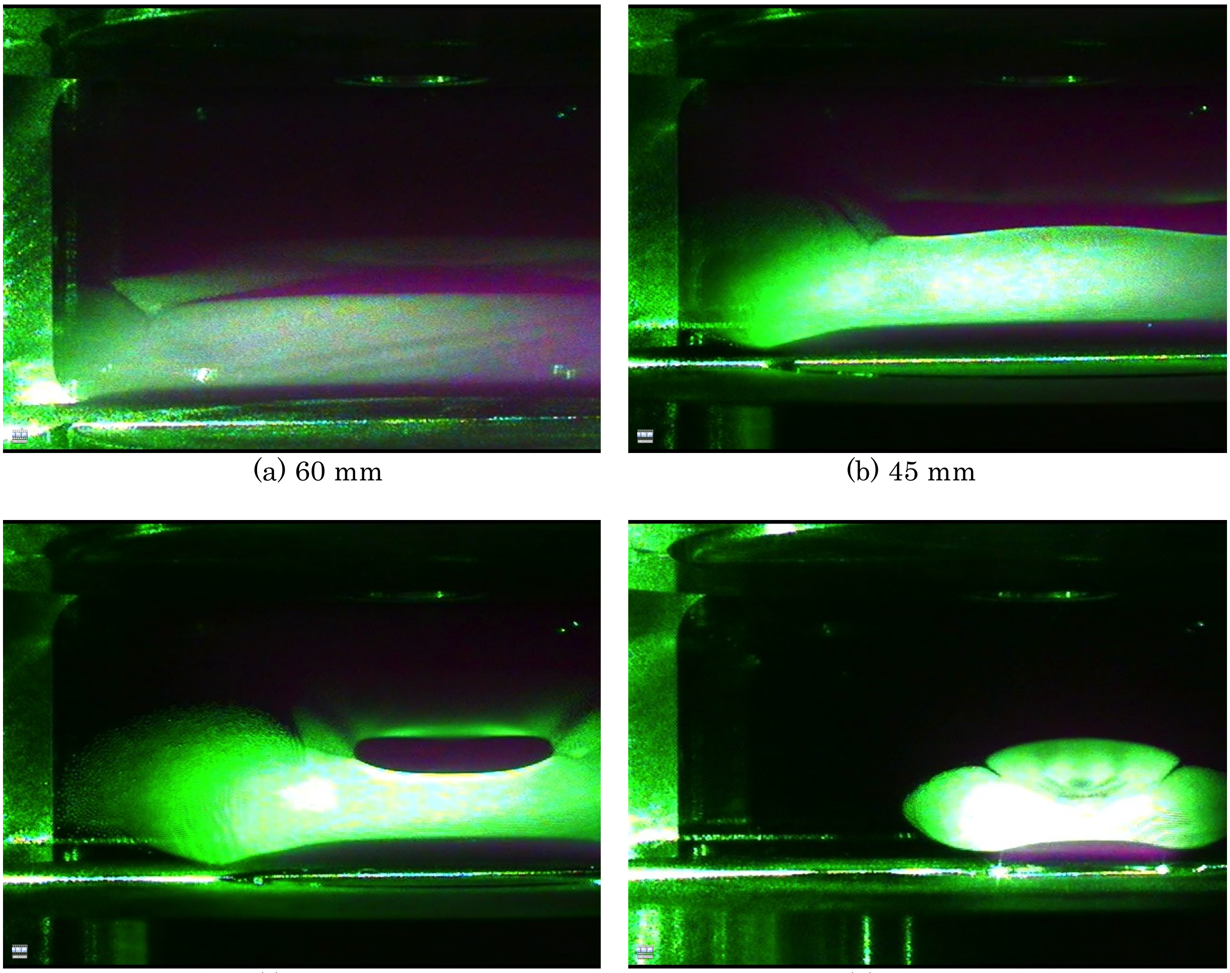
Plasmas including dust particles (typically, micrometer sized), so called complex plasmas (or dusty or fine particle plasmas), have attracted much interest of scientists for a few ten years. The dust particles are charged by fluxes of electron and ion in the plasmas. The charge of dust particles can be on the order of a few thousands of elementary charge in typical laboratory plasmas. The charged dust particles are regarded as a strongly-coupled Coulomb system. In the system, one can observe many physical phenomena found in solid or liquid state, such as crystallization, phase transition, wave propagation, and so on, at kinetic level. Complex plasma experiments have been done in microgravity conditions with apparatuses boarding on parabolic flight, sounding rockets, and the international space station for recent years. Several physical phenomena, e.g., wave propagation and so on, reported by MPE and JIHT in the experiments on the ISS. The utility for complex plasmas on the ISS was replaced an apparatus denoted by PK-3 plus set in the Russian module at the end of 2005 [1].

Several scientists in Japan joined to the mission of PK-3 plus for demonstrating a critical phenomenon in complex plasmas predicted by Totsuji [2] since July 2009. The data analyses were done under the scientific agreement between the Japanese scientists and JIHT with support from JAXA. The prediction requires high density of plasmas to approach the critical point. Based on results of diagnostics in PK-3 plus, high power and pressure conditions were employed to obtain the high-density regime. With increasing power and pressure, a region dust particle free, so called void, appeared at the center of plasmas and expanded. The void formation had come to be known well in experiments under microgravity with the previous apparatus of PK-3, PKE-Nefedov. It seemed that the void resulted in non-uniformity of plasmas enhanced with increasing plasma density. The void-less, homogeneous, system would be necessary to demonstrate physical phenomena as well as the critical in complex plasmas. Furthermore it is also expected to be useful for plasma process in the future space activity. Mixture of massive matters and plasmas not accomplished under gravity would develop something new as functionalized materials. As crystals come from epitaxial growth on surface under gravity, bulk crystals may be formed with suspending in bulk plasmas activated by abundant radical and energetic electron under microgravity.

The present study is dedicated to diagnostics of the void to understand the mechanism of formation of the void.

2. Void and Diagnostics in Complex Plasmas

Formation of the void was simulated with changing electrode configuration on the earth (Fig. 1). Size of the void changed with changing diameter of the powered electrode at bottom. The electrode of 30 mm showed clearly the void.



(a) 60 mm (b) 45 mm

(c) 30 mm (d) 15 mm

Fig. 1 Voids simulated on the earth with changing electrode configuration.

Conversely, measurements of electron temperature and ion density were performed in dust clouds with double-probe method. When tips of the probe were inserted to dust clouds, they were surrounded by sheath formed by Bohm criterion. Thickness of the sheath was less than separation of the tips. The Ion density and electron temperature were estimated form current-voltage characteristics of the probe and regarded as parameters in complex plasmas. The ion density was reduced in the regime of dust particle-rich where was just close to disappearing the plasma or did not change so much comparing with a pristine plasma. The electron temperature was enhanced by injection of dust particles. Electrons attach on the dust particles, which work as a sink of the electron. Therefore electron density goes down, which derives to enhance the electron temperature.

Void formation seems to be related with spatial distribution of plasma potential. The distribution is determined by diffusion process of charges in plasmas. Furthermore dust particles contribute to form the spatial distribution of the potential. Electric field derived from gradient of the potential should be gently varied from the region of plasma production to wall for dust cloud without the void

Acknowledgments

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