【Grant-in-Aid for Specially Promoted Research】

**Science and Engineering**

**Title of Project : Research for new paradigm of transport due to phase space fluctuations in fusion plasma**

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Keyword : fusion plasma, phase space fluctuation, transport

## 【Purpose and Background of the Research】

With the goal of realizing fusion energy as an incentive, research on fusion plasmas has focused on methods to maintain high central temperatures up to 100 million degrees Celsius and the necessary density, and on understanding transport (the relationship between gradient and flux) as important issues. This transport has strong "nonlinearity," "nonlocality" where the amount of heat flux is not determined only by the local temperature gradient, or the existence of "hysteresis" and "nonperiodic oscillation. These discoveries indicate the existence of a complex interaction between "real-space fluctuations", "velocity-space distortions" and "transport" in plasmas, and suggest that "velocity-space distortion fluctuations" are important for understanding "transport".

The purpose of this study is to interrogate transport physics by observing fluctuations of velocity-space distortions in plasma and extending the study of fluctuations from "real space" to "phase space". We aim to obtain knowledge that will lead to a paradigm shift in transport based on the observation of "phase space distortion fluctuations".

## 【Research Methods】

In this project, we will 1) develop a measurement system to detect fluctuations in the velocity and spatial distortions of ions and electrons, 2) experimentally observe high-temperature plasma in a generator, and 3) compare the results with theoretical and simulation results.

(1) Measurement system for velocity-space distortion of ions and electrons

1-1 Fast charge exchange spectroscopy system: We have developed a fast charge exchange spectroscopy system using the charge exchange reaction between a neutral beam and a bulk plasma to measure the ion velocity space distortion from the Maxwell distribution at a fast frequency well above the ion collision time frequency.

1-2 Electron cyclotron emission measurement System: The frequency spread due to the non-Maxwell component of electrons will be measured by a wide frequency band electron cyclotron radiation intensity measurement system with a line of sight that minimizes the frequency spread of radiation due to changes in the magnetic field strength.

1-3 Detection of fast electrons by line ratio spectroscopy: The intensity of emission lines from the plasma depends on the velocity coefficient determined by the excitation cross section of electron impact excitation. By focusing on emission lines from several upper levels with different velocity dependence of the excitation cross section, we measure the high velocity component in the electron velocity distribution function.

(2) High-temperature plasma generation system

LHD and JT-60SA will be used as plasma generators. In the fiscal year 2021-2022, we will demonstrate and verify the measurement of the velocity space fluctuation of ions and electrons in the LHD. After improving the performance of the system by using multiple channels, we will conduct observations using JT-60SA in 2024.

(3) Comparison of experiment and theory

In this research project, we will develop a theoretical model of velocity-space distortion fluctuations, and develop a simulation code that can be compared with experiments and observations.

## 【Expected Research Achievements and Scientific Significance】

The expected result of the research is to obtain "velocity space distortion fluctuations" of ions and electrons in ultra-high temperature plasmas for the first time in the world, simultaneously and at multiple locations, by using a fast charge exchange spectroscopy system and a wide frequency band electron cyclotron emission.

By understanding the nature of the "velocity space distortion fluctuation," we can extend the plasma fluctuation (turbulence), which has been confined to "real space," to "phase space fluctuation," which includes "velocity space. This extension to "phase space" will greatly advance the study of plasma turbulence, which has been treated as fluctuations of three physical quantities (density, temperature, and velocity) assuming a Maxwell distribution, and will open up a new science of "phase space fluctuations" of plasma. The results of this study will also have a significant impact on fusion research and development, such as fusion burning experiments in ITER (International Thermonuclear Experimental Reactor), because they can provide academic guidelines for improving confinement.

## 【Publications Relevant to the Project】


- “Bifurcation phenomena in magnetically confined toroidal plasmas“, K.Ida, Advances in Physics: X Vol.5 1801354 (2020).
- “Abrupt onset of tongue deformation and phase space response of ions in magnetically confined plasmas“, K.Ida et.al., Scientific Reports Vol.6 36217 (2016).


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