Transports in Plasma Multi-Phase Matter System

Organized Session: Nov. 10th, 15:00am - 18:00am (JST)

In a fusion reactor, high-temperature plasma must be maintained at a steady state to ensure a stable power supply. The main heating source is the fusion reaction in the central plasma. A certain fraction of heat reaches the first wall, the divertor plate, causing damage to the device wall material. Fusion power is generated by the fusion reaction of fuel particles, deuterium and tritium, but the burning efficiency is extremely low at a several percent of the fuel supplied. Therefore, fusion reactor systems in steady-state operation require sophisticated control of energy and particle transport.

Thermal energy is converted from kinetic energy of plasma particles to light and electromagnetic waves, which further interact with matter. Depending on their energy states, materials circulating in the system undergo phase transitions to charged particles (plasma), neutral particles (gas), liquids, or solids. The purpose of this unit is to comprehensively understand energy and particle transport across such multiple phase states, including the interactions among the phases, and to establish a new picture of fusion reactor systems.

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In the transport of thermal energy, we focus on the effects of vibrational and rotational states of molecules in the conversion between kinetic energy of charged particles, light and electromagnetic waves via atomic and molecular processes, as well as on the role of thermal instability in relation to the confining magnetic field geometry, on the dynamic response due to the nonlinearity of atomic and molecular processes. Furthermore, by viewing these physics as the interaction between light and matter, and delving into the interaction between the electromagnetic field or momentum of light, the atomic nuclei and bound electrons in matter, we aim to expand our research into areas, such as the formation of organic molecules in space (astrobiology) and plasma biotechnology.

For particle circulation, this is taken as "non-equilibrium cross transport". Non-equilibrium cross transport here is synonymous with the non-equilibrium cross effect, in which multiple gradients are driven and coupled in a general sense, but it also includes the meaning that the flow of circulation with directionality is considered as a non-equilibrium flow (transport), which is then driven by the cross transport. For example, in the case of plasma and neutral particles, the research will be conducted by considering both the control of plasma by neutral particles (micro) and the control of particle circulation by neutral gas (macro), each from a bird's-eye viewpoint.

For the solid materials of the device wall of a fusion reactor, we will analyze the mass transfer phenomena between dissimilar materials such as copper alloy and the metal to be bonded with atomic-level precision, and elucidate the question "Why is a strong joint with very few voids (high continuity) possible? from a microscopic viewpoint. The results obtained in this research have potential for a wide range of engineering applications, including aerospace and electronics fields.

These issues will be addressed through experiments in torus-type and linear magnetic field devices, and through simulations using fluid models, particle and kinetic models, and molecular dynamics methods.

In the invited lectures on the plasma-material interaction in a fusion device, physics in plasma, neutrals, and solid state in the boundary region of nuclear fusion device will addressed along with the latest research results, in order to show how the interaction of various physical processes such as solid state physics, atomic and molecular processes, and plasma transport can help us understand the phenomena observed in the region surrounding fusion devices.

In the invited lecture on light-matter interaction, the lecturer will give the basic physics and properties of light using examples of various light production using synchrotron radiation sources, as well as unresolved research issues in photon science. We will discuss the possibility of new applications of photon science in the field of nuclear fusion, and the interdisciplinary development in the interaction of light with various phase states, plasma, neutral particles, liquid metals, and solid metals in a fusion reactor.

In the invited lecture on astrobiology, the lecturer will introduce the chemical and physical processes that are important in the formation of organic molecules as an origin of life and an emergence of homochirality in the space. Historical background and the latest research results in the field are also given. Based on the lecture, common scientific principles between nuclear fusion science and astrobiology, and interdisciplinary developments of both fields will be discussed.

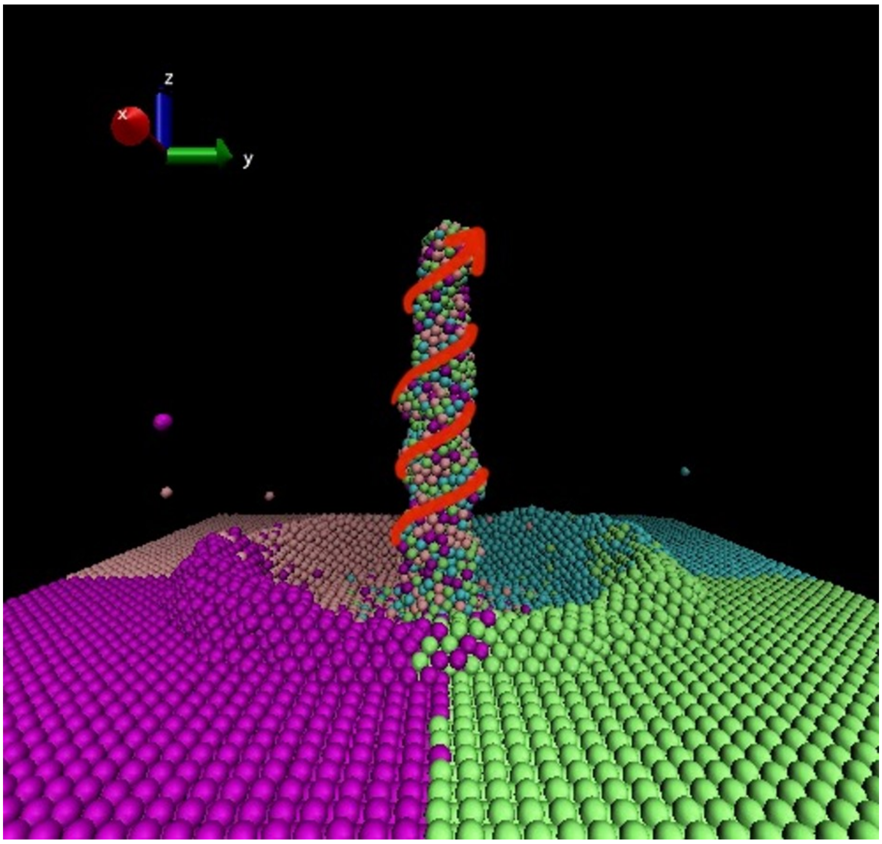

Figure 1. Example of light-matter interaction: Screw-shape protrusion called achiral nano-needle, developed through optical vortex laser irradiation to tantalum. The results have been obtained by a molecular dynamics simulation. (H. Nakamura et al. submitted to JJAP)