Computational Sciences and Engineering at JAERI
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The Japan Atomic Energy Research Institute (JAERI) is a core organization for nuclear related research and continuously develop innovative and advanced concepts for a stable supply of energy, keeping the earth environment and human safety. JAERI also covers various applications in a wide area of nuclear science. The research contained is not only project-oriented research for next generation atomic energy system, such as advanced nuclear fission and fusion reactors, but also basic science backing nuclear energy, such as neutron and advanced photon science, material science, and environmental and health science. Such a nuclear related science involves highly complex technical and academic problems which are characterized by rich phenomena from micro-scale atomic and/or molecular level dynamics to meso-scale material deterioration or macro-scale structural deformation. The key processes or events are often dominated by many strongly coupled effects spanning wide range of spatial and temporal scales or by a mixture of qualitatively different physical/chemical processes. For example, fluid in a fuel rod of a fission reactor and a burning plasma such in ITER (International Thermonuclear Engineering Reactor) are known to be dominated by turbulence that is highly non-linear and non-equilibrium. Due to these facts, the results are hard to predict based only on a conventional experimental and/or theoretical approach, which assume one to one correspondence between cause and result.

With an aid of an exponential growth of massively parallel computer power, large scale simulations have been introduced as a mature partner of experiment and theory as a third research methodology and has become indispensable to develop nuclear energy science. Actually, simulation results are used as the basis of important decisions to guide a long term project like the construction of ITER. In JAERI, large scale codes that are tuned in several 10 tera-flops machine including the Earth Simulator have been developed. Large scale simulation of multi-phase flow in tight-lattice fuel bundles in a Reduced-Moderation Water Reactor (RMWR) is an example [1]. Direct numerical simulation (DNS) and experiments are closely incorporated to verify and validate the code reliability. Turbulence and magneto-hydrodynamic (MHD) processes which crucially regulate the fusion reactor has been extensively studied based on newly developed large scale gyro-kinetic and fluid simulations [2]. The DNS is resolving the
underlying physical mechanisms of the transport barriers and key non-linear processes for the stable sustainment of high performance plasmas, and plays an essential role for guiding the fusion program. Aiming at innovative applications utilizing ultra-short high-power laser-matter interaction, such as short pulse X-ray and neutron sources for microscopy, compact laser accelerator for medical treatment, large-scale kinetic codes which self-consistently solve the interaction in relativistic regime including complicated atomic and molecular processes have been developed. Femto-second micro-scale dynamics in material irradiated by the laser is resolved, leading to guiding principles of various photon applications. First principle quantum dynamics simulation has resolved the mechanism of weakening the material, which may contribute to develop new material preventing the nuclear material from fatigue.

The drastic growth of computer power is now launching a paradigm shift to nuclear energy and related science field. Conversely, the nuclear energy science may offer opportunity to lead the computational science due to their severe social requirements for predicting the possible events. The nature of nuclear energy science is of inter-disciplinary and inter-society character. Therefore, in order for the computational science to be more accepted to the society, not only numerical schemes which can treat the wide dynamical range for precise prediction, but also an advanced computing system which allows for many scientists to join and collaborate with each other. A concept of internet based laboratory and advanced corroboration system based on large scale numerical simulation has also been developed under the joint program between JAERI and major institute and universities.

Reference