§27. Nuclear Fusion Simulation at Exascale

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i) Introduction A fusion plasma which has a extremely high temperature is a collision-less plasma. In such a plasma, there are a lot of phenomena should be described by not fluid approximation but kinetic theory. Especially, the quantitative analysis of anomalous transport which is driven by micro turbulence requires the 5 dimensional gyro kinetic simulation. Therefore in order to understand transport system and prescribe the confinement performance, a number of large scale gyro kinetic simulation code have been developed in all over the world. Since the gyro kinetic simulation includes not only 3 real space variables but also 2 velocity space variables, this simulation requires a lot of computational resources.

Moreover, in fusion plasmas, there are a lot of phenomena that have various temporal and spatial scale. However, it is difficult for a single simulation code to cover whole time and space scale. Thus, for the analysis of such phenomena, it is required that several simulation codes, each code covers a different scale phenomenon, are integrated into a whole and operate self-consistently. This process also requires huge computational resources.

In those reasons, massively parallel and massively large-scale simulation codes are required for the fusion simulation.

The aim of our project is the development and enhancement of the fusion simulation code to be suitable for the coming exa-scale generation. The one of our project theme is to implement GPU acceleration for the fusion simulation code. This project have been advanced on Tsukuba university HA-PACS which implement GPUs as accelerators. The other project is to port simulation codes on several supercomputers. On this purpose, we tried to port GT5D which is a 5 dimensional gyro-kinetic Vlasov simulation code on SR16000.

ii) Porting At first, on SR16000, we tried to port the conservative global gyro-kinetic toroidal full-f 5D Vlasov code, GT5D[1)], which is already performed on JAEA Altix3700Bx2 system, Univ. of Tsukuba HA-PACS system and IFERC-CSC Helios system , into NIFS SR16000 system. GT5D is a code which is hybrid parallelized by MPI and OpenMP.

On NIFS SR16000, however, the porting was failed due to the errors about OpenMP. The code could be executed normally with auto parallelization, but it could not be executed with OpenMP option. The trouble could not be repeated on the other environment such as Helios and HA-PACS.

The reason of the trouble was that LAPACK library of SR16000 was not threads safe library. In present, since the threads safe LAPACK library have been implemented on the machine, the code can run right.

iii) The other work Now our project is in charge of the other works. As mentioned in introduction section, one of them is the GPGPU acceleration of the fusion simulation code on HA-PACS. On this work, in order to speedup of GT5D code which is written in Fortran, we tried to extend the code by using PGI CUDA Fortran. In present status[2)], we achieved 2.57 times speed up by using 4 MPI processes and 4 GPU units per node compared to using 4 MPI processes and 4 CPU threads per node (16 CPU cores). The other work is

Furthermore, the other work have been in progress. On this work, GTC-P code developed in Princeton university is extended by using XcalableMP[3)]. XcalableMP is a directive-based language extension that allows users to easily develop parallel programs for distributed memory systems and to tune performance with minimal and simple notation.

1) Y. Idomura, M. Ida, N. Aiba, S. Tokuda, Computer Physics Communications, **179** (2008)

2) N. Fujita, H. Nuga, T. Boku, Y. Idomura, IPSJ SIG Technical Report, Vol. 2012-HPC-135, No. 41, pp. 1-6, 2012, (in Japanese)

3) Directive-based language eXtension for Scalable and performance-aware Parallel Programming, http://www.xcalablemp.org/