NEUP Nuclear Energy University Programs
U.S. Department of Energy

Development of a Novel Accelerator for Neutron Transport Solution Using the Galerkin Spectral Element Methods

PI: Dean Wang – University of Massachusetts Lowell

Collaborators: Yulong Xing – University of Tennessee; Thomas Downar and Yunlin Xu – University of Michigan; Emily Shemon – Argonne National Laboratory

Program: NEAMS-1

ABSTRACT:

PROTEUS is a high-fidelity neutron transport code developed by the DOE Nuclear Energy Advanced Modeling and Simulation (NEAMS) program at Argonne National Laboratory. An efficient accelerator is one of the key components in PROTEUS, and the Diffusion-Synthetic Acceleration (DSA) acceleration scheme is currently employed. The other commonly used accelerator is the Coarse-Mesh Finite difference (CMFD) type scheme. In this work, we propose to develop a novel accelerator for neutron transport calculations by combining these two techniques using high order accurate Galerkin Spectral Element Methods (SEMs), and implement this accelerator in PROTEUS to verify and validate their performance.

The objective of the proposal is to develop a novel accelerator for neutron transport calculations in PROTEUS based on the SEMs: continuous Galerkin (CG) and discontinuous Galerkin (DG) approximations. SEMs have been proposed and studied for a long time, and recently there have been enormous development and application of these methods in a wide range of engineering problems. As compared with conventional numerical methods such as finite difference or finite volume methods, SEMs often become more efficient than lower order ones because they have a very low numerical diffusion and allow for a coarse-mesh discretization. Their efficient parallel implementation, high computation intensity and efficiency of memory usage make SEMs good candidates for large computation on exascale computers. The CG and DG SEMs will be used to solve the multi-group neutron diffusion equation on the coarse-mesh structure (e.g., pin-size up to assembly-size), which is then coupled with the high-order neutron transport solution. The proposed SEMs can reduce lower frequency components of the error more effectively and efficiently than the DSA methods since they employ the coarse-mesh grid. As compared with the CMFD, one novel feature of the Galerkin SEMs is that they can predict a more realistic flux profile within each coarse-mesh element and therefore they may greatly improve the convergence rate of iteration between the coarse-mesh Galerkin SEM solution and the transport solution. We expect it to lead a great reduction in the number of neutron transport sweeps.

An accurate, efficient SEM may provide a viable acceleration for neutron transport calculations. This work would have a great impact on the neutronics simulation of the DOE NEAMS program and Consortium of Advanced Simulation of Light Water Reactors (CASL) program.