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Whole-volume gyrokinetic simulation of magnetic fusion plasmas with in-situ data processing

Collaborating Researchers

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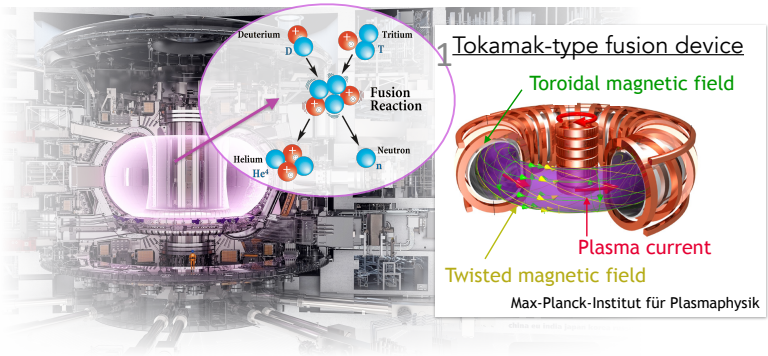
Background (1) Magnetic fusion device

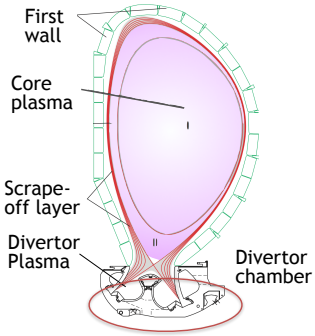


International Thermonuclear Experimental Reactor (ITER)

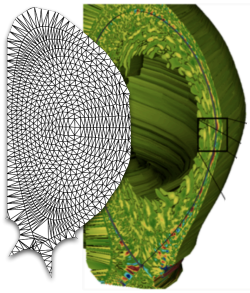
- Nuclear fusion reactions, e.g., D-T reaction, can be a sustainable energy source to meet world-wide energy demands.
- To produce net power from the reactions, we have to confine the fuels with high temperature (> 10^8 ℃) in the reactor.
- Torus-type magnetic configurations with twisting field lines have been proposed to confine the fuels.

Background (2) Whole-volume modeling of fusion device

Cross section of ITER



XGC simulation using unstructured mesh



- Precise prediction of device heat load by whole device kinetic modeling has a critical importance in ITER operation and future reactor designs.
- Robust computational model and large computational resources are required for multi-physics simulation including core and edge regions.
- X-point Gyrokinetic Code (XGC)
  - Field solver using finite element method on unstructured mesh
  - Hybrid use of Lagrange (PIC) and Euler (5D mesh) descriptions for kinetic plasma dynamics

https://hbps.pppl.gov/computing/xgc-1

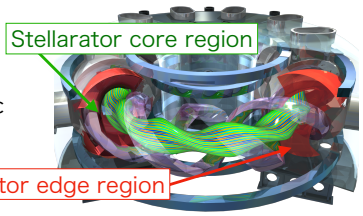
Results in FY 2019

Extension to Stellarator-type fusion devices

- Stellarator
  - Another candidate of magnetic fusion device
  - Stable but complicated 3D (non-axisymmetric) magnetic field created by twisted external coils

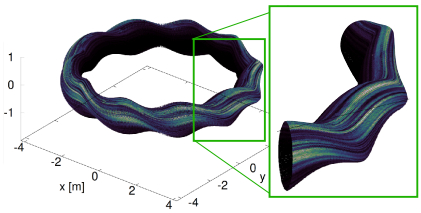
T. Moritaka et al Plasma, 2, 179-200 (2019).

Large Helical Device (LHD)

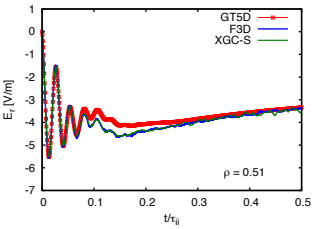


- We have completed the basic development of the extended version of XGC including non-axisymmetric configurations.
- Fundamental plasma physics in the core region of LHD are successfully demonstrated and benchmarked with the other established codes

Microscopic instability on flux surface

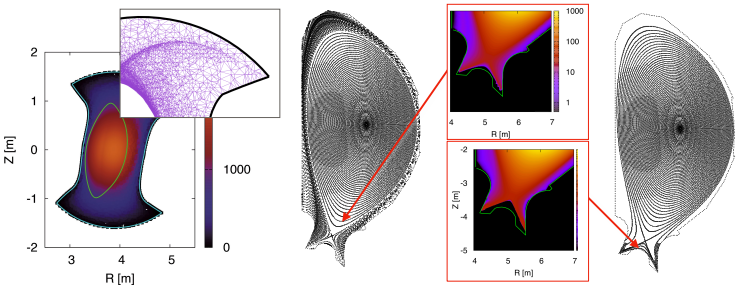


Radial electric field & GAM oscillation



- We have developed a new mesh generation scheme and finite element field solver for stellarator edge region and compared with the conventional scheme using ITER configuration.

Mesh generation by field line tracing　Mesh generation by flux function



Code-code coupling using Adaptive I/O System (ADIOS)

J. Choi, et al. 2018 IEEE 14th International Conference on e-Science

ADIOS

- Middleware for high performance parallel I/O
- "on-the-fly" data aggregation, relocation and reduction among parallel computational, staging and I/O nodes

- ADIOS has been successfully installed on TSUBAME and other US DOE machines.
- We are now working for code-code coupling for effective whole-volume modeling.
- Expensive computation with full-f scheme for edge region occupies GPUs, and dynamically coupled with the core plasma simulation.