FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Software for 3D modelling of plasma-wall interaction and impurity transport

ERO2.0 is a software for simulating the PWI (plasma-wall interaction) in fusion devices, in particular the erosion and material migration. The software has been initially developed at Forschungszentrum Jülich and is strongly embedded in the EUROfusion and international fusion research programme. The particular advantage is the possibility to describe the plasma-wall interaction in a fully three-dimensional (3D) approach and to calculate the impact energies and angles of particles hitting the wall with multiple geometries The simulation results can be used for important predictions concerning reactor availability (due to component lifetime, fuel retention and dust production) but also can find promising applications in plasma propulsion and plasma coating where transport model are needed.

Description of the technology

The plasma-wall interaction is simulated using data provided by binary-collision approximation (BCA) or molecular dynamics (MD) codes, such as sputtering yields and reflection coefficients. The impurity transport is simulated by calculating the trajectories of a test particle ensemble, representing the impurities created either by erosion or external injection, by solving the Fokker-Planck equation. The transport model assumes trace impurity approximation: the plasma background, which is taken as input from other codes, is treated as static and collisions are described by drift and diffusion terms in the Fokker-Planck equation. The software offers a range of synthetic diagnostics, such as wide-angle spectroscopic and infra-red images, for comparison and verification with experimental data.

The software was designed for high-performance computing (HPC) and shows a near-ideal parallel scaling on more than 1000 CPU cores. Together with various optimizations addressing performance and memory management, this allows simulating the entire 3D volume of an ITER or DEMO-sized device. Further optimization by taking advantage of graphic processing units (GPUs) on supercomputers is currently in progress.

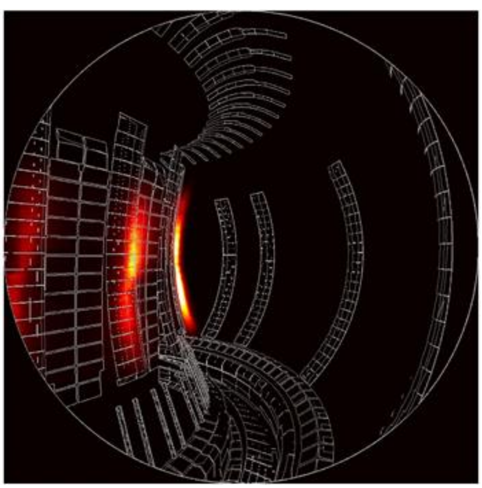

Figure 1 Synthetic beryllium line emission in a JET discharge, simulated with the ERO2.0 software.

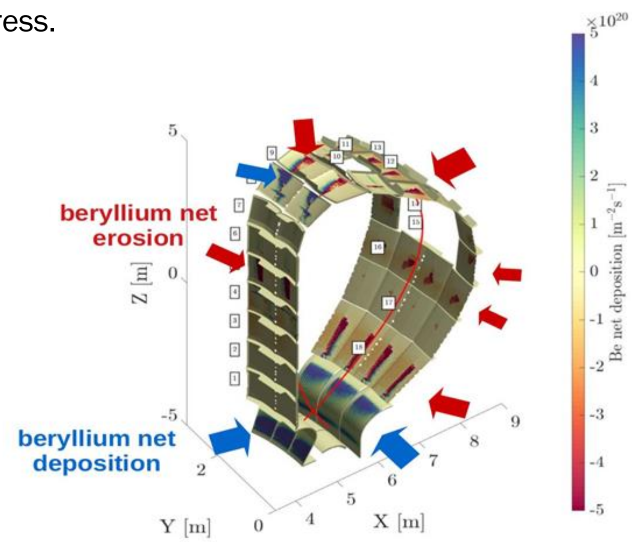

Figure 2 :Net erosion and deposition flux of beryllium in an ITER discharge, simulated with ERO 2.0 software

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Innovation and advantages of the offer

The particular advantage of the software is the possibility to describe the plasma-wall interaction in a fully three-dimensional (3D) approach. Complex and large wall components can be described using technical drawings, with a high resolution of geometric details.

Another advantage is the possibility of a full orbit (FO) resolved description of ion gyration in the magnetic field. Combined with a comprehensive model for the sheath potential, it is thus possible to calculate the impact energies and angles of particles hitting the wall, which is essential for estimating the sputtering yields. Also, effects such as prompt deposition of heavy ions (e.g. tungsten (W)) can be accounted for. On the other hand, for transport sufficiently far away from the surface, the guiding center approximation (GCA) can be used, which gives a speedup of about a factor 10. The software combines the advantages of both FO and GCA descriptions, with an automatic transition between the two schemes performed at a certain distance from the wall.

Non-fusion Applications

This ERO 2.0 code shows promising applications in plasma propulsion and plasma coating where transport model are needed.

The technology host offers advanced know-how with development of scientific codes, performing simulations/modelling/analysis, and high-performance computing on large-scale supercomputers.

EUROfusion Heritage

The technology development was motivated by the gap in HPC software capable of fully-3D simulations of large and complex fusion devices. The software is further developed within EUROfusion to enable description of additional physical processes or improving existing ones, as well as to embed the software in the integrated modelling efforts of EUROfusion.

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