Press release

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Otto Hahn Medal: This work will soon make ITER plasmas predictable

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Wladimir Zholobenko's dissertation enables realistic simulations of turbulence at the edge of nuclear fusion reactors built according to the tokamak principle for the first time. For this work, the physicist from the Max Planck Institute for Plasma Physics (IPP) is being awarded the Otto Hahn Medal today. In the next step, Dr. Zholobenko will adapt the simulation code for the international research reactor ITER.

The phenomenon of turbulence in fusion plasmas plays a crucial role in the development of nuclear fusion power plants. Without turbulence, energy could be much better confined within the magnetically trapped plasma. On the other hand, turbulence is helpful, for example, in flushing impurities out of the plasma. Moreover, thermal energy must escape from the plasma at some point. If there were no turbulence at all, it would escape in a narrow spatial area. The stress on the wall material there would be so great that it would melt. Therefore, a certain amount of turbulence is desirable – even if it worsens the energy containment. Only turbulence makes it possible to dissipate heat in a controlled and distributed manner to the most heat-resistant part of the wall, i.e., the divertor.

How turbulence can be controlled and optimally used is being investigated by researchers worldwide. Wladimir Zholobenko has now succeeded in predicting this turbulence behaviour with simulations. For this, he will be awarded the Otto Hahn Medal at the annual meeting of the Max Planck Society in Göttingen today, 21 June 2023. The prize is endowed with 7,500 euros.

Calculation times of three months for three milliseconds of turbulence progression

Dr. Zholobenko used the simulation code GRILLIX developed at IPP, which calculates turbulence specifically at the plasma edge. Within his doctoral thesis in the IPP division of tokamak theory, he further developed the code into the first realistic turbulence model that also takes into account the interaction of the charged particles in the plasma with the neutral gas. The latter forms outside the plasma, but also mixes with it in the edge layers. With the improved code, it is now possible to follow the temporal and spatial propagation of turbulence in tokamaks with divertors. Dr. Zholobenko adapted his model for fusion facilities with the size and design of ASDEX Upgrade in Garching. "During development, I constantly compared my calculations with experimental data from ASDEX Upgrade and was thus able to continuously improve the code," Dr. Zholobenko explained. "Now it is so realistic that it can be used to design experiments."

An enormous amount of computation was required to achieve this result. Dr. Zholobenko used the most powerful high-performance computers in Europe - including those at the Max Planck Computing and Data Facility (MPCDF) in Garching and Marconi Fusion in Italy. "To simulate turbulence processes within three milliseconds, these facilities were busy for three months," Dr. Zholobenko said. And even this period was only possible at all because the code was continuously optimised.

To simulate ITER, intermediate steps are needed

In the meantime, Dr. Zholobenko is working as a research associate at IPP and, as a member of the GRILLIX team, is pursuing his next goal: he wants to improve the performance and accuracy of GRILLIX to such an extent that it can also realistically predict turbulence in ITER. The experimental reactor is currently being built in Cadarache in the south of France and is intended to generate ten times as much fusion power as the thermal power that needs to be supplied. It is thus an important milestone on the way to a commercial fusion power plant. To achieve this, ITER will operate with a plasma volume more than 60 times that of ASDEX Upgrade. "Although we have continued to improve GRILLIX since I finished my PhD, it would currently take a year to calculate individual results for ITER," Dr. Zholobenko explained. "Moreover, it is to be expected that the physical phenomena would also change with such a jump in size."

Therefore, there are several intermediate steps (Wladimir Zholobenko was awarded a EUROfusion Researcher Grant in 2022 for funding this work): GRILLIX will first be further optimised on ASDEX Upgrade for scenarios that seem best suited for a reactor. The code will also be tested on the JET tokamak in the UK. This has only six times the plasma volume of ASDEX Upgrade. Extensive data exists from the experiments at JET over the past almost four decades, which can be compared with calculations. At the same time, the

GRILLIX team is rewriting large parts of the code to improve performance: "We still have to become three to five times faster to get to acceptable computing times for ITER as well."

Link to the dissertation: https://mediatum.ub.tum.de/1624673

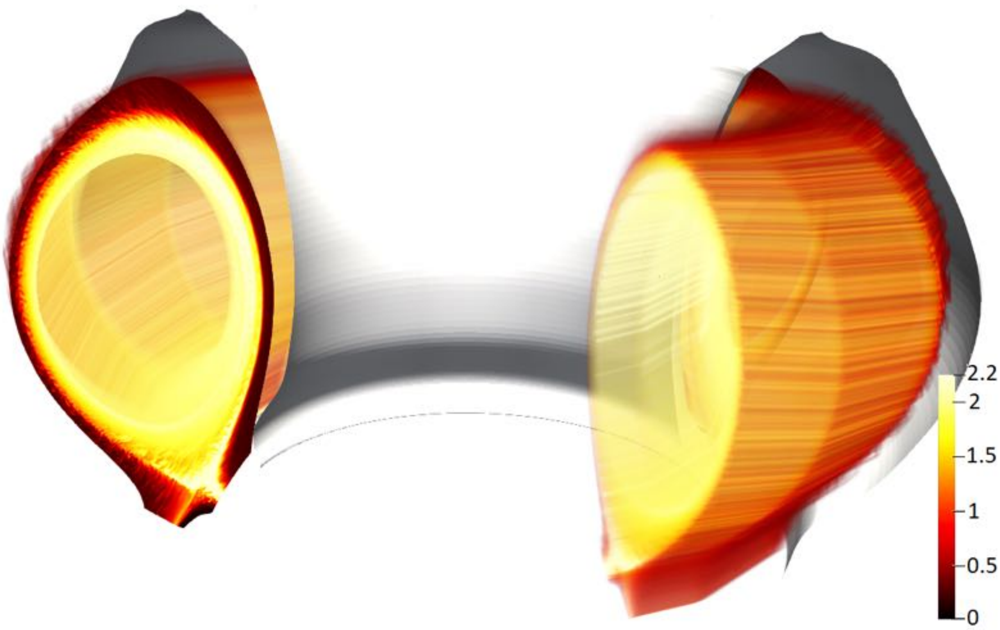

Figure 1: *Visualisation of the turbulence simulation with GRILLIX. The colour scale represents the plasma density in units [10^{19} particles per cubic metre. Other codes are used for the calculation in the plasma core, so the area here is empty. (Credit: MPI for Plasma Physics / W. Zholobenko*).

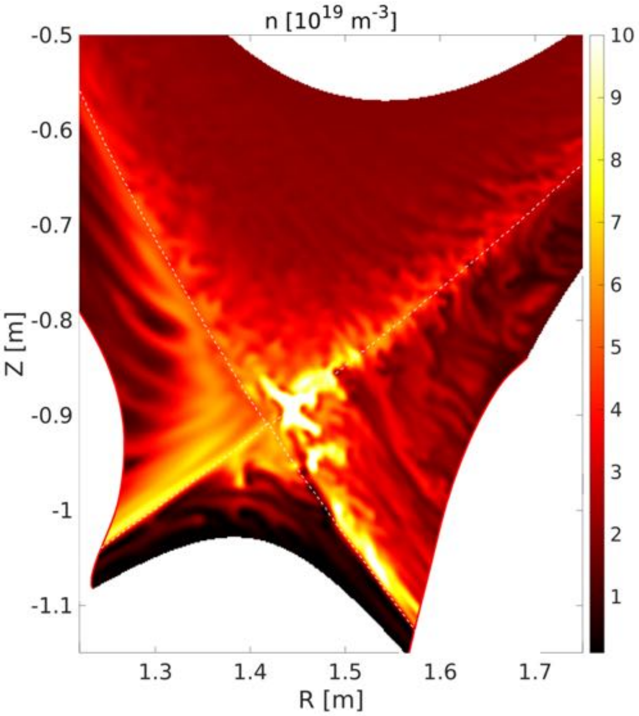

Figure 2: *Visualisation of the turbulence simulation near the divertor (cross-section through the vacuum vessel). The colour scale represents the plasma density in units [10^{19} particles per cubic metre]. The dashed lines (separatrix) mark the edge of the confined plasma (top), called the private flux region (bottom) and the scrape-off layer (right and left). The X-point is where all regions meet, i.e., at the lower tip of the confined plasma. The magnetic field around the X-point is strongly deformed. GRILLIX is one of very few codes that can efficiently simulate turbulence here as well. (Credit: MPI for Plasma Physics / W. Zholobenko).*

Figure 3: *IPP scientist Wladimir Zholobenko is being honoured with the Otto Hahn Medal. The Max Planck Society has awarded the prize annually since 1978 to a maximum of 30 young researchers for outstanding dissertations. (Credit: MPI for Plasma Physics / Frank Fleschner)*

About Max Planck Institute for Plasma Physics

The research conducted at the Max Planck Institute for Plasma Physics (IPP) in Germany (locations: Garching near Munich and Greifswald) is researching the physical foundations for a fusion power plant that will generate energy from the fusion of light atomic nuclei. IPP's research is part of the European fusion programme. With its workforce of approximately 1,100, IPP is one of the largest fusion research centres in Europe.

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