stellarator news

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Report from the 2019 ISHW Coordinated Working Group Meeting (September 24, 2019)

Overview

Following a successful Coordinated Working Group Meeting (CWGM) in March 2019, a second meeting was held to report on progress since that meeting. This took place as an evening session during the 2019 International Stellarator and Heliotron Workshop (ISHW) held in Madison, Wisconsin, USA. Reports from the session organizers of the previous meeting were presented, detailing status and progress since the meeting in March. A special discussion was held to explore the role of stellarators in the International Tokamak Physics Activity (ITPA), led by Carlos Hidalgo. Finally, the location of the next meeting of the CWGM was announced: Kyoto University, Japan.

Divertor and Edge Physics in Stellarators (M. Jakubowski)

The ongoing comparison between helical (the Large Helical Device, LHD) and island divertors (Wendelstein 7-X, W7-X) is yielding preliminary results. See Figs. 1 and 2 to compare these two geometries. Joint experiments exploring detachment, the role of particle drifts, the effect of finite beta, and migration of material are all aiding to better highlight commonalities and differences among divertors. The role of low- vs high-recycling impurities in detached divertor states has been explored in both devices. The injection of low-recycling impurities results in edge localized radiative behavior, while injection of high-recycling impurities has a more global effect on radiative cooling of the plasma. Stable detachment is found in both devices; it appears that the helical divertor requires perturbative fields to achieve this state, but this is not necessary for the island divertor. In both devices drift effects play a role in the highly three-dimensional (3D) structure of the divertor footprints. Experimental evidence suggests that plasma parameters also play a significant role in the divertor footprints of both devices. The lack of a high-recycling regime in LHD is attributed to counterflows on neighboring surfaces. As the comparison proceeds, each individual task will have a corresponding task coordinator. At the moment, Masahiro Kobayashi will coordinate seeding and detachment experiments between W7-X and LHD, and Ken Hammond will compare edge drifts between LHD and W7-X.

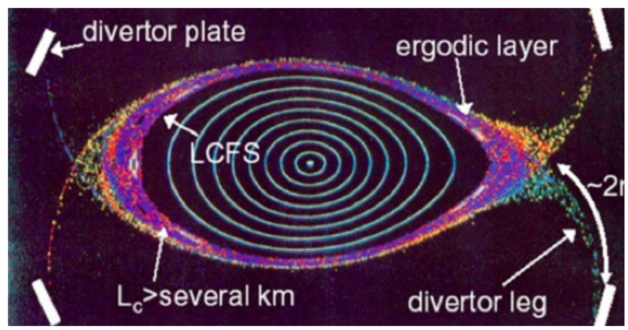

Fig. 1. Poincaré plot showing the LHD flux surfaces, ergodic layer, and divertor legs. Source: Y. Feng et al., Nucl. Fusion **49** (2009) 095002.

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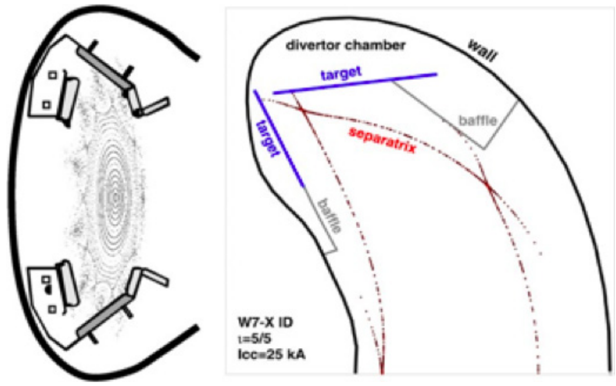

Fig. 2. Poincaré plots of the Wendelstein 7-X line of island divertors. Source: IPP-Greifswald.

Scaling and Operational Limits (E. Ascasibar on behalf of G. Fuchert)

Concerning scalings and operational limits, in LHD neutral beam injection (NBI)-heated plasmas with mixed H,D fueling have been studied and follow the mass-dependent energy confinement time scaling presented at the last CWGM. Helium plasmas are a work in progress. For W7-X, a paper summarizing the operational boundaries of the first divertor campaign is in preparation. Investigations of MHD-related instabilities are making progress. Two possible instabilities are being discussed in an upcoming paper. Further work will clarify how to distinguish these experimentally. Finally, initial studies have been started at the tokamak ASDEX Upgrade in order to compare the density limit of stellarators and tokamaks.

3D Fast Ion Physics (S. Lazerson)

A activity has begun to create a stellarator fast-ion database. This database will place discharges in LHD, TJ-II, Heliotron-J, and W7-X in the context of existing reactor designs. Such a database will allow us to better understand the role of fast ions in a reactor system and allow cross-machine comparisons to proceed. A set of machine parameters has been assembled, and collection of stereotypical discharge parameters from multiple machines has begun. Additional data from discontinued devices (e.g., ATF) is also being sought. A collaboration on the neutral beam modeling of HSX was also discussed. Finally, it was reported that through participation in the previous CWGM meeting a collaboration between the St. Petersburg Polytechnic University and the National Institute for Fusion Science (NIFS) has begun. This highlights the value of the CWGM in connecting researchers globally and broadening our scientific endeavors.

Fueling Pellets and Impurity Injection (N. Tamura)

Comparative studies of pellet fueling and impurity injection are being prepared for upcoming campaigns on multiple devices. Simulations with the HPI-2 pellet injection code have been performed for W7-X, TJ-II, and Heliotron-J. Benchmarking analysis is under way with special attention being applied to Heliotron-J. Explorations of the use of pellets to exceed the Sudo density limit are being conducted on LHD, TJ-II, and Heliotron-J. Additional data from TJ-II and Heliotron-J are needed to complete the analysis. Development of more detailed TESPEL (hydrocarbon pellet) ablation models is being supported by data from LHD, W7-X, and TJ-II. Isotope studies examining ratios of deuterium to hydrogen have been conducted in LHD using pellet injection. This work is being expanded to other device.

3D Turbulence (M. Nakata)

Studies to validate models of turbulent transport, zonal flows, radial electric fields, and fluctuations are being supported by interdevice comparative studies. Optimization of stellarators for turbulent transport has been identified as an emerging topic in this group. Such work will be highlighted at future meetings of the CWGM. Work is moving forward on formulating a stellarator base case turbulent transport simulation. This base case will be the analogue for the cyclone base case, which was previously developed for turbulence simulations. General features of this benchmark have been identified, and responsible persons are being identified for the majority of stellarator turbulence codes.

Impurity Transport (N. Pablant)

Work continues on five joint tasks in the impurity transport group. Assessment of the role of impurity charge number on impurity transport is ongoing as TESPEL data from W7-X is being processed. This activity will be extended through “super-multiple” TESPEL injection on LHD in the upcoming campaign. Radially global multi-species simulations are informing investigations into the LHD impurity hole. These simulations are being combined with analysis of impurity transport to further clarify the role of the neoclassical radial electric field. Simulations with the SFINCS, EUTERPE, FORTEC-3D, and KNOSOS codes including the effect of potential variation on a flux surface have been conducted. These simulations are awaiting experimental data to validate their models. Work is ongoing to incorporate the STRAHL impurity transport code into a W7-X data analysis workflow. A boron dropper installed on LHD will provide useful data to the impurity transport group in the upcoming experimental campaign. Initial data from W7-X is suggesting that impurity transport is being dominated by turbulent processes. Work is under way to model and assess these plasmas.

Conclusions

The sessions highlighted ongoing activities in the CWGM and continued to track progress on various activities. A general topic discussed among groups was the need for a clear link to the ITPA. Each group was tasked with identifying a representative from the CWGM who also participates in related ITPA activities. It was also suggested that the next meeting of the CWGM place a focus on contributions to upcoming IAEA Fusion Energy Conference.

New Joint German-US Stellarator Project

The Max Planck Institute for Plasma Physics (IPP) in Greifswald and the University of Wisconsin-Madison in the United States have founded a joint research project to investigate the power exhaust from a hot stellarator plasma. The Helmholtz International Laboratory for Optimized Advanced Divertors in Stellarators (HILOADS), in which Forschungszentrum Jülich and Auburn University in Alabama also participate, is financially supported by the Helmholtz Association of German Research Centres.

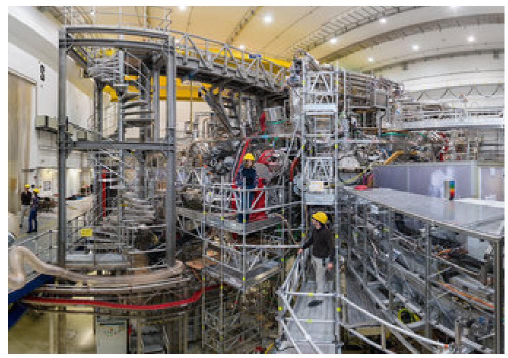

Fig. 1. The Wendelstein 7-X stellarator at Greifswald. Source: IPP, Volker Steger.

Fusion systems of the stellarator type promise high-performance plasmas in continuous operation. Accordingly, heat and particles from the hot plasma permanently stress the vessel walls. It is the task of the so-called divertor—a system of specially equipped baffle plates to which the particles from the edge of the plasma are magnetically directed—to regulate the interaction between plasma and wall. The structure of the magnetic field and the choice of material for the plates determine how well the divertor can perform this task and how well the plasma can be thermally insulated. The divertor design for new stellarators is therefore highly demanding in terms of both plasma physics and technology and requires extensive experimental and theoretical investigations.

To address these challenges, IPP in Greifswald and the University of Wisconsin-Madison have founded HILOADS. HILOADS offers a framework to intensify the successful cooperation of the University of Wisconsin-Madison as the central institution with IPP in Greifswald, Forschungszentrum Jülich, and other American universities. The scientists involved will optimize and coordinate divertor designs, materials, and plasma confinement.

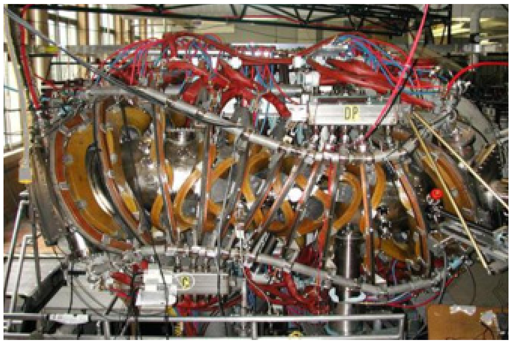

Fig. 2. The Helical Symmetric Experiment (HSX) at Madison, Wisconsin. Source: University of Wisconsin-Madison.

For the needed experiments, both Wendelstein 7-X (Fig. 1) in Greifswald, the world's largest stellarator, and the much smaller but very flexible HSX (Helical Symmetric Experiment) in Madison (Fig. 2) are available. The two devices differ not only in size, but also in their completely different concepts for the divertor and for optimizing plasma confinement. The small CTH (Compact Toroidal Hybrid) device at Auburn University (Auburn, Alabama) is another resource. In addition to these three stellarators, two linear plasma systems will be used for investigations of materials and wall conditioning, as well as for the development of measuring instruments: PSI-2 in Jülich and MARIA in Madison. Equipped in this way, HILOADS will promote the development of the next generation of optimized stellarators and, in particular, support the development of a concept for a new medium-sized stellarator experiment in Madison.

With the funding program of *Helmholtz International Labs*, the Helmholtz Association, to which the IPP is affiliated as an associated institute, aims to expand international cooperation with excellent research institutions and create visible research activities of the Association at locations abroad. The Helmholtz Association will provide 24 percent of the €6.125 million estimated for HILOADS over the next five years. The universities in Madison and Auburn will contribute 35 and 15 percent, respectively; IPP and Forschungszentrum Jülich, 18 and 8 percent, respectively. HILOADS is scheduled to start in spring 2020.

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