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## 14th Coordinated Working Group Meeting Warsaw, 17–19 June 2015

The 14th Coordinated Working Group Meeting (CWGM14) was held 17–19 June 2015 at the Golden Tulip Warsaw Center, hosted by the Institute of Plasma Physics and Laser Microfusion (IPPLM, <http://www.ipplm.pl/en/>). This was the first CWGM in Poland, reflecting the expanded coordinated collaborations based on EUROfusion, Mission 8: Stellarator. The IPPLM has been especially known for its cutting-edge diagnostics development. Thus, a dedicated diagnostics session was held at this meeting to stimulate international collaborations on diagnostics development and applications. Impurity transport was the subject of the standing session, as suggested and agreed to at the Stellarator-Heliotron Strategy Workshop, Nagoya, March 2015 (see *Stellarator News*, No. 147, April 2015). C. Hidalgo (CIEMAT) provided a kick-off talk via remote video to raise critical issues in impurity transport.

Session summaries and formulated action lists are presented here. The presentation materials will be posted on the EUROfusion wiki page, eventually.

### Session summaries

#### *Strategic Collaboration (A. Dinklage / F. Warmer)*

- ⇒ The EUROfusion Mission 8 activities focus on the exploitation of Wendelstein 7-X (W7-X) and actions to prepare a physics basis for a HELIAS Fusion Power Plant (FPP).
- ⇒ International collaborations within the work package objectives can be supported by missions (mobility) and resources (within the WPS1 activities). The IEA Stellarator-Heliotron Implementing Agreement has proven to be the right frame for joint actions.
- ⇒ The CWGM is proposed as a framework to prepare further input to strategic discussions focused on reactor issues such as:

- Common systems assessments
- Clarification of “road map” targets
- ⇒ Large Helical Device (LHD) (M. Yokoyama) is setting up TASK3D-a to provide confinement and profile data on a regular basis.
- ⇒ For the task of updating the International Stellarator/Heliotron Profile Database with HSX data,
- ⇒ An interim responsible officer has been identified: F. Warmer (IPP-Greifswald),  
[\[https://ishpdb.ipp-hgw.mpg.de/ISHPDB/public/\]](https://ishpdb.ipp-hgw.mpg.de/ISHPDB/public/).

#### *Alfvén Eigenmodes (AEs) and Energetic Particles (S. Yamamoto)*

Discussion focussed on aspects of AEs that we should investigate to prepare for a stellarator-heliotron DEMO.

- ⇒ Effect of ECH/ECCD on AEs for control of AEs:
  - TJ-II: “Impact of ECRH on the NBI-driven Alfvén activity in the TJ-II stellarator: experiments and data analysis” by Á. Cappa.
  - Heliotron J: “External Control of Energetic-ion-driven MHD instabilities by ECH/ECCD in Heliotron J Plasmas” by S. Yamamoto.
- ⇒ Fast ion generation by ICRF: “Fast-ion generation with ICRF at Wendelstein 7-X in high-density regimes” by Y. Kazakov.

#### *Experiment (S. Masuzaki)*

- ⇒ The status of Uragan 2M was presented by V. Moi-

## In this issue . . .

### 14th Coordinated Working Group Meeting Warsaw, 17–19 June 2015

The 14th CWGM was hosted by the Institute of Plasma Physics and Laser Microfusion. Long-term and short-term joint tasks were coordinated and assigned. .... 1

### This is the 150th issue of *Stellarator News*

The Editor wishes to thank the community. .... 4

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seenko. A dedicated RF conditioning study has been conducted. A stellarator with an embedded mirror configuration has been examined both experimentally and numerically. This stellarator-mirror configuration is envisioned as the basis for a fusion-fission hybrid device.

- ⇒ Status of the development of 3D fluid code “Findif” for edge plasma modeling was presented by G. Pelka. Findif was applied to modeling the edge plasma in TEXTOR DED and W7-X. Benchmarking is necessary.
- ⇒ S. Kumar presented a study of flows and electric fields ( $E_r$ ) in HSX measured using Pfirsch-Schlüter flows and motional Stark effect (MSE) polarimetry. The measured  $E_r$  was compared to the numerical simulation data using the PENTA code. It is larger than the numerically expected values near the core. Benchmarking the  $E_r$  calculated by SFINCS and FORTEC-3D to the PENTA results is under way.

#### *Impurities and Transport (N. Tamura)*

- ⇒ Kick-off for the new standing session: C. Hidalgo brought up important issues related to impurity control. The question to be answered is: “What are the optimum profiles for achieving high fusion gain without impurity accumulation (high and low Z) in stellarator-heliotron plasmas?”
- ⇒ LHD: The existence of an impurity transport boundary layer inside the last closed flux surface (LCFS) is suggested, which alters the accumulation of core-born impurities.
- ⇒ HSX: Laser blow-off (LBO) and a system of 5 photodiode arrays are ready for an impurity transport study in HSX; collaborations (e.g., LBO system, STRAHL analysis) are highly welcome.
- ⇒ Uragan 2M/Uragan 3M: U-2M suffers from impurities from the wall, and U-3M indicated the possibility of controlling impurities using RF heating.

#### *Theory/Simulation*

- ⇒ The importance of the parallel inertia force, which can cause impurity density variations in stellarator/heliotron plasmas, was highlighted.
- ⇒ The neoclassical-based impurity transport problem, such as potential variations on a flux surface, etc., is being numerically (EUTERPE, FORTEC-3D, ...) analyzed.

#### *Diagnostics (M. Kubkowska)*

- ⇒ W7-X: Limiter diagnostics including visible cameras and a low-resolution near-infrared (NIR) camera for plasma monitoring, wall inspection and thermography; a higher-resolution camera for scrape-off layer

physics; a set of Langmuir probes; a pulse height analysis (PHA) system; and a light impurities monitor (for carbon and oxygen) were presented.

- ⇒ LHD: The following diagnostics systems were described:
  - Density and temperature, radial electric field and rotational transform profiles: YAG Thomson scattering, far infrared (FIR) and CO<sub>2</sub> interferometer, charge exchange spectroscopy (CXS), heavy ion beam probe (HIBP), MSE
  - Impurity: Infrared (IR) imaging bolometer, vacuum-ultraviolet (VUV) spectrometer, extreme-ultraviolet (EUV) spectrometer, CXS.
  - Turbulence: HIBP, phase contrast imaging (PCI), microwave frequency comb reflectometer, correlation electron cyclotron emission (CECE), beam emission spectroscopy (BES).
- ⇒ Heliotron J: Thomson scattering, CXS based on Czerny-Turner spectrometer, Langmuir probe, BES, 60-channel soft X-ray system, and fast-ion diagnostics were listed and described.
  - In the PHA system for W7-X, Si drift detectors will be used at the beginning. SiC or other detectors could be considered as a candidate for the deuterium campaign. Tests at LHD during the deuterium campaign may be possible.
- ⇒ Application of gas electron multiplier (GEM) detectors for soft X-ray measurements with energy discrimination capability was presented. This kind of detector could be interesting for W7-X diagnostics.
- ⇒ Scintillators for gamma-ray diagnostics were presented in detail.

#### *Fueling and Particle Transport (K. McCarthy)*

- ⇒ 4 talks showing growing collaborations on pellet injection experiments and particle transport issues involving LHD, W7-X, and TJ-II.
- ⇒ Review of the need to find means of avoiding hollow density profiles in stellarators that can lead to discharge termination (core pellet fueling, role of radial electric field, and transport need to be considered in detail).
- ⇒ Reports on pellet injection systems and recent upgrades on LHD and TJ-II, with capabilities and limitations of each system.
- ⇒ Reports on pellet fueling experiments conducted on LHD and TJ-II that will provide input for presentation at the coming International Stellarator/Heliotron Workshop (ISHW).
- ⇒ Reports on data analysis by S. Cats and J.-L. Velasco (somewhat preliminary) should be completed by ISHW.
- ⇒ Discussion on pellet interaction in different plasmas and on additional data that should be considered for

analysis (plasma pressure in TJ-II, neutral beam particles, etc.).

## Action List

### *Strategic Collaboration (A. Dinklage / F. Warmer)*

- ⇒ Research issues for  $\tau_E$  documentation
  - Global scaling of HSX data
  - Renormalization factor,  $f_{\text{ren}}$  in the ISS04 (International Scaling) for updated LHD and HSX data.
  - Impact of plasma size (minor radius).
  - TJ-II NBI shot data to be provided.
  - Joint paper on configuration effects?
- ⇒ Update of profile database for code validation.

### *Alfvén Eigenmodes and Energetic Particles (S. Yamamoto)*

Short term:

- ⇒ Effect of ECH/ECCD on AEs for control of AEs: LHD, TJ-II, Heliotron J.
- ⇒ We should apply the same method, targeting similar modes to obtain unified knowledge.
- ⇒ Link to ITPA-EP (energetic particles) group, by S. Yamamoto and K. Nagaoka.

Long term:

- ⇒ Identification and parameter dependence of observed modes (excited by ions):
  - High magnetic shear: LHD [EGAM, BAE, EPM, GAE/RSAE, TAE, HAE]: K. Ogawa, K. Nagaoka.
  - Low magnetic shear, low iota, Heliotron J [BAE?, EPM, GAE]: S. Yamamoto.
  - Low magnetic shear, high iota, TJ-II [GAE, HAE]: Á. Cappa, A.V. Melnikov, B. J. Sun.
- ⇒ Loss mechanism of fast ions caused by AEs using lost-ion probe (LIP)/fast-ion loss detector (FILD).
- ⇒ LHD, CHS, Heliotron J (currently Japanese domestic collaboration/joint experiment): S. Yamamoto, K. Ogawa.
- ⇒ Prediction of AEs and their effect on particles in a stellarator/heliotron DEMO.
- ⇒ Experiment: Parameter dependence of observed AEs such as an observation region consisting of dimensionless parameters.
- ⇒ Simulation: Development of numerical codes for the prediction of AEs in the DEMO (need collaboration with D. A. Spong, Y. Todo, A. Könies, and others).

### *Impurities and Transport (N. Tamura)*

Short term

- ⇒ Experiment: Formulation of joint experiments
  - Resurvey and recharacterization of heating effects on impurity accumulation. (LHD, W7-X, TJ-II, Heliotron J, HSX, Uragan-2M/3M).
  - Turbulence characterization focusing on impurity transport (LHD, W7-X, TJ-II, Heliotron J, HSX).
- ⇒ Theory/simulation: Feasibility study of a joint paper regarding non-uniform potential and density on flux surface for IAEA-FEC2016 (Kyoto).

Long term

- ⇒ Experiment: Acquisition of an optimized heating scheme (power, deposition location) for the suppression of impurity accumulation.
- ⇒ Ensuring compatibility between a power exhaust scenario (detachment) and an impurity handling scenario.
- ⇒ Theory/simulation: Strategy for impurity code validation (improvement in prediction accuracy).
- ⇒ Production of an optimum profile from the viewpoint of impurity transport.

### *Fueling and Particle Transport (K. McCarthy)*

- ⇒ Perform simultaneous pellet/impurity injection experiments to determine how fueled particle/impurity confinement might be related.
- ⇒ For ISHW presentation, K. McCarthy will need to know the internal deadline of the LHD Experiment Group and also need to consider the EUROfusion deadline.
- ⇒ Consider possibility of a joint paper on pellet injection comparisons on LHD and TJ-II (after ISHW).

## Acknowledgements

We sincerely appreciate all the efforts made by the local organizers (IPPLM). The 14th CWGM was financially supported by the Polish Ministry of Science and Higher Education within the framework of the National Contact Point Euratom-Fusion located in IPPLM. It was also supported by the National Institute for Fusion Science and the National Institutes of Natural Sciences under the project, “Promotion of the International Collaborative Research Network Formation.” The participation of Arturo Alonso, Andreas Dinklage, and Jose-Luis Velásco was supported by EUROfusion. This work has been partly carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014–2018 under grant agreement 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Agata Czarnecka (IPPLM) and Arturo Alonso (CIEMAT) on behalf of all participants in the 14th CWGM



Participants attending the 14th Coordinated Working Group Meeting held in Warsaw, Poland 17–19 June 2015.

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## Wendelstein 7-X article in Science News

<http://news.sciencemag.org/physics/2015/10/feature-bizarre-reactor-might-save-nuclear-fusion>

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## This is the 150th issue of Stellarator News

This is the 150th issue of *Stellarator News* (SN). The purpose of SN has always been twofold:

- ⇒ To offer a fast track for the publication of results in stellarator/heliotron experiment, theory, engineering, and even speculation.
- ⇒ To help coordinate the activities of the stellarator community. The CWGM meeting report in this issue is an excellent example of this coordination aspect.

I want to thank the many contributors to SN, some of whom (including myself) have retired over the intervening years. I encourage any reader of SN to send contributions to me.

A special thanks must go to my incredible technical editor Margaret (Bonnie) Nestor who has edited every issue of SN. After I piece together the issue and fix obvious problems, Bonnie works her magic. Bonnie used to edit Fusion Energy Division publications, and is now Assistant to the ORNL Laboratory Director, Thom Mason. Bonnie's editing of your paper into correct, concise, and clear English is a special advantage of contributing to SN!

Again thank you Stellarator Community for your help over the years.

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