USBPO U.S. BURNING PLASMA ORGANIZATION

eNews

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CONTENTS

Dear Burning Plasma Aficionados:

This newsletter provides a short update on U.S. Burning Plasma Organization activities. E-News is also available online at http://burningplasma.org/enews.html Comments on articles in the newsletter may be sent to the Editor (Tom Rognlien trognlien@llnl.gov) or Assistant Editor (Rita Wilkinson ritaw@mail.utexas.edu).

Thank you for your interest in Burning Plasma research in the U.S.!

Director's Corner by Jim Van Dam

Planning for ITPA Joint Experiments

For the past seven years, the International Tokamak Physics Activity (ITPA) has served the international fusion community by coordinating joint experiments that are carried out on two or more experimental facilities. The most recent such meeting to coordinate this schedule of international joint experiments—officially called the Eighth IEA Large Tokamak Workshop (W71) on "Implementation of the ITPA Coordinated Research Recommendations"—was recently held December 15 and 16, 2009, in Daejeon, Korea, hosted by the National Fusion Research Institute. A total of 25 participants attended from the various ITER Member countries. Participants from the US were Stan Kaye, Bruce Lipschultz (by videoconference), and Ted Strait, representing the Transport, DivSOL, and MHD Stability topical groups, respectively; facility representatives Rich Hawryluk (NSTX), Earl Marmar (Alcator C-Mod), and Tony Taylor (DIII-D); and Ron Stambaugh (ITPA Chair), Erol Oktay, and yours truly from the ITPA Coordinating Committee.

Presentations were given from each of the seven ITPA topical groups describing the progress on last year's joint experiments, specifying which ones to close out or continue, and proposing new joint experiments to be added. Then, facility representatives presented brief status reports covering 12 experimental facilities around the world. Finally, there was a general discussion (characterized by Stambaugh as an "auction") of the proposed roster of joint experiments for 2010, with each facility indicating its interest in the various proposed experiments. The result was a giant spreadsheet. Typically, the ITPA has 60-70 joint experiments on the books each

Participants at the 8th IEA/ITPA Joint Experiments Workshop in Daejeon, Korea (photo courtesy of NFRI)

year. This year, approximately 15% of the experiments were marked as being completed. Only nine new joint experiments were proposed, compared to 23 last year—likely due to the fact that three of the world's large facilities (JET, DIII-D, and MAST) will not operate for much of this year to install upgrades. The ITPA also scheduled half a dozen so-called Joint Activities, in which theory/modeling/simulation is strongly involved. This part of the meeting concluded with a discussion of data base access policies.

The agenda for the Joint Experiments Workshop as well as the topical group presentations, the facility presentations, and the joint experiments master list are all posted on the workshop web site at http://ieaw71.nfri.re.kr/html/agenda.htm.

Immediately after the conclusion of the workshop, the meeting segued into an extraordinary executive committee meeting for the International Energy Agency (IEA) Large Tokamak Agreement. It was announced that Korea has joined the Large Tokamak Agreement. Also, the plan to combine the Large Tokamak Agreement and the Poloidal Divertor Agreement into a single International Agreement for Tokamak Activities is moving forward.

The next Joint Experiments Workshop will be hosted by Japan in mid-December 2010. In the spirit of "joint experiments," the participants agreed to consider holding this meeting by videoconference, with all US participants gathering in one location and likewise for the European participants and the Asian participants.

ITER Workshop on Plasma Control

The conceptual design activity for the ITER Plasma Control System (PCS) was launched with a 3.5-day workshop held December 8-11, 2009, at Cadarache, France. All seven ITER Members sent participants to the workshop. The six participants sent by the US Domestic Agency were David Gates, Bob Granetz, David Humphreys, Egemen Kolemen, Lynda LoDestro, and Mike

Walker. Of the 57 total participants, almost half (26 to be precise) were from the ITER Organization, which indicates the high degree of interest in this activity.

The agenda for the workshop was as follows: The first half-day was devoted to a description of the system requirements for the ITER Plasma Control System and the time schedule for its development. The next two half-day sessions reviewed the status of plasma control in existing experimental devices, the operating experience that has been gained by applying various approaches to plasma control, their applicability to ITER, and issues that might arise in implementation for ITER. The remaining four half-day sessions were working group discussions that focused on specific issues such as framework and architecture; types of control (magnetic, particle, etc.); event handling; sharing of different actuators; simulation needs; and infrastructure (code and testing issues).

Within the ITER Organization, the Department for Fusion Science and Technology has the responsibility to define the requirements for the ITER Plasma Control System. The Department for CODAC & IT, Heating & CD, Diagnostics will have responsibility for its construction. The ITER Integrated Modeling Expert Group (IMEG) will help with simulations needed for the Plasma Control System (see December *eNews* for a description of IMEG). Tasks to support the conceptual design of the ITER Plasma Control System will begin this year.

Transport Task Force Meeting

The next meeting of the U.S. Transport Task Force Workshop will be held April 13-16, 2010, in Annapolis, MD. Information is available at the workshop web site (http://ttf2010.ucsd.edu). Many physics topics of high relevance to burning plasmas will be discussed at this meeting. We encourage attendance.

Fusion in the news recently

The December 2009 issue of *Physics World* was dedicated to the subject of "Fusion Challenges and Solutions." The five articles cover JET, laser-driven fusion power, postgraduate training programs, the new European fusion supercomputer, and ITER and the future of fusion.

The December 4, 2009, issue of *EIR Science and Technology* features an interview with Gyung-Su Lee, president of the National Fusion Research Institute of Korea, about his vision for the future. The article is entitled "Fusion in Korea: Energy for the Next Generation."

Changes in European leadership

Jerome Pamela, Leader of the European Fusion Development Activity (EFDA), became the new director of Agence ITER France (CEA) as of January 1, 2010 (http://www.iter.org/newsline/Pages/112/1568.aspx). The December 2009 issue of *Fusion News*, which is published by EFDA, contains an interesting interview with him (http://www.efda.org/news_and_events/downloads/efda_newsletter/nl_2009_12.pdf).

Francesco Romanelli, EFDA Associate Leader for JET, has been asked to serve as EFDA Leader Ad Interim (http://www.jet.efda.org/jet/news/2009/12/efda-garching/).

Frank Briscoe, Operations Director at UKAEA Culham Fusion Science Center, was appointed Director Ad Interim of Fusion for Energy (F4E), which is the European Domestic Agency for ITER, on January 11, 2010. The outgoing director, Didier Gambier, will move to a position in the European Commission in Brussels. For further information, see the news release (http://fusionforenergy.europa.eu/documents/press_release/f4e_press_release_11_01_10.pdf).

ITER Booth at AAAS Meeting

The US ITER Project Office will have a display booth at the AAAS Meeting (18-22 February, San Diego, http://www.aaas.org/meetings/2010/). If anyone plans to be at the meeting and

could spare a few hours to help staff the ITER display booth, please contact Bonnie Hebert at the USIPO (865-574-8381, hebertb@ornl.gov). She will set up the schedule and provide any instructions.

ITER Workshop on TBM Impact

Breaking news: ITER just announced that it plans to hold a 2.5-day "Workshop on TBM Impact on ITER Plasma Physics and Potential Countermeasures," April 13-15, in Cadarache. Scientists who wish to attend this workshop and possibly make a presentation, are asked to contact Joe Snipes (Joseph.Snipes@iter.org) and Luciano Giancarli (Luciano.Giancarli@iter.org) by January 22. Anyone interested in participating should indicate how many days you would plan to attend the workshop, submit a title for your presentation, and estimate how much time you would like for the presentation.

Happy New Year

As we enter the new decade, we look forward to further exciting developments in burning plasma science.

Incidentally, this month's issue is the 40th issue of *eNews*. I'd like to take the opportunity to thank our new editor, Tom Rognlien, and our USBPO administrator, Rita Wilkinson, for their dedicated and inspired work in publishing this electronic newsletter each month.

Reports

Meeting of the ITPA Pedestal Topical Group

Compiled by Phil Snyder (General Atomics)

The 17th meeting of the ITPA Pedestal Group was hosted by PPPL on October 5-7, 2009. There were approximately 35 scientists attending from the Pedestal Group, and a further 30 in the ITPA Transport and Confinement group, with whom we shared a joint session on the low-to-high (L-H) confinement transition. The meeting was organized into sessions focused on each of five urgent tasks: pedestal structure and H-mode physics, impact of magnetic perturbations on ELMs, L-H transition, impact of magnetic ripple on the pedestal, and pellet pacing. The meeting concluded with discussion of joint experiments.

Alberto Loarte opened the meeting with an overview of the urgent issues for ITER. He discussed a number of key H-mode-related issues pertinent to operation with a power amplification of Q = 10, emphasizing issues that have not received substantial focus in the past. These issues included: both access to and exit from the H-mode, access to an energy confinement parameter of H_{98} ~ 1, pedestal parameters and gradients in edge plasmas "thick" to neutral penetration, toroidal magnetic field (TF) ripple effects on the pedestal and required ripple "correction", ELM control compatible with Q = 10 scenario requirements, and H-mode in ramp-up/down phases. Furthermore, early ITER operation with H/He plasmas requires understanding the different behavior (compared to D or DT) for access to H-mode and H_{98} ~ 1, pedestal plasma characteristics, and ELMs and ELM control. Progress on each of the five urgent task areas listed in the previous paragraph is given below.

Pedestal Structure

Several talks on transport, stability, and fuelling of the pedestal were presented, including discussions of recent observations, theoretical progress, and simulations of existing experiments and ITER. A primary ITER urgent issue in this area is to explore the impact of heating source on pedestal structure and ELMs. Significant progress was reported on JET, DIII-D, and AUG experiments in which neutral beam power was exchanged for RF or electron

cyclotron power. In all cases, as long as input power was sufficient to maintain core plasma beta, both pedestal height and width were approximately constant, independent of power source. Additional results were discussed on dependence of pedestal width on the ion gyroradius normalized to the minor radius (rho-star) in JET and DIII-D, which continue to find that pedestal width is independent of (or perhaps even negatively correlated with) rho-star. Due to recent progress in extending Quiescent H-Mode (QH) operation to a broader parameter regime, a subgroup on QH mode has been created. QH mode results on DIII-D were discussed, including extensions of QH mode to co-rotating plasmas and plasmas with near zero (slightly negative) input torque, as well as relatively high density, high pedestal, high performance plasmas.

Impact of Magnetic Perturbations on ELMs

Observations on DIII-D, NSTX, MAST, JET, and LHD were reported, as well as modeling efforts aimed at quantifying stochastic transport. On DIII-D, the parameter range of Resonant Magnetic Perturbation (RMP) ELM-suppression has been significantly extended, including high-performance discharges and studies of suppression dependence on plasma beta, collisionality, and safety factor (q_{95}). On MAST, initial experiments with internal coils have found density pump-out, but not ELM suppression. A coordinated effort between the MAST and DIII-D teams is planned to better quantify necessary criteria for full ELM suppression. NSTX and JET find mitigation, but not full suppression, of ELMs using external control coils. A planned set of internal coils for AUG is expected to be available in late 2010, with an extension to 8 coils available in spring 2011. LHD finds increased particle transport with imposed perturbations having 1/1 poloidal/toroidal mode numbers. A new subgroup has been formed to explore ELM pacing using imposed time varying magnetic perturbations. NSTX reported ELM pacing results using magnetic perturbations and vertical jogs of the magnetic equilibrium, and both NSTX and DIII-D plan additional experiments to further study magnetic ELM pacing.

L-H Transition

A productive session on L-H transition observations and physics was held in conjunction with the Confinement and Transport Topical Group. The dependence of the L-H transition power on a number of parameters was discussed. The dependence on ion species is of special interest for the initial hydrogen and/or helium operational phase of ITER. While results across machines are reasonably consistent for the ratio of hydrogen to deuterium threshold power (~2:1), there is significant variation in the He:D ratio, with JET, MAST, DIII-D, and C-Mod finding a power ratio of 1.2-1.8, while AUG and NSTX find a ratio ~1. Observed confinement time in H or He is generally found to be ~20-30% lower than in D for reasons that are not well understood. The variation in L-H power with several “hidden variables” including magnetic geometry, wall conditions, rotation, and recycling was also discussed, noting that the strong variation in P_{LH} with rotation found on DIII-D is not consistently found on all machines (AUG and JET see little variation in P_{LH} with heating source). A two-stage plan for the L-H transition database was presented by J. Hughes, starting with a scalar database and progressing to profile data. The pedestal group plans to focus its efforts on understanding the L-H transition in terms of local parameters near the separatrix and continuing theory and computational efforts.

Effect of Ripple

Results and plans for studies of the impact of magnetic ripple on the pedestal were reported for JT-60U, JET, and DIII-D. On JT-60U it has been found that the pedestal height increases ~10-20% when ripple was reduced using ferritic inserts in a high ripple configuration. However, in the JET/JT-60U similarity configuration, no impact of ripple on the pedestal was found. On JET, a significant impact of ripple was found at high plasma current (2.6MA), but not at 1.0 or 1.7MA. In a dedicated JT-60U/JET comparison experiment, no impact was found on pedestal height for ripple values from 0.1-1%, but rotation was reduced at higher ripple. Plans for upcoming

experiments (now completed in December) using a mock-up Test Blanket Module (TBM) on DIII-D were described.

Pellet ELM Pace-Making
A progress report on ELM pace-making was presented. Technical difficulties with the JET pellet injector have allowed only limited progress in recent studies of pace-making. The DIII-D pellet dropper has not been successfully used in pace-making, and a modification of the existing pellet fueling system is being considered for ELM pacing. On AUG, the possibility of using solid state pellets (*e.g.*, C, Be) has been discussed and an injector identified; however, no further steps have yet been taken due to a lack of manpower.

Status reports were presented for 14 joint experiments in the pedestal topical area. A great deal of progress was presented here, and at the preceding H-Mode Workshop in Princeton, and several journal articles are being submitted or are already published. Four topics were closed, and three new joint experiments planned, all dealing with aspects of the L-H transition (critical parameters, profile evolution, and X-point height effects).

The next ITPA Pedestal Topical Group is planned for April 21-23, 2010, to be hosted by JAEA at the Naka Fusion Institute in Naka, Japan.

Further details about the meeting are available in the full report at
http://itpa.ipp.mpg.de/pedestal_edge/PEP17-summary.pdf

Summary of the US-Japan Workshop on "Interaction between plasma and high Z material towards steady state operation"

Compiled by Mizuki Sakamoto (Kyushu University, Japan) and Bruce Lipschultz (MIT)

The US-Japan Workshop on "Interaction between plasma and high Z material towards steady state operation" was held November 9-10, 2009, at the Plasma Science and Fusion Center of MIT. Sixteen scientists participated in the workshop (10 from the US and 6 from Japan). The purpose of this workshop was to discuss Plasma Surface Interaction (PSI) phenomena of high Z materials from both microscopic and macroscopic viewpoints (*i.e.*, multiscale) directed towards understanding steady state operation, and to exchange information on these phenomena. The main topics were as follows: (1) hydrogen recycling/retention observed in fusion devices, (2) impact of radiation damage and He bubble on hydrogen retention, (3) erosion and surface modification including nano-structure formation, arcing, and dust, and (4) material modeling including H trapping, defect and bubble formation, and others. The details follow.

Fuel retention results from Alcator C-Mod indicate that 1-2% of the ion flux/fluence on the divertor plates is being retained during normal, non-disruptive discharges. This value is ~5-10x higher than what the equivalent laboratory data would predict. The difference between lab and C-Mod data may be due to any of the following: direct creation of traps in the Mo and W by impurity ions (*e.g.*, B), reduction of the surface recombination rate by impurities, or the high plasma fluxes on C-Mod. Analysis of real-time particle balance in Alcator C-Mod showed that, during stationary plasma density conditions, the wall materials had ~zero retention rate globally, *i.e.*, fuel was neither released nor retained. This balance was found in cases where the divertor plasma was strongly pumped. The result is contrary to the expectations from shot-averaged retention, and it is unclear if this is an effect of the refractory metal or due to some plasma physics effect. In TRIAM-1M at Kyushu University, indications are that co-deposition of hydrogen with eroded Mo produces substantial wall pumping, and the level of hydrogen retention depends on the grain size of the deposits. Oxygen strongly affects the structure of the deposits. Comparing particle balance in cases of cold walls and hot walls in TRIAM-1M

indicates that wall temperature is a key factor for steady state particle control. Microscopic modification and particle retention in tungsten exposed to LHD divertor plasmas were also presented. Analysis of a W divertor tile from LHD showed that many small hydrogen cavities existed in the tungsten matrix. Because the cavities likely arise from radiation damage, such radiation is expected lead to a general enhancement of the hydrogen retention in W.

Effects of material damage on retention were shown from laboratory experiments. Tungsten (W) samples with displacement damage produced by 12 MeV silicon ion irradiation were exposed to lab deuterium plasmas in PISCES-A and to divertor (D) plasmas in DIII-D. Nuclear reaction analysis showed that the quantity of trapped D is small due to slow permeation at 200ºC and below, and that trapping is also small due to weaker binding of D to traps and defect annealing above 400ºC. The results indicate that the tritium inventory from trapping at neutron-damage sites in tungsten should be small in ITER. In another experiment, it was shown that the D/W ratio increased strongly until 0.2~0.3 dpa, and then saturated or increased more slowly with increasing dpa. Results of tritium plasma exposure were shown from TPE, and bulk tritium diffusion in W and Mo was discussed. In addition, characterization of H adsorption on W(100) was reported.

Results of the formation mechanism and properties of a fuzz layer on tungsten due to helium plasma exposure were presented from PISCES and NAGDIS devices. The response of tungsten surfaces to bombardment of pure helium and mixed deuterium/helium plasma was reported from PISCES. The response of the surface varies with the surface temperature. At low surface temperature (a few 100°C), small nano-bubbles are formed from the helium in the near surface region. These nano-bubbles appear to inhibit the diffusion of deuterium deep into the tungsten bulk. At higher surface temperature (800°C–1500°C), surface tungsten nano-structures appear. The surface fuzz appears to have a reduced sputtering yield, consistent with an increased probability of the sputtered material redepositing in the highly textured surface structure. In NAGDIS, it was shown that the fuzz layer formation caused a decrease in optical reflectivity by changing the surface morphology. For ruby laser irradiation of the W fuzz, the ablation threshold of W significantly decreased by the synergetic effect of laser and helium irradiation, leading to W impurity emission and W dust formation. Results of W fuzz exposure to the TEXTOR edge plasma indicates that a W fuzz layer changes the surface condition so as to increase carbon deposition. Also, *in situ* and real time measurement of surface modification of W due to low energy helium plasma irradiation in the APSEDAS device at Kyushu University was reported.

Turning to modeling, how ambient hydrogen influences vacancy formation in tungsten crystals was discussed. Improved understanding of experimental results may be obtained by taking into account surface-energy corrections for the density-functional calculations in the generalized gradient approximation. Based on present calculations, it was shown that the di-vacancy states possess almost zero or negative binding energies. This means that the di-vacancy easily disintegrates into mono-vacancies. However, formation energies found for a complex of the di-vacancy and a hydrogen atom (V_2H) were smaller than those for the di-vacancy alone. Thus, in the presence of hydrogen, the V_2H complex would be more stable. It was suggested that oxygen impurities have a similar effect on the di-vacancy nucleation. Results were also shown for kinetic Monte Carlo (KMC) simulations of helium bubble evolution in tungsten, which covered helium bubble diffusion, coalescence, surface pore formation, and helium implantation.

Results of fuel retention in fusion devices are complicated due to the complex circumstances of PSI processes, and they are often different from the predictions of the equivalent laboratory data. It was pointed out that cooperation among fusion experiments, laboratory experiments, and modeling/simulation is important to get a better understanding of high Z material (*e.g.*,

tungsten) for use in fusion. Participants agreed to hold another US-Japan workshop to make additional progress in this key area of steady state plasma operation with high Z wall materials.

Announcements

Submit BPO-related announcements for next month's eNews to Tom Rognlien at trognlien@llnl.gov .

Upcoming Burning Plasma Events

2010 Events

January 18-21
Workshop on Opportunities in Plasma Astrophysics (WOPA)
Princeton, USA

February 16-19
Innovative Confinement Concepts Workshop (ICC 2010)
(abstracts due **Dec. 4)**
Princeton, USA

Week of 22 March
ITPA Transport & Confinement Topical Group Meeting
Oxfordshire, UK

April 12-15
16th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating
Sanya, China

April 13-15 NEW
ITER "Workshop on TBM Impact on ITER Plasma Physics and Potential Countermeasures"
Contributors contact: Joseph.Snipes@iter.org and Luciano.Giancarli@iter.org by Jan. 22
Cadarache, France

April 13-16
U.S. Transport Task Force Workshop
(abstracts due **Feb. 4**)
Annapolis, Maryland USA

April 13-16
International Conference on Plasma Diagnostics
Pont-à-Mousson, France

April 19-21
Sherwood Fusion Theory Conference
(abstracts due **Feb. 26**)
Seattle, Washington USA

April 20-23 UPDATED
Integrated Operational Scenarios ITPA Meeting
Princeton, New Jersey USA

April 21-23 NEW
ITPA Pedestal Topical Group Meeting
Naka, Japan

May 16-20 NEW
18th ITPA Diagnostics & HTPD Topical Group Meetings
Wildwood, New Jersey USA

May 19-21
STAC-8
Cadarache, France

May 24-28
19th International Conference on Plasma Surface Interactions
(abstracts due **Nov. 20**)
San Diego, California, USA

May 31-June 4
4th ITER International Summer School
(abstracts due **April 30**)
Austin, Texas USA

June 21-25
37th European Physical Society Conference on Plasma Physics
(abstracts due **Feb. 27**)
Dublin, Ireland

June 21-25 NEW
37th IEEE International Conference on Plasma Science (ICOPS 2010)
(abstract submission extended to **Jan. 23**)
Norfolk, VA USA

Aug 30-Sep 3 NEW
Theory of Fusion Plasmas Joint Varenna-Lausanne International Workshop
(abstracts due **June 18**)
Varenna, Italy

Sept 27-Oct 1
26th Symposium on Fusion Technology (SOFT2010)
Porto, Portugal

Oct 11-16 UPDATED **NOTE DATE CORRECTION**
23rd IAEA Fusion Energy Conference
(U.S. synopsis due **Feb. 8**)
Daejeon, Korea

Oct 24-29
9th International Conference on Tritium Science and Technology
Nara, Japan

Nov. 7-11 NEW
19th Topical Meeting on the Technology of Fusion Energy (TOFE 2010)
Embedded with 2010 ANS Winter Meeting
Las Vegas, NV

Fall
ITPA Transport and Confinement Topical Group Meeting (following IAEA)
South Korea

Fall
ITPA IOC Topical Group Meeting (following IAEA)
South Korea

Fall
ITPA Diagnostics Topical Group Meeting (following IAEA)
Japan

2011 Events

Spring
ITPA Transport & Confinement Topical Group Meeting (following US/EU TIF)
San Diego, California USA

Please contact the administrator with additions and corrections.