USBPO U.S. BURNING PLASMA ORGANIZATION

eNews

May 9, 2012 (Issue 64)

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Dear Burning Plasma Aficionados:

This newsletter provides a short update on U.S. Burning Plasma Organization activities. E-News is also available online. Comments on articles in the newsletter may be sent to the Editor (Dylan Brennan) Assistant Editor (Rita Wilkinson). Thank you for your interest in Burning Plasma research in the U.S.!

Director's Corner by C. M. Greenfield

US Burning Plasma Organization Current Activities

Following last month's US Disruption Workshop, we are planning the next steps. As always, we have individual research groups (C-Mod, DIII-D, NSTX) working on different aspects of disruption mitigation. We anticipate the USBPO Disruption Task Group taking a leading role in fostering collaboration within and outside the US research program, with the expectation that addressing this critical need for ITER can be done better with a community-wide response. You should hear more in the coming weeks about how you can participate.

The slides from the workshop have been posted in the Disruption Task Group web forum. Note that the forums are open to USBPO members only. A report on the workshop is nearly complete and will be posted here soon.

A new USBPO Task Group is being formed to develop a US community vision for the modes of collaboration on ITER. This builds on the recent report of the FESAC subpanel on International Collaboration, and responds to one of its recommendations. Although detailed planning has not yet started for how the partners will work together on an ITER research program, there is a wealth of knowledge, and many opinions, within the US community based on years of experience in collaborative research. The intent is to work toward a US community vision before such discussions commence amongst the ITER partners. Although we're still several years away from the beginning of the ITER research program, there is already some urgency, since some of the infrastructure for collaborative work on ITER is already being specified. Rajesh Maingi (ORNL), deputy leader of the USBPO Pedestal and Divertor/SOL Topical Group, has agreed to lead this group. We hope for broad community participation in this activity that may impact how we all work on ITER 10 years from now.

Another effort going on within the USBPO is broadening our outreach to students and scientists outside of the Fusion Energy Science community. We are collecting presentation materials from USBPO members and developing a full presentation suitable for a seminar or colloquium to communicate what we do to our non-fusion colleagues. The repository we're building can also provide material to help members of the community in constructing their own talks. In the coming months, we will seek opportunities (perhaps starting with web seminars) to present some of this material. We will also seek partners in this endeavor, since communicating outward is not a unique role of the USBPO. David Pace (GA, and deputy leader of the USBPO Energetic Particle Topical Group) is leading this effort.

US Burning Plasma Organization Council Election

In the coming days, members of the USBPO will be asked to vote on candidates to fill two positions on the USBPO Council. This will fill half of the vacancies being created as the terms end for four current members: Mike Mauel (Chair), Michael Bell (Vice Chair), Wayne Meier, and Phil Snyder. The other two vacancies will be filled by appointment (as described on our by-laws) following the election. This year's process will be particularly challenging for me since both our Chair and Vice Chair are departing. Those posts will be filled from existing and/or new Council members.

The Council represents the US MFE research community in providing oversight of USBPO activities, and is the primary USBPO element responsible for long-term strategic planning of burning plasma research. The Council is responsible for setting the policies and procedures of the USBPO, including establishing the by-laws governing operations.

Following the election, we will move on to normal rotation of half of the topical group chairs. The following chairs will be completing their terms this summer; members of their topical groups should watch their email in June or July for a request for nominations:

Confinement and Transport	John Rice (MIT)
Diagnostics	Jim Terry (MIT)
Integrated Scenarios	John Ferron (GA)
MHD and Macroscopic Plasma Physics	Ted Strait (GA)
Modeling and Simulation	*Dylan Brennan (U. Tulsa)

*Note that Dylan is also the editor of the eNews.

Progress at ITER

Earlier this month, the ground support structure for the Tokamak Complex—the basemat, 493 columns and seismic bearings, and retaining walls—was completed. The next step will be formwork and reinforcement for the Tokamak Complex basemat, the actual floor of the installation that will rest on the seismic bearings. Work is also scheduled to begin on the foundation of the Assembly Hall, which will be erected adjacent to the Tokamak Complex. More information on this can be found in a recent ITER Newsline article.

The concrete pillars (1.7m tall) and their seismic pads form an army of standing columns upon which the Tokamak Complex will be built. The area between the two concrete basemats will remain accessible for regular inspection of the seismic pads. Photo © ITER Organization.

USBPO Topical Group Highlights

(Editors note: The BPO Confinement and Transport Topical Group works to facilitate U.S. efforts to understand plasma confinement via improved measurements and computational models for existing and future magnetic fusion devices [leaders are John Rice and George McKee]. This month's Research Highlight by M.W. Schafer et al., discusses the comparison between experimental measurements and simulations of the spectrum of plasma turbulence, which is known to dominate the physics of particle, energy and momentum transport. Comparisons such as these can lead to significant breakthroughs in our understanding of these mechanisms, and enable us to predict experimental outcomes.)

2D Properties of Core Turbulence: Measurement and Gyrokinetic Simulation

***M.W. Shafer**, **G.R. McKee** and **R.J. Fonck** (University of Wisconsin-Madison, Madison, Wisconsin)*

Understanding the characteristics and dynamics of fully developed turbulence in tokamak plasmas is crucial to predicting energy confinement and ultimately the fusion power output in ITER and other burning plasma experiments. This turbulence drives cross-field transport of particles, energy and momentum via correlated fluctuations in density, electrostatic potential, magnetic field, rotation, and temperature. Unlike many fluids, turbulence in magnetically confined plasmas is strongly spatially anisotropic, with $k_{\parallel} << k_{\perp}$ ($k_{\parallel}$ scales with machine size, while $k_{\perp}$ scales with ion gyroradius); the critical turbulence dynamics of eddy shearing, interaction, and energy transfer thus take place primarily perpendicular to the magnetic field. The 2D characteristics in this perpendicular (approximately radial-poloidal) plane are thus crucial to turbulent transport, which is governed by pressure-gradient-driven drift-wave type instabilities. This research highlight describes recent comparisons between measurements and simulations of 2D turbulence characteristics in plasmas on DIII-D.

During transport model validation experiments [1], relatively good agreement has been obtained between measurements and simulations of heat transport as well as local, long-wavelength turbulence characteristics in the core region (r~0.5), while notable discrepancies were found in the outer regions (r³0.7) [2]. Simulations have been performed with GYRO and other nonlinear simulation [3]. While the fusion-power phase in ITER will be in high confinement (H-mode) plasmas, the plasma will be in low confinement (L-mode) during most or all of the long (~50-100 second) current ramp-up, until the L-H transition occurs, as well as during the current ramp-down. Furthermore, transport modeling and measurements have shown discrepancies in modeling the electron temperature profile evolution during current ramp-up, which will be important to calculating the inductance, q-profile evolution, and ohmic power supply requirements [4]. These discrepancies may well be linked, and it is thus important to resolve them.

Quantitative 2D measurements of turbulence characteristics were obtained across the plasma radius during these experiments on DIII-D with a high-sensitivity array of Beam Emission Spectroscopy (BES) channels [5] that measured long-wavelength density fluctuations [6]. These measurements were obtained with a 5 (radial) x 6 (poloidal) grid of discrete BES channels (approximately 1 cm spatial resolution in radial and poloidal directions). The radial profile of the broadband density fluctuation frequency spectra is shown in Fig. 1, which illustrates the spatial and spectral behavior. Fluctuations are

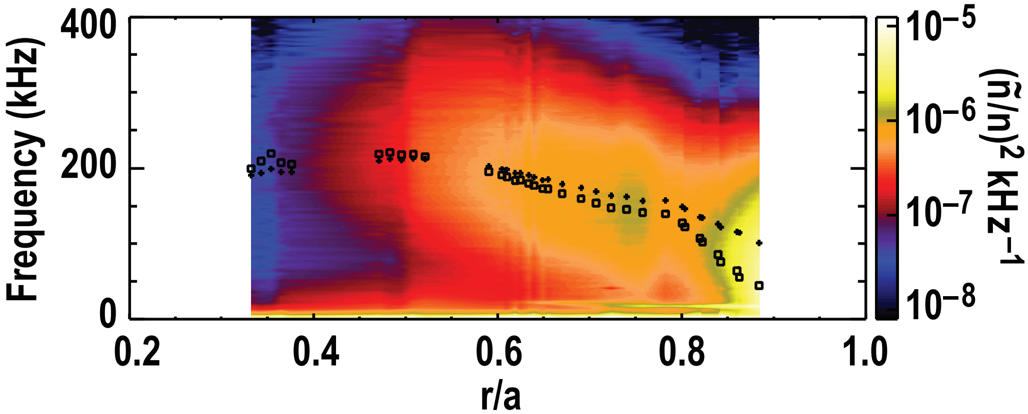

Figure 1. *Radial profile of the density fluctuation spectra (crosses represent spectra centroid, while squares represent spectral peak).*

Doppler shifted up to several hundred kHz towards the core, as a consequence of $E_r \times B_T$ rotation, and are more intense towards the edge of the plasma, rising to a normalized amplitude of ñ/n~3% at r=0.9, while ñ/n≤1% throughout much of the core. The 2D spatial cross-correlation function for a quasi-stationary phase of the plasma (MHD and sawteeth-free) is shown in Fig. 2(a) for the 5x6 array of channels; a model fit to the 1D radial and poloidal cross-correlations is shown in Fig. 2(b). The poloidal correlations exhibit a decaying wavelike behavior, while the radial is monotonically decaying.

The 2D $S(k_r, k_\theta)$ wavenumber spectrum, shown in Fig. 2(c), shows a peak near k_q=1.3 cm^{-1} ($k_q r_I$~0.25) and k_r=0. The top graph shows the raw spectrum, and the bottom has been deconvolved using the calculated point-spread-function (PSF) for BES [7], compensating for the finite spatial extent of the

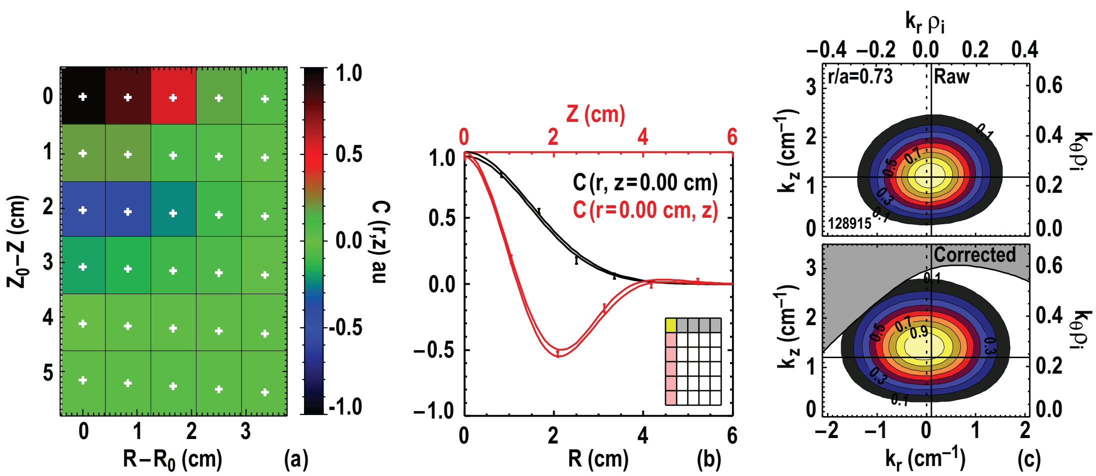

Figure 2. *(a) Spatial cross-correlation magnitude (time-lag=0) among the discrete channels, and (b) the radial and poloidal cross-sections and model fits, and (c) the $S(k_r, k_\theta)$ wavenumber spectra, raw on top, corrected for point-spread-function on bottom.*

individual channels. The measured spectra obtained at r=0.5 and r=0.75 are compared with calculations of the wavenumber spectra from GYRO simulations in Fig. 3. GYRO was run using the measured temperature, density, and rotation profiles and equilibrium for the same plasmas. The resulting density

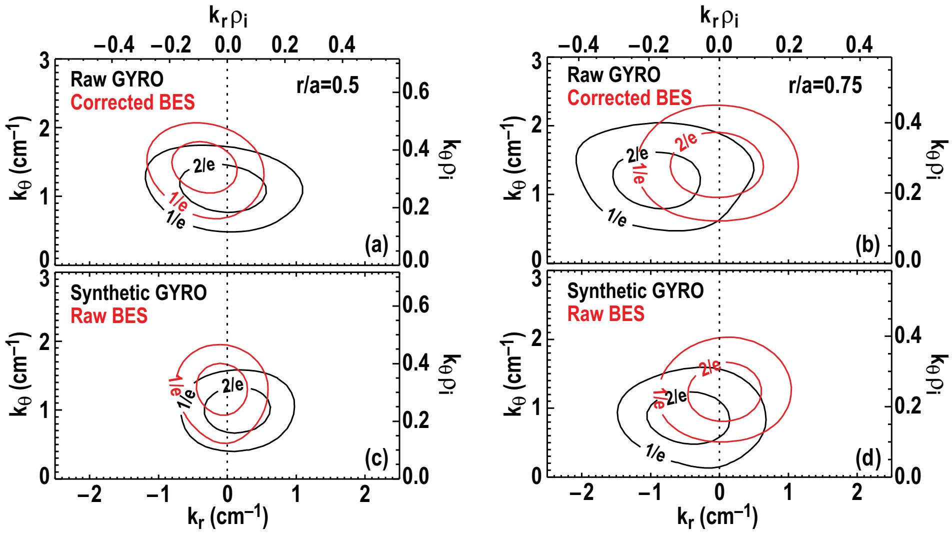

Figure 3. *Comparison of the* $S(k_r, k_\theta)$ *from BES and GYRO at* $\rho \approx 0.5$ *and* $\rho \approx 0.75$.

fluctuation spectra were filtered using a BES synthetic diagnostic, which accounts for the PSF and maps it to the simulation geometry [2]. These comparisons are instructive and may indicate subtle but important differences between the experiment and simulation. While both spectra exhibit generally similar behavior, the measurements show somewhat higher k_q. More importantly, the simulation shows a distinctly finite k_r that is not seen in the experimental data, which reflects a more sheared eddy structure. It should also be recalled that the simulation under predicts the turbulence and transport at this outer location, while excellent agreement was found near mid-radius. These results suggest that the effects of rotational shear are not as prevalent in the experiment as the simulation, which could explain the lower calculated turbulence magnitudes.

The measured local turbulence decorrelation rates, obtained from poloidally-displaced BES channels, were compared with calculations with the TGLF code of local maximum linear growth rates. They were found to compare well across much of the radius, as shown in Fig. 4. In the mid-radial region,

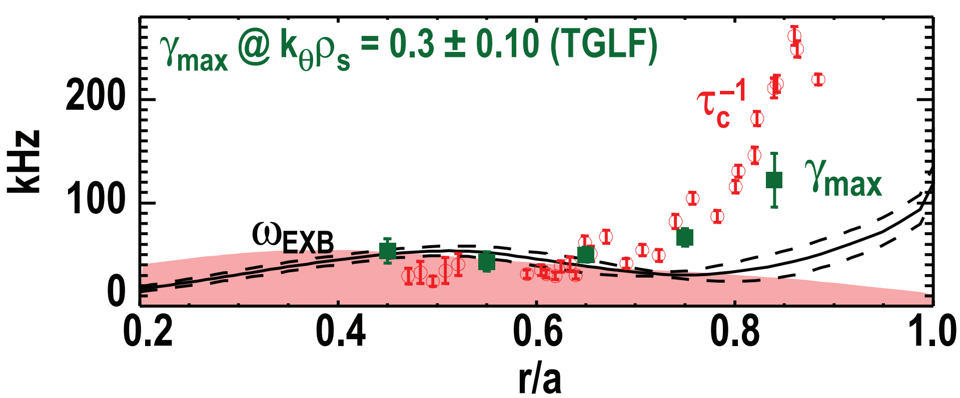

Figure 4. *Profile of the measured turbulence decorrelation rates, TGLF maximum linear growth rates, and measured ExB shearing rates.*

the ExB shearing rates are comparable to the decorrelation rates while, towards the edge, they increase relative to the ExB shear rates. Other explanations for the discrepancy are under investigation, including: spreading of intense edge turbulence into the outer region, and breaking of the gyrokinetic ordering by the large fluctuation amplitudes. By probing the 2D spatiotemporal characteristics of turbulence, and quantitatively comparing with nonlinear simulations, greater confidence can be obtained in the predictive capabilities of transport simulations. Discrepancies are being investigated to determine what additional physics may be required in the transport models.

References

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ITPA Report

Summary of the 16th Meeting of the Divertor and Scrape Off Layer ITPA Group

Bruce Lipschultz *(Massachusetts Institute of Technology) and* ***Tony Leonard*** *(General Atomics)*

The 16th meeting of the Divertor and SOL ITPA topical group was held in Jüelich, Germany on Jan. 16-19, 2012. The main topics discussed at the meeting were 1) the JET ITER-Like wall experiment, 2) Fuel retention, 3) Tungsten erosion and damage, 4) Steady-state heat flux, 5) Disruption heat flux, and 6) Dust monitoring.

The JET ITER-Like Wall Experiment

The first session of the meeting summarized the initial JET experiments with an ITER-like wall, beryllium covering the walls and a tungsten divertor. JET reported a very good start to experimental operation with the first startup shot running to completion. Impurity levels were low and the H-mode power threshold was reduced. However the H-modes were limited due to low power availability, primarily ICRF. Without extra gas puffing the H-mode discharges had low ELM frequency with significant tungsten accumulation. Extra gas puffing produced a much higher ELM frequency and the core concentration of tungsten remained low. It is uncertain whether the source of tungsten was standard divertor erosion, or some interaction with the ICRF heating.

Fuel Retention

The session on fuel recovery featured an interesting result from Tore Supra. There has been a long standing discrepancy on the level of retained fuel in carbon tokamaks between gas balance measurements and post-mortem analysis of tiles, with the latter exhibiting a factor of 3-5 lower retention rates. Measurements at Tore Supra now indicate that this difference may be due to long term outgassing under vacuum. This may lower the fuel retention that would be expected in ITER with carbon divertor targets.

Tungsten Erosion and Damage

A number of presentations concerned the performance of tungsten under repeated thermal transients. A new phenomenon was described where under thermal cycling the tungsten grain structure evolves into larger grain size. This may explain the observed cracking of the surface after 1000's of thermal cycles. Another report of tungsten operation in a tokamak was presented by C-mod. A complete toroidal row of tungsten tiles in C-mod operated without incident until several became loose with a leading edge which caused significant melting; Normally a field line, and thus the heat flux, incidence angle is ~ 0.5 degrees on divertor surfaces. This spreads out the heat toroidally. However, when a tile is missing the heat is incident on the side of the next tile toroidally still remaining giving much higher heat loads and melting. Normal operation of the tokamak then became more difficult and care had to be taken to make sure the divertor strike-point was not placed on the melted tungsten tile. Other presentations described measurements and modeling of tungsten erosion and migration.

Steady-State Heat Flux

The heat flux footprint in US and EU tokamaks was reviewed in several presentations by characterizing the divertor heat flux based on IR camera measurements. This was an update to work presented at the previous meeting. Both the US and UE analysis has settled on a two parameter fit to the divertor heat flux profiles measured by IR cameras. The two parameters describe the widths of the common flux and private flux sides of the strike-point separately. The general conclusions from the previous meeting remain, implying a narrow heat flux in ITER, ≤ 2 mm, mapped to the midplane. Concern was raised however that scaling the EU and US data to ITER would imply exceeding ideal ballooning stability limits. This topic will be examined in more detail.

Disruption Heat Flux

The presentations on disruptions concentrated on measurements of heat flux to surfaces during both unmitigated and mitigated disruptions. This session included presentations from a number of facilities, including DIII-D, C-mod, JET, MAST, Tore Supra and TEXTOR. Most of these measurements are in the development phase and more results should be forth coming shortly. An estimate for the expected heat loads during ITER disruptions, particularly VDEs, is very important for the divertor design.

Dust Monitoring

Development of dust monitoring diagnostics was the emphasis of the dust session. This included presentations from KSTAR, Tore Supra, EAST and ASDEX-Upgrade. A database of the current state of dust monitoring capability was summarized. The consensus is that ITER will not exceed its limit of cold dust, but that such dust may present operational difficulties and will have to be monitored.

The proposal for the next meeting for the Div/SOL ITPA topical group was for the week following the IAEA meeting in San Diego in October 2012. While there will be some joint sessions with other topical groups it was felt best to keep these to a minimum.

Announcements

Submit BPO-related announcements for next month's eNews to Dylan Brennan.

"ITER Research Needs" *a report by David Campbell, Plasma Operation Directorate, ITER Project, presented to the ITPA Coordinating Committee, Cadarache, France; December 12, 2011.*

Upcoming Burning Plasma Events

2012 Events

May 14-17, 2012
ITPA Diagnostics Topical Group Meeting
Kutchatov Institute, RUSSIA

Jul 8-12, 2012
39th IEEE International Conference on Plasma Science (ICOPS2012)
Edinburg, UNITED KINGDOM

Jul 10 and 11, 2012
Sixth US-PRC Magnetic Fusion Collaboration Workshop (contact Dr. George Tynan for information)
San Diego, CA

Aug 27-31, 2012
American Nuclear Society 20th Technology of Fusion Energy Conference (TOFE)
Nashville, TN

Sep 2-7, 2012
Joint IAEA_NFRI Technical Meeting on Data Evaluation for Atomic, Molecular and Plasma-Material Interaction Processes in Fusion
Daejeon, KOREA

Oct 8-13, 2012
24th IAEA Fusion Energy Conference
San Diego, CA

Oct 15-17/18, 2012
ITPA T&C, MHD, PEP, EP, IOS, DSOL
San Diego, CA USA

November 2012
ITPA Diagnostics
INDIA

December 2012
ITPA CC & CTP-ITPA Joint Experiments and CTP
Cadarache, FRANCE

Directories of Other Plasma Events

IEEE Directory of Plasma Conferences
Fusion Ignition Research Experiment (FIRE) Physics Meetings
Fusion Power Associates Meetings Calendar

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