USBPO U.S. BURNING PLASMA ORGANIZATION

eNews

March 17, 2011 (Issue 53)

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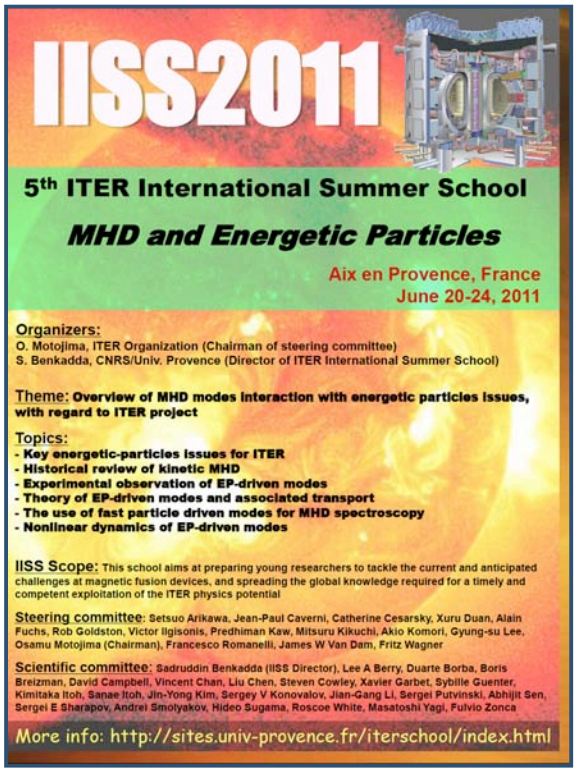
Dear Burning Plasma Aficionados:

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 (Tom Rognlien) or Assistant Editor (Rita Wilkinson). Thank you for your interest in Burning Plasma research in the U.S.!

Director's Corner by Jim Van Dam

Second Notice: Scholarships for 2011 ITER Summer School

The 5th ITER International Summer School will be held in Aix en Provence, France, during June 20-24, 2011. The theme of this year's Summer School will be "MHD and Energetic Particles." These Schools are primarily designed for graduate students, postdocs, and young researchers. If you are interested in attending, please go to the School's website and register. The registration deadline has been extended to April 1.



The USBPO will make available eight scholarships for US participants to this year's ITER Summer School. "US participants" must be US citizens working at US institutions. The scholarships will cover round-trip airfare, registration fee, and six nights of student housing, which are the three items that constitute the bulk of the expenses. Participants' home institutions are encouraged to supplement the scholarships to cover other travel-related expenses. Please send applications to Professor Michael Mauel chair of the USBPO Council. In each application, please include (1) a vita, (2) a list of publications, (3) a statement about the reasons why your participation at this School would be beneficial, and (4) a letter of reference from a senior scientist who is knowledgeable about you. Please submit applications for scholarships by March 23.

New Appointments

Since the USBPO is integrated with the ITPA on the national level, let me report that the international leader of the ITPA Topical Group on Energetic Particles, Prof. Dr. Sibylle Guenter, became the new Scientific Director of the Max Planck Institute of Plasma Physics on February 1 of this year. She stepped down as the ITPA topical group leader and was replaced by the then-deputy leader, Dr. Kouji Shinohara (JAEA). Congratulations to Sibylle. The detailed news release from the Max Planck Institute about her new appointment can be found at the Institute's website.

Sibylle Guenter
(photo courtesy of Max Planck Institute)

The ITER Organization has announced that Dr. Richard Hawryluk (Princeton Plasma Physics Laboratory) has been appointed as the new Deputy Director-General for Administration. Rich is well known in the US and international fusion science communities. He led the deuterium-tritium campaign on the TFTR tokamak, was deputy director of PPPL during the period 1997-2008, and more recently served as the head of the ITER and Tokamaks Department at PPPL. Rich also chaired the US Fusion Facilities Coordinating Committee and led the international working group to design in-vessel coils for vertical stability and ELM control on ITER. The ITER Organization will greatly benefit from his broad range of experience and capabilities.

Rich Hawruluk
(photo courtesy of PPPL)

ITER Progress

A new gallery of photographs can be viewed on the ITER Organization website. Recent photos in this collection show the significant progress in construction on the ITER work-site at Cadarache.

Video clips are posted in another website; go here if you wish to view movies of construction, of presentations, and related material.

In addition, as reported in the *ITER Newsline* (issue #165), the ITER Webmaster has installed the first of several live webcams on the construction site (click on the link provided on the web page. You can now watch the construction progress on your computer screen in real time (but only during daylight hours).

Excavation for the future Tokamak Complex Seismic Isolation Pit
(photo courtesy of ITER Organization)

Spring 2011 ITPA Meetings

One of the ITPA topical groups, namely, that for MHD Stability, already held its spring 2011 meeting (March 1-4, Ahmedabad, India). The next topical group meeting will be for the Pedestal and Edge Physics Topical Group, March 30-April 1, Cambridge, MA. You can see the complete schedule of ITPA spring meetings on the USBPO ITPA listing page.

Postings for Senior ITER Positions

We just received word that the following senior positions at the ITER Organization have been posted.

- Director of Directorate for General Administration, ADM-001
- Director of Directorate for Plasma Operation, FST-001
- Director of Directorate for Tokamak, TKM-001
- Director of Directorate for Central Engineering & Plant, CEP-001
- Director of Directorate for CODAC, Heating & Diagnostics, CHD-001
- Head of Finance and Budget Division ADM-003

Detailed job descriptions can be accessed on the ITER website. Applications from qualified and interested persons should be submitted by the deadline of April 3. Be sure to include the Personal History Form as well.

USBPO Topical Group Highlights

(Editors note: The BPO Diagnostics Topical Group works to facilitate U.S. efforts in developing advanced measurement techniques for existing and future magnetic fusion devices [leaders are Jim Terry and David Brower]. This month's Research Highlight by Novimir Pablant et al. summarizes development of an x-ray imaging crystal spectrometer system that measures ion temperature and toroidal rotation in existing devices and is now being designed for use in ITER.)

X-ray imaging spectroscopy for ITER and beyond

N.A. Pablant, M. Bitter, L. Delgado-Aparicio, K.W. Hill (Princeton Plasma Physics Laboratory); P. Beiersdorfer (Lawrence Livermore National Laboratory); and J. Rice (Massachusetts Institute of Technology)

Measurements of the ion temperature (T_i) and plasma toroidal rotation velocity (V_ϕ) across the minor radius are crucial for understanding burning plasmas and ITER as well as current tokamak devices. The rotation velocity profile is important in understanding and controlling the plasma stability, while measurements of the ion-temperature profile are important for plasma heating, the study of confinement modes, and heat transport. For ITER, profiles of both T_i and V_ϕ need to be measured with a spatial resolution of 1/30 the minor radius, and with a time resolution of 10 ms for V_ϕ and 100 ms for T_i. In current devices

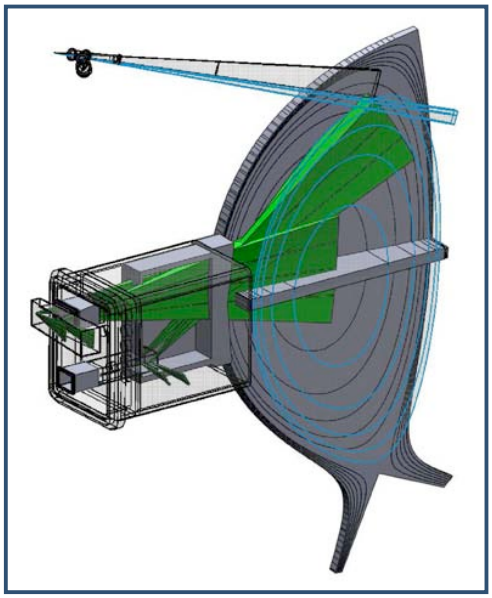


Fig. 1. Proposed layout geometer for the ITER x-ray imaging crystal spectrometer system. Here both the core system (shown in green), which is a US undertaking, and the edge system, which is an Indian contribution, are shown. For the core system both a radial view and a view with a tangential component are used to distinguish V_θ and V_φ. In addition, to obtain coverage across the minor radius two arrays are needed, leading to a total of four XICS arrays for the core system.

these parameters have typically been measured using charge-exchange recombination (CER), which relies on neutral-beam injection. In future devices, such as ITER, CER-based diagnostics are expected to have difficulties in making temperature and rotation measurements deep in the core due to poor neutral-beam penetration.

New developments in x-ray spectroscopy have made these types of measurements possible using an x-ray imaging crystal spectrometer (XICS) system, which has been selected for ITER to be a primary diagnostic for profile measurements of T_i and V_ϕ, and to be a secondary diagnostic for the electron temperature (T_e) and poloidal velocity (V_θ) [1,2]. The development of this diagnostic for ITER has been allocated to the US, and detailed design work is currently underway as a joint project between PPPL, LLNL and MIT. The planned ITER XICS system (shown in Fig. 1) will use emission from intrinsic impurities, providing a non-perturbative measurement. The conceptual design review for this diagnostic is scheduled for November 2011.

X-ray emission from highly charged impurity ions has been an important diagnostic tool for magnetically confined fusion plasmas for the last three decades [3]. Recent developments in diagnostic design and detector technology have allowed tremendous advances in x-ray measurements, and in particular for the XICS diagnostic. This type of diagnostic in now installed at many of the major fusion facilities including Alcator C-Mod, NSTX, KSTAR and EAST, and an installation is underway at LHD. At C-Mod this diagnostic is now considered an essential diagnostic for profile measurements of the ion-temperature and toroidal rotation velocity.

The XICS diagnostic utilizes a spherically bent quartz crystal to provide a 1D image of line-integrated spectra from highly charged impurity species in the plasma. A conceptual diagnostic layout is shown in Fig. 2. At the temperatures routinely seen in current devices, T_i = 1-3 keV, the typical impurity used is helium-like Ar^{16+}. At the higher temperatures expected in ITER, helium-like Fe and neon-like W have been identified as favorable impurities. Measurements of the ion-temperature (T_i) are made from the Doppler broadening of the spectral lines, while the electron-temperature (T_e) is found from the relative intensities of dielectronic satellite lines to resonant emission lines. The Doppler shift of the lines is used to measure the plasma rotation velocities (V_θ and V_ϕ). Local temperature and rotation values can be inferred from these line-integrated spectra through tomographic inversion, which relies on a plasma equilibrium reconstruction. The XICS system can also play an important role in the monitoring of intrinsic impurities.

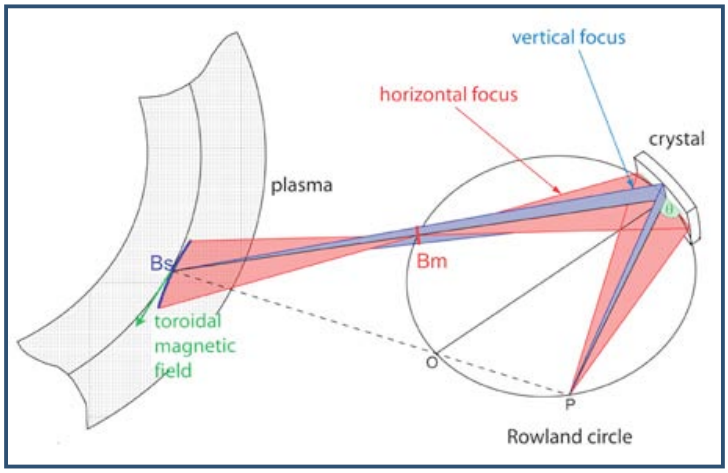


Fig. 2. Conceptual diagram of the XICS diagnostic geometry. Shown is a representation of the light cone corresponding to a single pixel on the detector (point P), which is placed on the Rowland circle. Because of the astigmatism of the spherically bent reflector, one obtains two mutually perpendicular (meridional and sagittal) line foci of the point P at Bm and Bs, respectively. Imaging is done in the vertical direction, allowing a full profile of the plasma to be recorded. Spectra are recorded in the horizontal direction on the camera based on the requirement that the Bragg condition is satisfied for the incoming x-rays. Each wavelength corresponds to a range of toroidal angles due to the astigmatism (exaggerated in this diagram); this is the preferred experimental arrangement on tokamaks where the x-ray emissivity is uniform along the field lines. The arrangement shown has rotational symmetry about the line normal to the crystal center (which passes through the point O).

The XICS diagnostic technique has benefited greatly from the development of x-ray detectors based on modern CMOS hybrid-pixel technology, in particular the Pilatus II

detector developed by the Paul Scherrer Institute and commercially produced by Dectris [4,5]. Each of these detectors comprises ~100,000 pixels, and has a pixel pitch of 172 × 172 μm^2. Each pixel has a high single-photon count rate capability of 2 MHz and low neutron response. These detector modules are radiation hardened and have been tested to a fluence of 10^{14} cm^{-2} using 1 MeV neutrons.

The non-perturbative nature of the XICS diagnostic has allowed it to play an integral role in studying RF heating and intrinsic rotation in recent experiments at C-Mod. A variety of experiments have been carried out to study the intrinsic (spontaneous) plasma rotation in L-mode, H-mode and internal transport barrier (ITB) plasmas [6]. These experiments are an important step towards the understanding of the physics behind intrinsic rotation and the extrapolation to ITER plasmas. In a different set of experiments using lower-hybrid current drive (LHCD), the XICS diagnostic was critical for the observation of localized self-generated flows caused by the driven current [7]. Similarly experiments have been done using ion-cyclotron radio frequency (ICRF) minority heating (MH) and mode conversion (MC), demonstrating that while MH ICRF has little effect on the flow velocities, MC ICRF can be used as an effective tool to drive toroidal and poloidal plasma rotation [8]. All three of these experiments have important implications for rotation and velocity shear control without the use of neutral beam injection. Before the installation of the XICS diagnostic these types of experiments were difficult, if not impossible, since the standard measurement technique, charge exchange recombination spectroscopy, requires beam injection, which adds both momentum and heating to the plasma. Data from the XICS system at C-Mod is illustrated in Fig. 3 showing both the raw spectra and the measured rotational velocity.

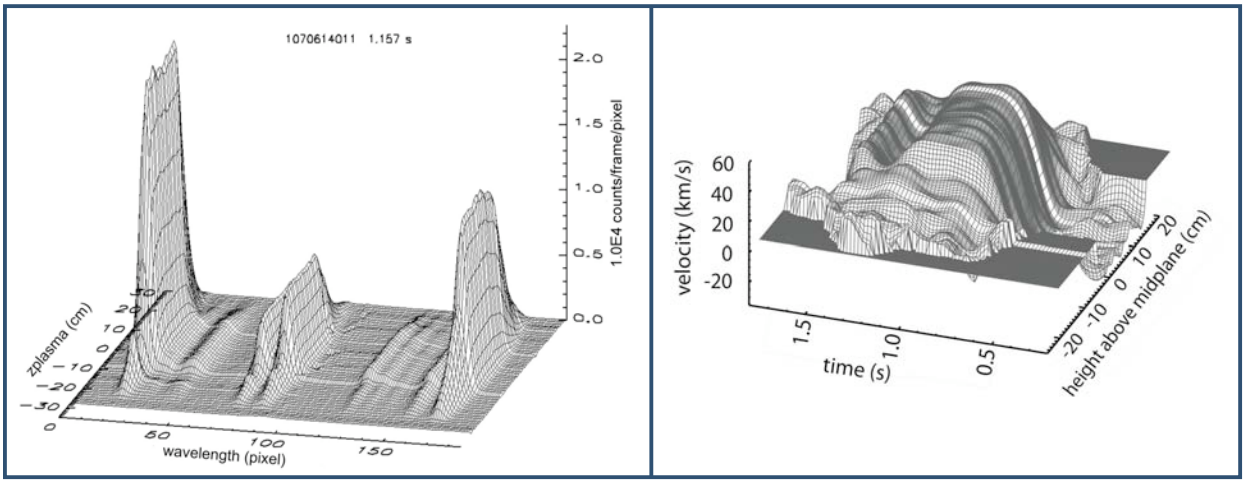


Fig. 3. Data from the XICS system on Alcator C-Mod (shot 1080306014). The figure on the left shows raw spatially resolved spectral data for a single time-frame. The apparent toroidal velocity, measured from the Doppler shifts of the emission lines, is shown in the right figure. In the initial Ohmic mode phase, the plasma is rotating counter to the plasma current direction. ICRF heating is added at t = 0.6 s causing the toroidal rotation to change direction and reach a value of 40 km/s. Between t=1.1 and 1.4 s, LHCD is added, reducing the rotation velocity, which recovers afterward until the end of the ICRF heating at 1.5 s.

Implementation of XICS on ITER has unique challenges, many of which have already been addressed by the teams at PPPL and LLNL, while others are being addressed in current and planed experiments. One challenge for deployment on ITER is the handling of the large neutron background. This background poses two problems: reduced signal-to-noise ratios leading to a reduction in measurement accuracy, and diagnostic lifetime due to damage of the detectors. We are currently working with several groups to develop radiation-hardened detectors that will address these concerns. The signal-to-noise issue can be largely eliminated though the use of a detector with adjustable lower and upper energy discriminators [2]. Testing

of such a detector, produced by the Medipix consortium, of which the ITER organization is a part, will be done on NSTX and C-Mod.

Another challenge for the ITER system will be maintaining an accurate wavelength calibration. For the current diagnostic installations, this calibration has been done by utilizing locked-mode plasma discharges where plasma rotation and, therefore, the Doppler shift of the emission lines, is expected to be zero. For ITER however this technique will not be feasible, and instead an external calibration source is required. Experiments are underway to determine the feasibility of using foils with absorption edges or known line sources to provide an in-situ wavelength calibration technique. To maintain an accurate wavelength calibration, the temperature of the crystal must be monitored and kept constant. As the crystal temperature changes, thermal expansion causes the crystal lattice spacing to change slightly. Even changes in the crystal temperature of ~1º C can have a significant impact on the final measured rotation velocity. The various sources of crystal heating are being studied on C-Mod, along with the development of techniques to regulate the crystal temperature.

This is an exciting time for the use and development of the XICS diagnostic technique. There are many experiments planned that will rely on data from this technique, and the diagnostic is maturing into a fully characterized and reliable system. Some highlights of upcoming experiments in the next year are:

- Additional studies of intrinsic rotation and momentum transport on C-Mod, EAST and KSTAR.
- Continued studies of RF heating (LH, ICRF and ECCD) on NSTX and C-Mod.
- Fast (20 kHz) XICS measurement on C-Mod using the newly developed Eiger detector from the Paul Scherrer Institute.
- Impurity monitoring and transport measurements utilizing intrinsic (Fe, Mo in NSTX, W in C-Mod) and injected impurities (Ar, Kr, Ca). In particular, analysis is underway to understand the effect on transport and MHD stability of non-deliberate release of Mo from the walls in C-Mod. These experiments will also allow for improved characterization of the emission spectra from these various species.
- Investigation of non-Maxwellian electron energy distribution functions though line intensity ratios in C-Mod. Particular emphasis will be on the effect of RF heating on the high-energy electron tail.
- Extension of the XICS diagnostic technique to stellarator geometries on LHD in Japan. This project will provide the highest spectral resolution of any of the currently installed systems. The lack of toroidal symmetry will provide a challenge in the development of accurate inversion techniques.

In addition to the continued development of XICS diagnostics, we are also developing other x-ray diagnostic techniques that utilize this new x-ray detection technology. An example is the energy resolving pinhole camera diagnostic, which is currently being developed for installation on Alcator C-Mod.

References

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Announcements

Submit BPO-related announcements for next month's eNews to Tom Rognlien.

Upcoming Burning Plasma Events

2011 Events

March 30 - April 1, 2011
20th ITPA Pedestal and Edge Topical Group Meeting
Cambridge, Massachusetts, USA

April 4-5, 2011
ITPA Transport & Confinement Topical Group Meeting
San Diego, California USA

April 5, 2011 abstract deadline closed
Edge Coordinating Committee Workshop on RMP
San Diego, California USA

April 6-9, 2011 abstract deadline closed
Joint US-EU Transport Task Force (TTF) Workshop
San Diego, California USA

April 11-13, 2011
ITPA Energetic Particles Topical Group Meeting
Frascati, ITALY

April 11-14, 2011
ITPA Integrated Operation Scenarios Topical Group Meeting
JET, Culham, UNITED KINGDOM

April 11-14, 2011 abstract deadline closed
Workshop on Stochasticity in Fusion Plasmas (SFP 2011)
Jülich, Germany

April 20-22, 2011 abstract deadline closed
2011 IEA Fusion Modeling Workshop on Materials
Lawrence Livermore National Laboratory, Livermore, CA

May 2-4, 2011
2011 International Sherwood Fusion Theory Conference
Austin, TX USA

May 9-13, 2011
13th International Workshop on Plasma-Facing Materials and Components for Fusion Applications (PFMC-13) and 1st International Conference on Fusion Energy Materials Science (FEMaS-1)
Rosenheim, Germany

May 15-19, 2011
15th International Conference on Emerging Nuclear Energy Systems (ICENES)
San Francisco, CA USA

May 16-19, 2011
ITPA SOL and Divertor Topical Group Meeting
Helsinki, FINLAND

May 23-26, 2011
ITPA Diagnostics Topical Group Meeting
FOM, NETHERLANDS

June 1-3, 2011
19th Topical Conference on Radio Frequency Power in Plasmas (CK Phillips and JR Wilson PPPL)
Newport, RI USA

June 20-24, 2011 registration deadline April 1
ITER International Summer School on MHD and Energetic Particles
Aix en Provence, FRANCE

June 26-30, 2011 abstract deadline closed
38th IEEE International Conference on Plasma Science (ICOPS) and the 24th Symposium on Fusion Engineering (SOFE)
Chicago, IL USA

Jun 27-Jul 1, 2011
38th European Physical Society Conference on Plasma Physics
Strasbourg, FR EPS

Fall 2011
ITPA Diagnostics Topical Group Meeting
CHINA

Sep 5-7, 2011
IAEA Technical Meeting on Theory of Plasma Instabilities
Austin, TX USA

Sep 8-10, 2011
IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems
Austin, Texas USA

TBA---tentatively scheduled
ITPA MHD Topical Group Meeting
Padova, ITALY

Sep 11-16, 2011
10th International Symposium on Fusion Nuclear Technology
Portland, Oregon USA

Sep 19-21, 2011
13th International Workshop on Plasma Edge Theory in Fusion Devices
South Lake Tahoe, California USA

October 5-7, 2011
ITPA Transport & Confinement Topical Group Meeting
Cadarache, FRANCE

October 5-7, 2011
ITPA Pedestal and Edge Topical Group Meeting
York, UNITED KINGDOM

Oct 16-21, 2011
15th International Conference on Fusion Reactor Materials (ICFRM-15)
Charleston, SC USA

October 18-21, 2011
ITPA Integrated Operational Scenarios Topical Group
Kyoto University, JAPAN

Nov 14-18, 2011
53rd APS Division of Plasma Physics Annual Meeting
Salt Lake City, Utah USA

December 2011 or January 2012
ITPA Divertor and SOL (PSI Selection Committee) Topical Group Meeting
Jüelich, GERMANY

December 12-15, 2011
ITPA CC & CTP-ITPA Joint Experiments Meeting
Cadarache, FRANCE

Directories of Other Plasma Events

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

Please contact the administrator with additions and corrections.