ITPA Topical Group on Diagnostics
Report on Activities in the period July 2010 – December 2011

The coordinated activities of the Topical Group on Diagnostics were continued over the period of July 2010 to December 2011, with an emphasis being placed on designated high priority topics. There were three meetings of the ITPA Topical Group (TG) on Diagnostics during that period.

1. Meetings of the Topical Group on Diagnostics

The Nineteenth Meeting of the ITPA Topical Group (TG) on Diagnostics was organized by the Japan Atomic Energy Agency (JAEA) from October 18 thru 21, 2010. The meeting was combined with a Progress Meeting on ITER relevant diagnostic developments in Japan, which took place on October 18 2010. The meeting was opened by Dr. H. Takatsu, and was attended by 46 participants drawn from Japan (29), EU (7), Korea (1), RF (5), USA (2) and the ITER IO (2), [no participants from China, India]. The meeting was scheduled immediately after the IAEA meeting in Korea.

The Twentieth Meeting of the ITPA Topical Group (TG) on Diagnostics was organized by the FOM Institute from May 23 thru 26, 2011. The meeting was combined with a Progress Meeting on ITER relevant diagnostic developments in Europe, which took place on May 23rd 2011. The meeting was opened by Dr. T. Donné, and was attended by 60 participants drawn from EU (32), China (5), India (2), Japan (5), Korea (1), RF (4), USA (7) and the ITER IO (4).

The Twenty-first Meeting of the ITPA Topical Group (TG) on Diagnostics was organized by the ASIPP Institute from October 17 thru 20, 2011. The meeting was combined with a Progress Meeting on ITER relevant diagnostic developments in China, which took place on October 17th 2011. The meeting was opened by Prof. J. Li, and was attended by 66 participants drawn from China (51), EU (5), Japan (2), Korea (1), RF (1), USA (4) and the ITER IO (2) [no participants from India].

A special attention was given to the High Priority Items. In addition to the special sessions, the key topics reviewed and discussed at the TG meeting were:

- Progress and plans in meeting the goals of the Physics Voluntary R&D tasks in Diagnostics and especially the high priority topics;
- Developments in the ITER measurement requirements and justifications of these measurements;
- Review of critical areas of ITER diagnostic design and integration, and their physics implications;
- Recent progress in ITER relevant diagnostic development and application in the Parties;
- Review the responses to the action items from the previous meetings of the ITPA Diagnostic TG and plan future actions;
- Review progress by the Specialist Working Groups in Diagnostics;
- Discussion on the date of the 22nd meeting and location of the 23rd meeting of the TG;
- Future activities.

2. High Priority Topics

Good progress has been made in the tasks designated as high priority:

2.1. HP#1: Development of methods of measuring the energy and density distribution of escaping α-particles

One key task that was identified in this task corresponded to the need to identify proper alpha particle orbits that can reach a potential detector. These orbits were calculated in 2 scenarios, and show that a smooth/flat outer wall would prevent a direct detection of particles. Options including wall modifications are still being evaluated, although difficult to implement. Orbit calculations will be continued which would include a quantification of alpha particle populations in the relevant orbits.

In order to fully assess the feasibility of a standard (e.g. pitch-angle, energy resolved) lost alpha detector, the following items have to be completed and forms the required work plan.

- Develop full orbit detection efficiency (status: nearly complete)
- Develop full MCNP neutron and gamma calculation including angular dependence (status: partial completion)
- Obtain full proposed detector response to ions, gammas, neutrons and secondary electrons (status: partial completion)
- Obtain full detailed 3D description of First Wall (status: partial completion, still evolving)
- Include full description (e.g. dimensions) of probe head in orbit description and detection efficiency (status: not started)
- Evaluate full heat flux calculation on probe head (status: partial completion)
- Incorporate full description of image/signal path (e.g. light collection efficiency) (status: partial completion)

A possible implementation of an escaping alpha detector based on a reciprocating probe was presented. The concept takes advantage of brief probe incursion to “catch” fast ions on escaping orbits while reducing heat flux issues, a concept that could reduce some of the issues mentioned above. However, the need for a comprehensive analysis of feasibility remains.

Progress of the conceptual design of an escaping fast alpha diagnostic based on activation technique has been presented and discussed. Improvement of the activation technique by using special detector material is possible. Materials that exhibit both high alpha activation yield and high purity properties are attractive candidates. A sample of highly enriched in isotope 76 germanium detector, and of high purity (99.9999%) was tested in an experiment at the TEXTOR tokamak. Compared to previous experiments, the time between the exposure and the measurement was reduced considerably allowing for the measurement of gammas emitted by short-lived radio-nuclides. Detailed data analysis is still ongoing. Preliminary results confirmed the detection of the 3 MeV fusion protons. A joint experiment is being proposed (DIAG-5) to further develop this concept on existing devices. Detailed concept studies for ITER have not been conducted, but likely require an in-situ detection (e.g. within the port plug). This scheme would offer spatial and pitch-angle resolution, energy selection but virtually no time resolution.

A review of the present understanding of issues and possible techniques for escaping alpha detectors has been presented at the last meeting (21st). Standard escaping loss detection techniques (Faraday cups and scintillator based) do not extrapolate favourably to ITER. Presently the best prospects remain in using so-called proxys, an intermediate medium for the diagnosis of alphas, possibly on escaping trajectories. These include: Ion Cyclotron Emission (passive and possibly active) and FIDA-like charge exchange (edge) measurements. A specially modified first wall module (blanket module) could be devised as to be able to separate fast ions (with large gyroradii) from standard heat flux (with small radial scale length). A concept based on laser induced breakdown spectroscopy could bring additional distribution and energy information. However, the feasibility of these concepts will require dedicated studies.

This high priority activity will continue.

2.2. HP#2: Assessment of the calibration strategy and calibration source strength needed

To achieve the required 10% accuracy in total fusion yields (e.g. neutron), a functional combination of neutron flux monitors, neutron profile monitors, and the activation system are needed, together with their in-situ calibrations, cross calibration, and establishment of reliable neutron transport calculation. In addition, since the needed dynamic range in neutron detection is rather large, and since limited strength calibration sources are available, cross-calibrations between detectors will be necessary, as it is normally performed in existing devices. This can be done with dedicated plasma discharges, and supported by appropriate MCNP calculations. The suitable calibration source is either a DT or DD neutron generator of source strength of 10^{10} n/s for DT and 10^{8} n/s for DD or better. While taking into account these generator yields, it is estimated that 2 neutron calibrations will be required, of 2 and 8 weeks duration respectively, which does not presently include the usually significant set-up time. Efforts are continuing in devising ways to optimize the number of calibration steps and to reduce the time necessary to complete it, while meeting the required accuracy. Options are being developed which may include additional or more sensitive detectors, additional calibration sources or slight changes to detector configuration. Finally, additional efforts will be required to minimize the self-shadow effects of the source/generator on the actual calibration results.

The Neutron Working Group has presented the final report regarding the neutron calibration strategy. Considering that the needed dynamic range in neutron detection in ITER is rather large, and since limited strength calibration sources and generators are available, cross-calibrations between detectors are necessary. This can be done with dedicated plasma discharges, and supported by appropriate MCNP calculations. While taking into account reasonably available neutron generator yields and source strengths, it is presently proposed to have 2 neutron calibrations, of approximately 2 and 8 weeks duration respectively, not including the usually significant set-up time. These durations are largely driven by meeting the required 10% accuracy in total fusion yield measurements. Efforts are continuing in devising ways to optimize the number of calibration steps and to reduce the time necessary to complete it, while meeting the required accuracy. Options are being developed which may include additional or more sensitive detectors, additional calibration sources or slight changes to detector configuration.

In view of these results, this HP item is now closed with a final report (**ITER_D_4LTLXC**) submitted to IDM. Results were also published in Rev. Sci. Instrum. (M. Sasao *et al.*, Rev. Sci. Instrum. **81**,10D329 (2010))

2.2.1 HP#2 (New): Assessment of the Plasma Control System measurement requirements.

One of the more urgent items of discussion was to review and update the needs for diagnosis of very fast electron populations (e.g. runaways) that could be generated during ramp-up and/or disruptions. Proposals for updating the measurement requirements include changes to energy (maximum and average) measurements, total current, and position and shape of the runaway channel. These changes will be iterated within the Topical group and with the IO PCS working group. In addition, potential measurement techniques have been assembled and will be evaluated against the requirements after they are reviewed. This will be part of the contribution to Charge 5 of STAC 10. Additional discussions will include avoidance scenarios and measurement requirements, and any special need associated with disruption mitigation.

2.3. HP#3: Determination of life-time of plasma facing mirrors used in optical system

The report of the Specialist Working Group on First Mirrors gave an overview of all activities in the field of first mirrors. Much ITER-diagnostic specific research is in progress at many laboratories worldwide, but in general more solution-oriented research is needed and should be supported. More refined geometries are continuously being introduced for predictive modelling, although gas/plasma background conditions need considerable refinements. The effort in this field should be intensified and accelerated to serve the rising needs. Further progress was reported in the field of deposition mitigation (e.g. by flowing gas in front of the mirror) and mirror cleaning, coated mirrors, mirror manufacturing and irradiation testing of mirrors. With the progress accomplished so far, it was agreed that the development of mitigation methods for metallic (beryllium, tungsten) deposition is fast becoming urgent.

A roadmap to direct the international R&D in the field of first mirrors has been prepared and has been further detailed and evolved in special breakout sessions during both TG meetings. The roadmap is now actively used to direct the international research in the field of first mirrors and the priority of these activities has been established and agreed upon. One step proposed is to cluster the various diagnostic mirrors in groups with approximately the same functional requirements and operational environment in order to recommend baseline solutions for each group on the basis of present knowledge. Furthermore, it was agreed that candidate mitigation methods to be used against deposition need to be reviewed in order to identify the most promising ones for further development.

Recent developments and research plans in the area of diagnostic mirrors were reviewed in the regular report of the FM SWG. The report outlined the progress in fulfilment of the Work Plan (WP) - the coordinated and prioritized plan of R&D on first mirrors.

The WP contains of 6 main areas (tasks):

- Performance under erosion-and deposition-conditions: material choice
- Predictive modelling of mirror performance in ITER
- Mitigation of deposition
- Cleaning of deposited layers on the mirror - surface recovery
- Tests under neutron, gamma and X-ray environment
- Engineering and manufacturing of ITER first mirrors.

The current research is already largely aligned with main areas of the work plan. In particular, promising results were presented on active control over carbon deposition in diagnostic ducts and remote areas – the complete suppression of carbon deposition was attained in the prototype of diagnostic duct by the deuterium gas feeding in the duct interior. Encouraging results were achieved on the cleaning of mirrors exposed in tokamaks: softer carbon films formed on the surfaces of the mirrors exposed in the divertor of DIII-D were cleaned completely and the reflectivity was restored, whereas harder films originating from TEXTOR were largely removed leading to the significant increase of the mirror reflectivity. Results from laser cleaning were reported from many laboratories was used to remove deposits. Important results were recently obtained in mirror cleaning techniques using laser irradiation. Significant improvement of optical reflectivity of treated mirrors was reported. However, in some cases the laser cleaning resulted in additional damage to the mirror surface. Applicability of these techniques for ITER conditions should be fully assessed.

Set of new molybdenum- and rhodium- coated mirrors were produced by evaporation and magnetron sputtering techniques at the University of Basel was exposed under erosion-dominated conditions in TEXTOR tokamak. Surface and optical characterizations revealed acceptable performance of all exposed mirrors: the reflectivity decreased insignificantly. Recently, the new experiment was carried out at higher fluence of eroding particles. Molybdenum mirrors withstood the erosion, the moderate decrease of the reflectivity was noticed for the Mo-coated mirrors. On a contrast, the Rh-coated mirror was severely sputtered by the plasma. This activity is being performed in the frame of collaboration program between FZJ and the University of Basel.

Single crystal molybdenum mirrors demonstrate an excellent performance under erosion-dominated conditions in tokamak experiments. Mirrors withstood fluences of eroding particles corresponding to several hundreds of ITER discharges without noticeable degradation of their reflectivity. The availability of such mirrors has recently increased significantly following new developments with industrial partners.

Studies of the shielding structures for the protection of retroreflectors were continued at LHD. V-shaped protection was introduced to mitigate the deposition on the mirror guiding the light to the retroreflector. The baffling of the optical channel was used to mitigate the impurity transport towards the retroreflector. Mitigation techniques were able to completely suppress the deposition on the retroreflector routinely observed under these conditions before.

A new topic is being added to the Work Plan. Investigations of diagnostic mirrors and in particular the assessment of the impact of conditioning discharges on the mirror performance is of significant importance. Therefore, it was decided to expand this area of the WP by introducing tests of ITER-relevant mirror under relevant conditioning techniques. The investigations of an impact caused by O-bake treatment of the tokamak were started as a collaboration effort between DIII-D and TEXTOR teams. Molybdenum and copper mirrors were placed in the main chamber and in the divertor where they were exposed for several hours in oxygen and helium mixture. Investigations are in progress.

Extensive predictive modeling of the mirror lifetime in ITER have been reported. This modelling focussed on particle transport in presence of mirrors and ducts with relevant species (D, C, Be). Deposition of material onto the mirror surface is dominated by particle reflecting or originating from the surface of the optical ducts. The flexible modeling tool is capable to handle ITER mirrors of different size, located at different distances from plasma at various angles of view and having variable conicity of the diagnostic ducts. The promising results were shown for the deposition mitigation by the fins installed in long diagnostic ducts. However, the large scatter in the input data on fluxes of particles, their energies, re-erosion coefficients presently leads to a relatively large uncertainty in predictions. The benchmarking experiments based on the modeling predictions are under preparation to narrow significantly the scatter in predictions and to reveal the mitigation effect of fins. These tests are presently being designed and implemented at various devices (TEXTOR, EAST, LHD, DIII-D). These dedicated experiments, made with various geometries of diagnostic ducts exposed under well-diagnosed plasma conditions, are important in validating these predictive models.

A few options for corrective mitigation of deposition have been described. These include laser cleaning, cascaded-arc source and microwave source particle flux cleaning. Each presents some challenges and R&D is presently being pursued at many laboratories.

The properties of several ITER-candidate mirror materials under erosion conditions were reported. Two exposures were performed in TEXTOR with single-crystal, Mo-nanostructure coated molybdenum mirrors along with Rh-coated mirror deposited by evaporation technique. The mirrors were kept under the same plasma conditions allowing for a direct comparison of the change of optical properties. During the first exposure at relatively mild erosive fluence, all studied mirrors demonstrated an acceptable performance. The maximum decreases of the reflectivity did not exceed 4%. However, after exposure to higher fluence, the Rh-coated mirror demonstrated a significant drop of reflectivity, reaching 25% at the UV range. Mo-coated mirrors demonstrated acceptable performance in the IR and VIS wavelength ranges, but with a 12% of decrease of reflectivity in the UV range. No significant change on the reflectivity of a single crystal mirror was detected, which seems to confirm the selection of single-crystal molybdenum as a prime candidate to be used in ITER diagnostics. Mirrors coated with fine-grain molybdenum layers represent another attractive concept for ITER first mirrors. Apart from good resistivity under erosion conditions, such coated mirrors are free from size limitation. The tests of industrial prototypes of magnetron coated Rh and Mo mirrors are underway. Additional tests were also performed on recrystallized tungsten mirrors at various temperatures to study the potential formation of blisters, which appeared to be dependent on sample manufacturing.

Prospects for the manufacturing of large, cooled, mirrors with adequate optical properties have also been presented.

With this so-far obtained knowledge and experience, we are poised to assemble and propose a first set (draft) of guidelines and resources for first mirror implementations that can be used by diagnostic designers. Also, in view of the present design cycle, it is now urgent to accelerate the R&D efforts in mitigating Be, Be-like and mixed deposits on mirrors, including model validation. A formulation of urgent tasks is being developed and resources sought to complete these in a timely fashion. Contributions from facilities/devices are particularly sought after. In addition, the evaluation of the impacts due to an early tungsten divertor installation needs to be undertaken.

Additional details can be found in Appendix 2, which covers the tasks made under the Joint Experiment umbrella. This HP item will remain.

2.4. HP#4: Development of measurement requirements for measurements of hot dust, and assessment of techniques for measurement of hot dust.

Recall that recent studies and discussions within the ITER Organization reached the conclusion that the inventories for dust and tritium are expected to reach their maximum limits on a timescale comparable to the target erosion lifetime. Based on this, a control strategy for dust and tritium had been formulated. Dust would be removed during the scheduled divertor replacements (approximately every ~4 years). Additionally the dust will be monitored during and before shutdowns. Local measurements will be benchmarked versus the tritium and dust recovered during the replacement of the divertor cassettes. The first benchmarking will be done in the hydrogen phase. Following these findings, the HP item was refocused on the remaining issue of hot dust, e.g. dust can be found on hot surfaces, that if exposed to steam could lead to an explosive situation.

An evaluation of the requirements on the presence of dust on hot surfaces (i.e. hot dust) has been formulated. It was found that a maximum of ~18kg of hot dust can be tolerated within the vacuum vessel. Separately, if one accounts for the total amount of dust that could be found within the vacuum vessel, it is estimated that up to ~40kg of dust could be uniformly distributed on hot surfaces, which would represent a factor of 2 above the safety limit derived above. With these estimations and constraints we are now ready to derive the relevant measurement requirements, and these will be reviewed at the next meeting. They will be the basis for the TG recommendations to the IO for inclusion in the full measurement requirements table.

Initial concepts for the development of a technique for measuring hot dust were also presented. Four techniques are presently under consideration. They are 1) Dust-steam reactivity measurement (controlled injection of water-steam), 2) Infrared methods (thermal analysis of surface emission), 3) Surface ranging by erosion monitor and 4) Ultrasonic detection (time-of-flight measurement within tile/shield module). Presently, the most promising candidates are 2) and 3).

While the topic of measurement requirements of cold dust appears resolved, the testing of the proposed technique (capacitance micro-balance) is still outstanding. However, the instrument has not been fully tested in a tokamak environment. Consequently, the testing is now underway as a Joint Experiment (DIAG-4) at AUG and KSTAR (see section 5.7 and Appendix 2). First results are expected towards the end of 2012.

A comprehensive summary of the findings can be found in ITER_D_4EF2ZJ (see publications). In view of the progress this HP item is now closed, although discussions and results of the testing(s) will be ongoing.

2.5. HP#5: Assessment of impacts of in-vessel wall reflections on diagnostics

Many of the optical diagnostics will have to work against the background of stray light coming from the plasma and, because the ITER plasma is much larger than existing tokamak plasmas, this problem will be more severe than that experienced thus far. The problem needs to be evaluated through a process of modeling and measurements on existing machines, and measurements of the reflectivity of relevant materials. Codes are being developed at UKAEA (and other labs) that can now include arbitrary sources of light (vs edge/divertor only) such as neutral beam emission. This work has also been extended to spectroscopic measurements where reflections can actually perturb the measured spectrum, and not just its apparent intensity.

In parallel, commercial packages have been evaluated within the IO, and many appear suitable for the task. These commercial packages may greatly reduce the development needed for in-house codes. In order to be fully integrated, they will require a full 3D rendition of the internal components of ITER, with the proper reflections coefficients. As a test, and using a much simplified optical model, this approach has been used to model the effects of reflected DNB emission on the active spectroscopic measurements. Depending on details of the blanket surface, the reflected edge CXRS signals from the beam could significantly pollute the core signals for upper port viewing systems. The situation appears less severe for the equatorial systems. The software is readily available and permits the quick importation of 3D CATIA models as well as scans of Bidirectional Reflectance Distribution Function (BRDF) effects. Such packages would be a powerful tool for simulating and qualifying diagnostic performance on many existing devices. They are also being used successfully to simulate plasma radiation loads on in-vessel components.

Extensive R&D efforts are ongoing at W7-X to quantify and study the effects of stray microwave radiations onto diagnostics and other in-vessel components. The research plans were presented alongside with initial results, indicating the importance of understanding these effects in W7-X, and likely in ITER as well. Therefore, it is proposed to enlarge the scope of this item to include effects of stray microwave radiation on (all) diagnostics.

In fact, in ITER, the expected ECRH stray radiation during heating and current drive has been crudely estimated to be ~5% of the heating power of 24 MW, i.e. 1.2 MW @ 170 GHz, and 0.5 to 1 MW at 60 GHz from the CTS gyrotron(s). With ITER having a larger wall surface but being a highly reflective all-metal machine, the stray radiation problem can be expected to be very similar to the situation expected in W7-X. Furthermore, recent results from the tests of effects of ECRH stray radiation experiments in the MISTRAL test chamber at Wendelstein 7-X has been given. Details of the invessel cables, material, geometry and construction were found to be important to avoid overheating and/or arcing. Guidelines for protecting windows and instruments behind them were also shown. These included using metallic meshes, special ceramic coating and using etalon techniques. Large area stray radiation sinks may also help in reducing overall levels of microwave power.

We are now poised to start elaborating some possible strategies (guidelines) to limit the impacts of reflection.

This HP item will remain.

2.6. HP#6: Assessment of the measurement requirements for plasma initiation and identification of potential gaps in planned measurement techniques

The early phase of plasma formation and control may require additional or special measurements different than during the flat top phase. A special session was held during the Fall 2009 meeting to review the experience from existing devices and to project potential additions or changes to the ITER measurement requirements. The periods in question include in-between discharges, breakdown, ramp-up and ramp-down periods. Calibration needs are also very important, especially in terms of magnetic structure measurements. Results from KSTAR, EAST, JET, ASDEX, DIII-D, C-Mod, TCV, and others were presented and discussed.

Areas of interest include measurements between discharges (e.g. wall conditioning, gas composition, erosion, etc), at breakdown (e.g. null structure, impurity levels, etc), at the ramp-up phase (density, current profile, etc), and ultimately at the ramp-down phase (e.g. density, radiation levels, etc).

In regards to the first aspects (First plasma operation on ITER), discussions were held on the current diagnostic implementation plan. Still of concern is the lack of density measurement, and possibly a reduced visible/IR viewing coverage. In the case of density measurements, it may be possible to mitigate the lack of standard interferometry by using the low field side reflectometer and/or a simple

Bremmstrahlung measurement using the spectroscopic systems (visible and VUV). Issues may arise in the measurements of radiated power as levels may be too low for the standard set, an increased aperture system could be used for that purpose. Concerns have been expressed for diagnosing run-aways/slide-aways during that phase, and action items have been generated to help in further defining the requirements for this measurement (see HP#2).

These discussions were also made in the context of the proposed deferrals (cost containment) and how they could affect physics performance and research programs. In addition, the impacts on diagnostics of going directly to a tungsten divertor without going through a carbon version need to be examined.

In the second aspects (initiation of individual discharges), concerns have been raised in the capability of measuring current profiles during ramp-up. Extensive simulations were presented for the expected performance of the poloidal polarimeter system. Two major points were discussed: the first one concerns the measurement of the current profile during ramp-up, and the second one relates to the performance of the system with reduced number of chords. For the first point, it was recognized that the current profile during ramp-up would likely be measured by the polarimeter. For the second point, although the loss of some polarimeter chords can be accommodated, the loss of the upper port view may jeopardize the system, especially while considering constraints added to the MSE system (e.g. beams).

This HP item will remain.

3. Party Reports

During the Progress Meetings on ITER relevant diagnostic developments in Japan (combined with the 19th meeting), in the EU (combined with the 20th meeting), and in China (combined with the 21st meeting) Japanese, European and Chinese scientists, respectively, presented their work on a large variety of diagnostic systems in preparation for ITER. Many of these presentations were directly related to the high priority research topics of the TG.

Representatives of the ITPA Party Teams (PTs) reported steady progress for many diagnostic techniques that are ITER relevant. It is clearly evident that many scientists working on diagnostics in the various PTs are becoming more aware of the problems and challenges of implementing diagnostics on ITER. This is again demonstrated by the large attendance to the meetings. Emphasis in the presentations is now shifting from detailed integration and implementation as needed in fulfilling procurement arrangements to more generic issues, including impacts of the selected design on scientific capability and development of alternate techniques.

4. Specialist Working Groups

The eight Specialist Working Groups (SWGs) continue to work in a focussed manner in their specific fields (active spectroscopy, passive spectroscopy, neutrons, first mirrors, first wall, laser-aided, and radiation effects). Good progress was reported by the SWGs for many of the current action items. Most of the work described above under the high priority issues has been the result of the coordinated effort within the various SWGs. The work on many action items has been completed and a number of new action items were formulated at the meetings. The SWGs include now more than 200 participants distributed amongst all parties and the IO.

Table 1 summarizes the current list of chairs, and co-chairs (December 2011).

SWG	Chair	Co-Chair	IO Co-Chair
Active Spectroscopy	N. Hawkes (EU)	S. Tugarinov (RF)	M. von Hellermann
First Mirrors	A. Litnovsky (EU)	V. Voitsenya (RF)	R. Reichle
First Wall	C. Skinner (US)	D. Rudakov (US)	R. Reichle
Laser Aided	M. Beurskens (EU)	Y. Kawano[1] (JA)	G. Vayakis
Microwave	G. Conway (EU)	M. Austin (US)	V. Udintsev
Neutrons	S. Popovichev (EU)	D. Darrow (US)	L. Bertalot
Passive Spectroscopy	B. Stratton (US)	W. Biel (EU)	R. Barnsley
Radiation Effects	B. Brichard[1] (EU)	T. Nishitani[1] (JA)	C. Walker

Table 1. Chair and co-chairs for the Specialist Working Groups (December 2011). [1] Expected to be replaced over the next year

5. Progress in other specific fields

5.1. Current profile measurement Issues

Concerns continue to be raised for the capability of measuring current profiles during ramp-up (see also HP#6). Extensive simulations were presented for the expected performance of the poloidal polarimeter system. Two aspects were discussed: the first one concerns the measurement of the current profile during ramp-up, and the second one relates to the performance of the system with reduced number of chords. For the first aspect, it was recognized that the current profile during ramp-up would likely be measured by the polarimeter. For the second aspect, although the loss of some polarimeter chords can be accommodated, the loss of the upper port view may jeopardize the system, especially while considering constraints added to the MSE system (e.g. beams).

5.2 Coherence imaging and divertor flow measurements

First results of the coherence imaging technique on TEXTOR and DIII-D have been obtained. This technique allows the extraction of ion temperature and rotation velocity across a 2-D field using charge exchange emission. The technique is also being applied the analysis of the polarisation characteristic of MSE emission, again in two dimensions. As well as the extra physics information available from 2-D measurements, this technique offers the possibility of excluding parts of the image, which can be polluted by reflected light. This could be applied to presently unmet flow measurement requirements in ITER.

5.3 Fuel ion ratio measurements

Much progress has been reported in the last few years regarding the needed measurements of the ion fuel ration during D-T discharges. In the past these measurements appeared to be very difficult to perform. The proposed techniques for measuring the fuel ion ratio include neutron spectrometry, collective Thomson scattering, and CXRS. Each technique exhibits limitations, although perpendicular CTS probing may be possible through ion Bernstein excitation.

The collective Thomson scattering (CTS) group at Association EURATOM-Risø DTU, Denmark, has demonstrated that the isotopic composition (or fuel ion ratio in reactors) can be inferred from CTS diagnostic measurements. Under certain measurement geometries the CTS spectrum becomes sensitive to ion Bernstein waves and ion cyclotron motion, which in turn is sensitive to the ion species in the plasma. The proof-of-principle measurements were done at the TEXTOR tokamak in collaboration with FOM and Forschungszentrum Jülich, and is an important step towards a new diagnostic method, able to measure the fuel ion ratio spatially (approx 200 mm) and temporally (approx 100 ms) resolved in the core of a burning plasma. The ^{3}He content in the plasma were inferred from the CTS spectra and found to be consistent with values obtained from passive spectroscopy.

5.4 Microwave systems

A report (ITER_D_33ZRFR / MWG-55F-0902) was prepared on the generic calibration and test requirements of the ECE/Reflectometer microwave transmission system. The report highlights the importance for all ITER diagnostics to have established test and calibration procedures. For the generic antenna/waveguide transmission line systems of the microwave-based diagnostics the report identified some 18 specific sets of procedures and tests to be performed before, during and after the diagnostic system installation. These include testing and documenting individual component performance (to allow subsequent monitoring of component degradation) as well as the antennae and overall system performances. The diagnostic safety features (such as stray radiation protection) and the specific in-situ calibration hardware will also require periodic testing for correct functionality.

The MWG also presented the results from ASDEX-upgrade on the proof of performance of the position reflectometer technique. Results showed reasonable control of the plasma radial position, in L and H-mode conditions.

5.5 Data Analysis and Validation

Efforts are continuing in developing techniques for the data analysis of data sets encountered in present and future fusion experiments, including ITER. It is expected that the amount of data generated in each ITER discharge can exceed present-day approaches of data analysis and/or handling. A variety of issues are envisioned, such as fault conditions, pattern recognition, large data set handling, etc. These issues lend naturally to the necessary data validation and processing for advanced control, as expected to be developed and required in ITER. Particular attention is being devoted to calibration, data validation, prediction and automatic identification of events (for the management of large databases).

5.6 International Diagnostic Database

The activity levels of the International Diagnostic Database have been relatively low. Discussions are presently onging between the IO and the TG in regards to long term plans for the database.

5.7 ITPA TG web site

The migration of the TG web site to its new home at ITER is progressing well. We are continuing to transfer the large number of files from the previous meetings to the new location, including more general documents of interest to the group. The access point for the web site can be found at https://portal.iter.org/departments/FST/ITPA/DG/DIAG/default.aspx . The presentations and other files are behind individual usernames and passwords.

5.8 Joint ITPA/IEA Experiments

The Joint ITPA/IEA experiments in the field of diagnostics were discussed in these meetings.

Headings, spokepersons and devices are detailed in Appendix 2.

DIAG-2, which covers first mirror tests and mitigation techniques, has been already covered within HP#3.

A joint experiment (DIAG-3) to resolve the discrepancy between measurements made by ECE and Thomson scattering that occurs at high temperature under some conditions was launched by the end of 2007. First results of this activity were reported last year. New results from C-Mod have been reported, under a variety of RF heated heating schemes (minority heating and mode conversion heating). No discrepancy has been observed up to T_e<8keV.

DIAG-4 covers the test of capacitance micro-balances in tokamaks (AUG and KSTAR). This diagnostic aims at measuring cold dust contents and is presently scheduled to be installed in ITER, but lacks testing in fusion devices. No experimental data is available yet, but operation of these balances is expected in 2012.

DIAG-5, which proposes the test of (fast ion) activation probes, has not been taken by any device at this stage.

Discussions are ongoing for the possible inclusion of a new Joint Experiment (DIAG-6), which would involve operating devices with no or reduced set of inner wall magnetics.

6. Publications

Two papers co-ordinated by either the TG or by the SWGs have been presented at the 2010 FEC IAEA Conference on the following topics: progress in HP issues, and first mirrors. Also a paper from the IO on the implementation of diagnostics systems on ITER has been presented. New synopses, presently four, are being prepared for the 2012 FEC IAEA conference to be held in San Diego, USA. They are:

- *Overview of the ITPA TG diagnostics activities* – by H. Park and the TG
- *Overview of the First Mirror development activities* – by A. Litnovsky and the First Mirror SWG
- *Overview of microwave diagnostic design and selection* – by G. Conway and the Microwave SWG
- *Analysis of current profile measurement capability on ITER* – by R. Imazawa et al.

Titles and authors are tentative at this point. A companion paper is expected from the IO on *Progress in ITER diagnostic* (author TBD).

An overview of the publications by the ITPA TG on Diagnostics is included as Appendix 1.

7. Plans for Future Meetings

The 22nd meeting of the Diagnostics TG has been approved and will be organized by the Kurchatov Institute, RF from 14 - 17 May 2012. A special session will be held on the assessment of the measurement requirements for plasma control (HP#2). The meeting will be combined with a Progress Meeting on ITER Relevant Diagnostic Developments on-going in Russia. The 23rd meeting is tentatively scheduled to be held in India during late Fall 2012.

R.L. Boivin
H. Park
G. Vayakis

15 December 2011

Appendix 1
Publications by the ITPA TG on Diagnostics 2009-2010

Publications in peer-reviewed journals

- M. Sasao, L. Bertalot, M. Ishikawa, and S. Popovichev, *Strategy for the Absolute Neutron Emission Measurement on ITER*, **81**, Rev. Sci. Instrum.10D329 (2010)

- Litnovsky, M. Laengner, M. Matveeva, Ch. Schulz, L. Marot, V.S. Voitsenya, V. Philipps, W. Biel , U. Samm, *Development of in situ cleaning techniques for diagnostic mirrors in ITER*, Fusion Engineering and Design, Vol. 86, Issues 9-11, October 2011, Pages 1780-1783

Presentations at the 2010 IAEA Fusion Energy Conference, Korea

- R.L. Boivin, H. K. Park, G. Vayakis, for the ITPA Topical Group on Diagnostics*, R&D ITPA Activities in Support of Optimizing ITER Diagnostic Performance,* Paper ITR-P1-02

- Litnovsky, V. Voitsenya, D. Thomas, M. Rubel, G. De Temmerman, L. Marot, K. Yu. Vukolov, I. Orlovskiy, W. Vliegenthart, Ch. Skinner, D. Johnson, V. Kotov, J.P.Coad, A. Widdowson, G. Vayakis, R. Boivin, M. Joanny, J-M. Travere, and the members of the ITPA Specialists Working Group on First Mirrors, *Mirrors for ITER diagnostics: new R&D developments, assessment of the mirror lifetime and impact of the mirror failure on ITER performance*, Paper ITR-P1-05

- M. Walsh, P. Andrew, R. Barnsley, L. Bertalot, R. Boivin, D. Bora, R. Bouhamou, S. Ciattaglia, G. Counsell, M. F. Direz, J. M. Drevon, A. Encheva, T. Fang, G. Janeschitz, D. Johnson, K. Junghee, Y. Kusama, H. G. Lee, F. Le Guern, B. Levesy, A. Martin, R. Reichle, K. Patel, C. S. Pitcher, A. Prakash, N. Taylor, D. Thomas, V. Udintsev, P. Vasu, G. Vayakis, E. Veschev, C. Walker, A. Zvonkov*, Overview of high priority ITER Diagnostic systems status,* Paper ITR-P1-07

Internal reports submitted to ITER IDM system

- G. D. Conway, V.S. Udintsev, M.E. Austin, T. Estrada, W. Suttrop, J. W. Oosterbeek, J-L. Ségui, H.J. Hartfuss, A. Silva, A. Krämer-Flecken, N. Oyama, K. Shinohara, V.A. Vershkov, V. Poznyak, J.F.M. van Gelder, M. Zerbini, P. Blanchard, T. Tokuzawa, G. De Masi, R. Cavazzana, S. Schmuck, G. Vayakis, A. Isayama, M. Sato, C. Lau, G. R. Hanson, A. Dominguez*, Survey and assessment of ECE and Reflectometer calibration techniques,* ITER_D_3622CE/MWG-55F-1102

- G.D. Conway, G. R. Hanson, W.A.Peebles, A. Stegmeir, *Antenna configuration options for the ITER low-field-side (LFS) reflectometer*, ITER_D_35AHBB/MWG-55F-1104

- G.D. Conway, G. Vayakis, G. Hanson, T. Estrada, *Physics basis for reflectometer measurements in ITER and an assessment of the low-field-side reflectometer requirements*, ITER_D_3DD6K5 v1.1/RWG-55F-0903

- M. Sasao, S. Popovichev, L. Bertalot and the Neutron Working Group, *Calibration of Neutron Diagnostic Systems for Absolute Fusion Output Measurement on ITER* , ITER_D_4LTLXC

- J. Kim, *ITER PWI diagnostics (Dust, Erosion, Tritium retention)*, ITER_D_4EF2ZJ

This list does not include individual papers published by members on specific ITER diagnostics or non-ITPA R&D. Many additional publications and presentations were made at the IAEA meeting, HTPD conference on diagnostics, and other various diagnostic workshops held during that period. That list is too long to describe in details here and are summarized in the working groups' reports.

Appendix 2

ITPA Joint Experiment Diagnostic Tasks

DIAG-2 **Environmental tests on Diagnostic First Mirrors (FMs)**

DIAG-3 **Resolving the discrepancy between ECE and TS at high T_e**

DIAG-4 **Field test of a Capacitance Diaphragm Gauge as a Dust Monitor for ITER**

DIAG-5 **Field test of an activation probe (new)**

DIAG-2 Environmental tests on diagnostic first mirrors

Spokes person: **A. Litnovsky**

Key persons: **I. Orlovskiy (T-10), A. Litnovsky (TEXTOR), Th. Loarer (Tore-Supra), M. Rubel (JET), D. Rudakov (DIII-D), J. Chen (EAST, HT-7), A. Herrmann (AUG), N. Ashikawa (LHD), C.Skinner (NSTX), V. Voitsenya, Y. Zhou (HL-2A), V.Kumar (Aditya), G. Maddaluno (FTU), G. De Temmerman (MAGNUM PSI).**

Devices: **T-10, TEXTOR, Tore-Supra, JET, LHD, AUG, FTU, NSTX, HL-2A, Aditya, EAST, MAGNUM PSI**

Purpose and goals:

Mirrors will be used in all optical and laser diagnostics in ITER to observe the plasma radiation. The performance of respective diagnostics will rely on the characteristics of mirrors outlining the need in high-performance robust mirror solutions for ITER. Recently, the prioritized work plan (WP) of the R&D on diagnostic mirrors was developed. The aim of the WP is to provide the set of measures to be fulfilled to ensure the maximum lifetime of the high-performance mirrors in ITER – to enable the so-called baseline mirror solution. The WP consists from six main directions – tasks:

- **Performance under erosion- and deposition- dominated conditions: material choice;**
- **Modeling of the impact of plasma, neutral and neutron environment on optical properties of diagnostic mirrors;**
- **Mitigation of deposition;**
- **Cleaning of deposited layers;**
- **Tests under neutron, gamma and X-Ray environment;**
- **Engineering and manufacturing of ITER first mirrors.**

DIAG-3 Resolving the discrepancy between ECE and TS at high T_e

Spokes person: A. White

Key persons: M. Austin (DIII-D), T. Hatae (JT-60U), A. Isayama (JT-60U), F. Orsitto (FTU), S. Prunty (JET, UCC), C. Sozzi (JET, CNR), W. Suttrop (ASDEX-UG), G. Taylor (TFTR), A. White (DIII-D, C-Mod)

Devices: JET, JT-60U, ASDEX-UG, DIII-D, FTU and TFTR (using old data)

Status: **Continued**

Background: In auxiliary heated high-temperature plasmas in JET and TFTR, clear discrepancies (up to several tens of %) have been measured between the electron temperatures measured by electron cyclotron emission (ECE) and Thomson scattering (TS). The discrepancy (in plasmas without ECCD or LHCD) has been seen in JET with ICRF plasmas, above electron temperatures of ~5 keV, and at TFTR in ICRF+NBI plasmas above 7 keV. No discrepancy has been found at C-Mod for ICRF plasmas up to ~8.5 keV. No evidence of deviations from a maxwellian distribution of the bulk electrons has been seen at DIII-D in NBI+FW plasmas up to 9.5 keV, or in ECRH +NBI plasmas up to 15 keV.

DIAG-4 Field test of a Capacitance Diaphragm Gauge as a Dust Monitor for ITER

Spokes person: E. Veshchev (previously P. Andrew)

Key persons: S. H. Hong (KSTAR), A. Herrmann (AUG).

Devices: KSTAR, AUG

Status: **Continued**

Purpose and goals:

The ITER dust strategy includes monitoring local dust levels in the bottom of the machine (under divertor targets). The aim is to correlate local levels with dust removal activities in early phases of operation to get some indication of dust inventory during operation.

A microbalance based on a capacitive diaphragm principle has been investigated as a diagnostic method, and has the advantage of measuring directly measuring the weight of the dust. Although this technique has shown promise in controlled laboratory tests, it has never been tested in a tokamak environment where thermal cycling and a noisy electromagnetic environment can affect the measurement.

Local dust monitors have been proposed for ITER and these are nominally expected to be of the capacitive diaphragm microbalance type.

The object of this joint experiment would be to demonstrate the operational functionality of a capacitance diaphragm gauge in existing devices.

DIAG-5 Field test of an activation probe

Spokes person: G. Bonheure

Key persons:

Devices: NEW

Status: **NEW**

Background

Measurement of energetic ion losses (e.g. alphas) remains difficult, and alternatives are sought for ITER. A number of techniques have been proposed and are being considered. The performance and reliability of the standard ion loss measurement techniques based on direct particle detection are questionable as the detectors will have to operate in the harsh ITER first wall environment. New and more robust techniques need to be developed in order to minimize risks and increase measurements' reliability.

Recent experimental studies on JET [1] have shown that a technique based on charged particle in-vessel activation is able to generate absolute measurements of fusion proton loss. The same technique could be developed and used for measuring the loss of alpha particles in ITER.

Appendix 3
Members of the ITPA TG on Diagnostics 2010-2011

PARTY	FAMILY NAME, FIRST NAME	AFFILIATION
CN	Fan, Tieshuan	PKU
CN	Hu, Liqun	ASIPP
CN	Yang, Qinwei	SWIP
CN	Zhao, Junyu	ASIPP
CN	Zhong, Guangwu	SWIP
EU	Beurskens, Marc	UKAEA
EU	Donné, Tony	FOM
EU	Ingesson, Christian	F4E
EU	Koenig, Ralf	IPP
EU	Litnovsky, Andrey	FZ-Jülich
EU	Murari, Andrea	ENEA
EU	Weisen, Henri	CRPP
EU	Zoletnik, Sandor	HAS
IN	Pathak, Surya K	IPR
IN	Rao, CVS	IPR
IN	Vasu, P	IPR
IO	Barnsley, Robin	IO
IO	Vayakis, George	IO
JA	Itami, Kiyoshi	JAEA
JA	Kawahata, Kazuo	NIFS
JA	Kawano, Yasunori	JAEA
JA	Kusama, Yoshinori	JAEA
JA	Mase, Atsushi	Kyushu Univ.
JA	Peterson, Byron	NIFS
JA	Sasao, Mamiko	Tohoku Univ.
KO	Lee, HG	NFRI
KO	Lee, JH	NFRI
KO	Lee, SG	NFRI
KO	Nam, YU	NFRI
KO	Park, H	Postech
RF	Kaschuk, Yu	TRINITI
RF	Krasilnikov, A	RF DA
RF	Ljublin, B	Efremov Institute
RF	Petrov , M	Ioffe Institute
RF	Vukolov, K	Kurchatov Institute
RF	Zaveriaev, V	Kurchatov Institute
US	Allen, Steve	LLNL
US	Boivin, Réjean	GA

US	Brower, David	UCLA
US	Hillis, Don	ORNL
US	Johnson, David	PPPL
US	Stratton, Brent	PPPL
US	Terry, Jim	MIT