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R&D ITPA ACTIVITIES IN SUPPORT OF OPTIMIZING ITER DIAGNOSTIC PERFORMANCE

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and SPECIALIST WORKING GROUPS on DIAGNOSTICS

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GENERAL ATOMICS

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The mission of the International Tokamak Physics Activity Topical Group (TG) on Diagnostics is to develop and identify solutions for diagnostic techniques, which are necessary for the fulfilment of ITER scientific goals while remaining compatible with its predicted harsh environment. While much progress has been reported in the detailed design and integration of these diagnostics, a few generic issues related to ITER environment are still outstanding. These issues are the focus of the TG's high priority items and are highlighted in this paper.

Development of methods of measuring the energy and density distribution of escaping alpha particles. The direct detection of losses of fast ions (e.g. alpha particles) brings very difficult implementation issues in a Burning Plasma Experiment such as ITER. In such conditions two major issues may prevent standard techniques to be fielded. The first one relates to the need to install detectors very near, or at the surface of the first wall, where they would experience large radiation and heat fluxes. The second one relates to the need of including modifications of the first wall in order to allow escaping ions to reach the detectors before being intercepted by the surface of the blanket modules. In both cases, the development of a technique requires detailed calculations of the orbits, with a complete 3D description of the first wall.

Assessment of the calibration strategy and calibration source strength needed for the neutron diagnostics. The dynamic range required for neutron detection spans eleven orders between calibration and full power ITER operation. Since the source strength of available calibration sources is limited, potentially long calibration times and multiple cross-calibrations will be necessary for the neutron diagnostics. The development of stronger neutron generators is likely to be required. In addition, the cross calibration will require a certain number of dedicated plasma discharges, as well as comprehensive MCNP calculations. These calculations are presently particularly difficult as they are highly dependent on the final overall ITER configuration, including the presence of neutral beams, port plugs and other massive components. While taking into account reasonably available neutron generator yields and source strengths, the calibration of all neutron systems may require as much as two months. Efforts are continuing in devising ways to optimize the calibration and reduce the time necessary to complete it, and may impact the design of the neutron diagnostics.

Determination of the lifetime of plasma facing mirrors used in optical systems. Front-end components of ITER optical diagnostic systems will experience a very large flux of neutrals atoms and high levels of neutron irradiation. Under such harsh conditions, conventional optics often cannot be used and mirrors must be employed. However, plasma-facing mirrors are likely to suffer erosion and/or deposition depending on their location and geometry. These degradations will limit the useful lifetime of the diagnostics while replacement of a mirror will be a technically difficult operation. Consequently, the protection of mirrors, use of new materials to resist erosion, and in-situ cleaning of mirrors will be necessary.

Assessment of techniques for measurement of dust and erosion. A key measurement required for the operation of ITER is the accounting of the tritium inventory inside the tokamak. This in turn requires an accounting of dust and erosion within the vacuum vessel. Recent studies indicate that the inventories for dust and tritium are expected to reach their maximum limits on a timescale comparable to the divertor target erosion lifetime. Based on this expectation, a control strategy for dust and tritium has been formulated. Dust will be removed during the scheduled divertor replacements (approximately every 4 years). Additionally the dust will be monitored during and before shutdowns. During the replacement of the divertor cassettes, local measurements will be benchmarked against the tritium and dust recovered. The first benchmarking would be done in the hydrogen phase. To support this strategy additional diagnostics were added to the ITER baseline for measuring dust and erosion. They are the divertor erosion monitor, removable samples (dust generation), micro-balance (dust) and laser induced desorption (tritium). However, an outstanding issue remains for the measurement of hot dust, for which a finalization of the requirements is not complete. Techniques to address this remaining need have not been identified as of yet, and options are being explored.

The assessment of impacts of in-vessel wall reflections on diagnostics. Many of the optical diagnostics will have to work in the presence of the background of stray light originating from the reflection of plasma light by the first wall. Since the ITER first wall will be conformal and more reflective than that of existing devices, this problem is likely to be more severe than that experienced thus far. The difficulty lies in the need for a quantitative evaluation through modeling, and with detailed measurements of the reflectivity of relevant materials, in the relevant conditions. For this analysis, there is a growing consensus requiring the development of an approach based on bi-directional reflectance distribution function (BRDF) calculations, which is widely used in other fields, for the standardization of reflection coefficients. The modeling calculations remain to be confirmed on a tokamak with a set of completely characterized tiles. Measurements are also needed to establish whether or not *in-situ* checks of the evolution of the reflectance with exposure to plasma discharges are possible.

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 discharge flattop phase. The periods in question include in-between discharges, breakdown, rampup and rampdown periods. These include key parameters such as first wall conditions, impurity levels, magnetic structure and electron density.

Other topics. The presence of high power microwave energy within the tokamak from electron cyclotron heating sources could create additional hazards to diagnostics, which are not limited to microwave-based diagnostics. Stray (unabsorbed) microwave radiation generated during off-normal tokamak operation will have a major detrimental impact on the ITER microwave based diagnostics, such as reflectometry and electron cyclotron emission. Stray radiation can arise from poorly absorbed gyrotron beams (e.g. low plasma density, exotic heating schemes or fault conditions) as well as from fast/runaway electron-generated bremsstrahlung during breakdown and disruption events. Moderate radiation will cause signal corruption, while at extreme levels sensitive semiconductor detectors and waveguide components face destruction from power overload, cavity arcing and thermal heating. Other non-microwave diagnostics and in-vessel components also face potential damage. Various protection options for ITER are proposed, including fast-acting waveguide shutters, hardened filters, fuses or sacrificial elements and exotic radiation absorbing materials and gases.

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