Conceptual design of the ITER fast ion loss detector


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In ITER, the fusion reactions and the use of neutral beam and ion cyclotron heating systems will generate fast ions. These can be expelled from the core region to the plasma edge by various instabilities. Fast ion loss can adversely affect confinement and plasma heating and can lead to appreciable heat load on the plasma facing components. ITER currently does not have any diagnostic for fast ion loss measurements.

Fast ion loss detector (FILD) is one of the most widely used diagnostics for measuring fast ions in the plasma edge. A fraction of the incident fast ions are transmitted into a FILD where they encounter a detector consisting of a scintillator plate and/or an array of the Faraday cups. The interaction of fast ions with the detector provides measurements of their energy and the velocity pitch with the time response up to the Alfvénic frequency (~100kHz). This allows extracting information about the underlying loss process. FILDs are installed in all major tokamaks. The ITPA Topical Group on Energetic Particles has selected a FILD as the most preferred diagnostic for fast ion loss measurements in ITER. In response to this prioritization, the Port Plugs and Diagnostics Integration Division at ITER Organization (IO) initiated an effort to develop a conceptual design of a reciprocating FILD in ITER.

The harsh environment in ITER – a nuclear installation – places a number of requirements on the FILD design, unprecedented in tokamaks with easier access and more tolerable conditions. During the measurement, a FILD will be exposed to thermal plasma and fast ion heat loads. In its resting position, a FILD will be permanently exposed to nuclear heating (~10 MW/m³), gammas and plasma radiation (~100 kW/m²). The avoidance of jxB force due to Halo currents during unmitigated disruptions requires retraction of a FILD into the magnetic shadow of a port within ~10ms. The mechanical design must be also extremely reliable and safe because of no possibility of any kind of repair.

This contribution presents the conceptual design of the ITER FILD, developed jointly by IO and the University of Seville. The detector will be deployed to plasma edge by an energized solenoid, optimized numerically for the fast retraction. Movable parts will be connected through pivots, eliminating potentially problematic sliding and rolling contacts. ASCOT code simulations show that the insertion depth ~10 cm in front of the port will be needed in order to obtain representative fast ion measurements. This is associated with relatively modest (~10 MW/m²) time-averaged thermal plasma loads. On the other hand, active cooling of a scintillator is needed because of the nuclear heating and plasma radiation. The contribution will also present the possibilities of combining FILD with other techniques for fast ion loss measurements (gamma-ray spectroscopy, visible and infrared imaging), future R&D tasks (e.g. impact of neutrons, gammas and fast ions on the scintillator lifetime), and the project schedule.