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Overview of ASDEX Upgrade I-mode results and extrapolation to future devices

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The I-mode is an improved confinement regime of tokamak plasmas where an edge transport barrier is observed in the temperature but not in the density profile [1, 2]. This is in contrast to H-mode confinement, which is characterized by transport barriers for both heat and particles. The I-mode is ELM-free and it does not suffer from high impurity content, which makes it attractive regarding future devices, such as DEMO. In I-mode, the edge turbulence spectrum is dominated by an instability called the weakly coherent mode (WCM) which is coupled to a geodesic acoustic mode [3, 4]. The mechanism which creates a transport barrier in only one of the transport channels but not in the other is still not understood.

In the past few years, ASDEX Upgrade has made significant advances in the physics understanding of the I-mode. In particular, stationary NBI-heated I-modes have been developed [5] and the L-I power threshold and its dependence on the density and the magnetic field have been carefully studied [6]. In I-mode, the edge radial electric field deepens with respect to L-mode values, until a threshold value is reached, at which the I-H transition takes place [7]. The confinement quality and the dominance of the WCM increase with increasing edge radial electric field well depth. At the same time, transient and intermittent events are observed in the confinement region [7]. These events manifest in strong density fluctuation levels. They could be of importance for the I-mode confinement regime, since they are transported into the divertor, where they deposit energy onto the divertor plates [5]. Divertor heat flux profiles in I-mode are narrower than in L-mode, but wider than in H-mode, which can be related to the Spitzer-Härm dominated scrape-off layer conductivity [5] or volume-averaged plasma pressure [8]. Related to divertor studies, first results from I-mode detachment experiments will be presented. So far, detachment has not been obtained on ASDEX Upgrade, but studies are ongoing. Results seem to be comparable to those from Alcator C-Mod [9]. For any future device, including ITER or DEMO, detachment will be crucial for an operating scenario. Moreover, significant progress in numerical simulations of I-mode plasmas will be reported. Recent simulation results reproduce the appearance of the WCM coupled to a GAM in the case of strong temperature pedestals along with L-mode-like density profiles [10].

The presentation gives an overview of these recent I-mode results from the ASDEX Upgrade tokamak, with particular attention on the edge turbulence behavior and its connection to scrape-off layer and divertor transport. As an outlook, the extrapolability towards future fusion devices including DEMO will be assessed.

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