Control of the X-point radiator in fully-detached ASDEX Upgrade H-mode plasmas

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For tokamaks with full metal walls, such as ASDEX Upgrade (AUG) or JET, as the target becomes fully-detached, the divertor radiation concentrates in a small region at or above the X-point in the confined region [1]. This so-called X-point radiator can be induced at AUG through nitrogen or argon seeding and presents a stable regime of operation. This is contrary to carbon wall operation in which X-point radiation usually lead to disruptions.
The X-Point radiator region spatial width is at AUG about 5cm and can migrate further into the confined region; the distance above the X-point depends among others on the impurity influx and heating power and can be stably held up to 15cm above the X-point, corresponding to normalized flux surface radius of $\varrho_{pol}\approx 0.99$. A real time control scheme has been implemented in AUG which utilizes an array of poloidally-viewing diode bolometers to detect the location of the radiator. The nitrogen seeding level is varied to either move the radiation region further into the core plasma or back towards the X-point. The details of the feedback control system and effects on the divertor and core plasmas will be presented.
The new controller shows for the first time the control of a fully detached state and allows to control in an operational region between re-attachment of the divertor (radiation moves back below the x-point to the target) and the radiative collapse of the core plasma. This will be compared with other existing detachment controllers and the possible application for future devices.
When the radiator penetrates strongly into the confined region (reaching 7cm above the X-point, which is at the foot of the pedestal at $\varrho_{pol}<0.997$), it is observed that the pedestal stability is modified, leading to reduced pedestal pressure gradients but similar performance further inside the core plasma [2].In this regime, ELMs are mitigated, avoiding the intermittent heat fluxes of ELMs into the divertor, which would otherwise lead to a transient re-attachment of the divertor and significantly reduce the life time of a divertor in future reactors. This ELM-mitigated regime is currently being examined and will be discussed further.

[1] M. Bernert et al, Nucl.Mater.Energ. 12 (2017), 111-118
[2] F. Reimold et al, Nucl. Fus. 55 (2015), 033004