Shallow pellet fuelling under conditions of RMP ELM mitigation or divertor detachment in ASDEX Upgrade

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Pellets are used in ASDEX Upgrade [1] to control plasma density under conditions of ELM control or divertor detachment. In experiments presented here direct fuelling by gas is negligible. Relative pellet size and pellet deposition are aimed to approach those in ITER but differences still remain. ELMs are controlled by n=2 RMPs in feed forward mode [2]. Divertor detachment is controlled by nitrogen gas in feedback mode.

In low upper triangularity plasmas with ELM control by RMPs, pellets can refuel the RMP pump out using both gradual [3] and prompt [4] application of pellet trains. With application of pellets promptly after activation of the RMP fields the duration of the density transient can be reduced to 3 energy confinement times. The required pellet particle throughput to restore pre-RMP density is about Φ_{pel}~5.6×10^{21}at/s~$0.07P_{aux}/T_{ped}$ (P_{aux} is the auxiliary heating power and T_{ped} is the pedestal temperature) which is comparable to the RMP pump out rate Φ_{RMP}~1.7×10^{21}at/s determined from the time derivative of the plasma density after the RMP is switched on. The density increase by pellets approximately preserves ion pedestal pressure in the RMP phase. An unwanted side effect of pellet refuelling is the transition from ELM suppression to an ELMy regime, triggered by the first pellet. A favourable observation is that ELMs with pellet fuelling are still smaller than those without RMPs, and the ELM frequency is not modulated by pellets. At elevated upper triangularity the ELM suppression is restored after an ELM-like events triggered by the pellets [4]. With increasing density plasma eventually transitions to ELMy regime, similarly as in low triangularity case.

In plasmas with divertor detachment, density control by pellets without gas is demonstrated. The required particle throughput is about Φ_{pel}~19×10^{21}at/s. When normalised to heat flux the throughput is $\Phi_{pel}T_{ped}$ /P_{aux}~0.1 which is broadly agreeing with ITER prediction [5]. With detachment, an unwanted side effect is the pellet induced modulation of the plasma temperature (~2x) at the outer strike point and a consequential modulation of the nitrogen gas due to feedback control. This is caused by the modulation of the ELM frequency by pellets and not by a pellet induced cooling wave as one might expect.

[1] Lang P T *et al* 2012 *Nucl. Fusion* **52** 024002; [2] Suttrop W *et al* 2017 *Plasma Phys. Control. Fusion* **59** 014050, [3] Valovič M *et al* 2015 *Nucl. Fusion* **55** 013011, [4] Valovič M *et al* 2018 *Plasma Physics Contr. Fusion* to be submitted, [5] Polevoi A R et al 2017 *Nucl. Fusion* **57** 022014