Impurity Ion Emission and Edge Transport during ELMy H Modes in the New JET Divertor Configuration.

M G O'Mullane[1,2], H Chen[3], I H Coffey[4], N C Hawkes[2], M von Hellermann, L Lauro-Taroni, N J Peacock[2], A Rookes[5]

JET Joint Undertaking, Abingdon, Oxon., OX14 3EA, UK

[1]University College Cork, Ireland, [2]EURATOM-UKAEA Fusion Association, Culham Laboratory, Abingdon, Oxon., UK, [3]Southwestern Institute of Physics, Chengdu, China, [4]Queens University Belfast, Northern Ireland, [5]Imperial College, London, UK

Introduction

In H modes, impurities are expected to show accumulation. Experiments in DIII-D [1] have shown that the controlled removal of impurities is possible with long periods of grassy ELMs. An H-factor of 1.5 is maintained in these steady state discharges. In contrast, giant ELMs cause periodic collapses in confinement and can expel 5–10% of plasma energy on a millisecond timescale. They have the additional deleterious effect of being a source of fresh impurity influxes following energy deposition on the target plates. Clearly it is important to understand the impurity behaviour during these giant ELMs.

The typical giant ELM is triggered by a fast (τ~0.2ms) MHD event [2]. During this time the temperature in the outer part of the plasma falls on the same timescale with a concomitant rise in D_α. After the giant ELM (Type I) crash there may be a series of smaller, higher frequency, ELMs (Type III?) before H-mode is re-established. Alternatively the recovery to H mode can be free of D_α fluctuations. High time resolution ECE temperature measurements, fig.1, show that during this recovery period the temperature returns to its pre-ELM value.

The impurity transport behaviour of Neon (from gas puffing) during H mode with giant ELMs is modelled. Transport following the giant ELM and during the recovery of H mode are interpreted as distinct transport phases.

Impurity Transport Simulation of Giant ELMs

The SANCO 1.5-D impurity transport code has been used in all simulations. Particle transport is described by a diffusive and convective part with the flux of each ionisation stage

$$\Gamma_i = -D(\psi,t)\nabla \cdot n_i + V(\psi,t)n_i$$

The transport functions (D,V) are heuristically chosen and the solution is iterated until the transport is consistent with experiment.

In the case of low amplitude grassy ELMs it is possible to average the transport over a number of ELM periods (i.e. when total radiation is not perturbed). In the case of giant ELMs the transport is time-dependent.

A phenomenological model of impurity transport, within the constraints of the two function (D,V) formalism, during H modes with giant ELMs is proposed. The model assumes that H mode is established. Following the giant ELM crash there is a period of enhanced diffusion before ELM-free conditions are restored. This will be referred to as the H→L hybrid phase. It is characterised by smaller, high frequency, mini-ELMs and the recovery of the edge temperature during these mini-ELMs. The transitions between H-mode and the hybrid H→L phase and back to H-mode are modelled by a sharp switch (< 1ms) in the diffusion coefficient only. Both transport profiles are kept constant throughout each phase.

Experimental Observations

The impurity transport model requires many parameters that can vary both spatially and temporally. The model inputs are electron temperature and density profiles and a source function describing the impurity influx. The success, and limitations, of the model depend on these inputs and on the experimental data used for comparison to the simulation results.

Temperature and density are measured with ECE (15ms time resolution) and LIDAR (50ms). The source function follows the peripheral NeVII ($2s^2 - 2s2p$ 465.22Å) time history as measured by a survey VUV spectrometer (11ms). The instrumental time resolutions are not fast enough to follow the ELM event in detail.

The location of the transport barrier removes a free parameter from the simulations. Its location and width are found from the edge charge exchange measurements [4]. The change in density of Ne^{10+} inside and outside of the transport barrier is shown in fig.2. The barrier is located between r=3.68m and r=3.70m, corresponding to a normalised radius of 0.93. The change in the gradient of the ion temperature near the edge gives a barrier width of ~1cm.

There is *no* on-axis accumulation of Neon. Charge Exchange Recombination Spectroscopy (CXRS) shows hollow profiles. This necessitates the introduction of an outward convection term [3] (see fig.3).

The penetration of the ELM into the plasma column is followed from the time histories of the intrinsic impurities. NiXXV radiates at T_e ~ 500–700eV which, depending on plasma conditions, corresponds to radii of r ~ 0.7a – 0.9a. Fig.4 shows that, within the time resolution of the spectrometer, the impurities react simultaneously with the ELMs. In other discharges ELMs are seen clearly in the ClXV signal (T_e ~ 300–400eV) but not in the NiXXV. The penetration depth appears to depend on the abruptness of the recovery following the ELM crash.

Results

The model is adjusted to match the total number of Neon particles, the profile of the Ne^{10+} and impurity line intensities. A sudden drop (<1ms) in diffusion *only* following the ELM models the evolution of the Ne^{10+} profile (see fig.4). A transport barrier is essential throughout the simulation. A 'standard' convection of ($V=-2Dr/a^2$) during the H→L hybrid phase destroys the hollow profile. The allowable values of D(r) are intermediate between H and L mode

$$D_H(r)\ x2 < D_{H\to L}(r) < D_H(r)\ x4$$

where the L mode factor is typically x6–10 of H-mode value. Although the location is more important there is a sensitivity to the size of the barrier

$$-7\ ms^{-1} < V_{r=0.95a}(r) < -10\ ms^{-1}$$

There is qualitative agreement between the Ne^{10+} behaviour on either side of the transport barrier. Changes in diffusion during the H mode recovery have not been investigated although the simulations hint that there may be some change over the ELM-free part.

Conclusions

An impurity transport model has been applied to describe the behaviour of impurities during H mode with giant ELMs. There is a period of enhanced diffusion following the ELM crash. Although it can be interpreted as a H→L transition there is *no change in the convection barrier* and the change in diffusion is intermediate between the H and L mode values.

It is necessary to improve the time resolution, to sub-ms times, over that of present day spectroscopic instruments in order to follow the evolution of the transport barrier itself and the detailed behaviour of impurities during the ELM.

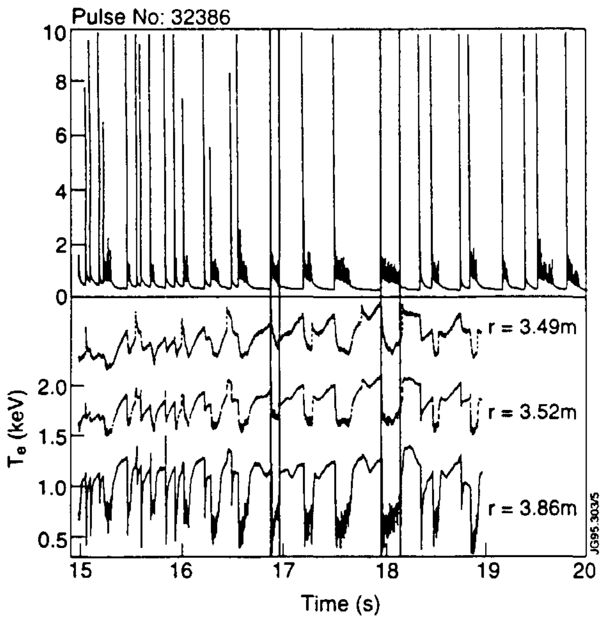

Fig.1 Edge T_e measurements during giant ELMs.

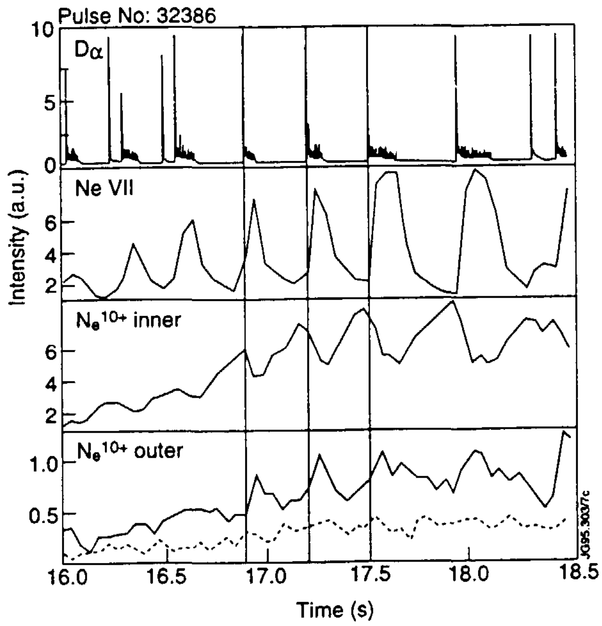

Fig.2 Evolution of spectroscopic signals.

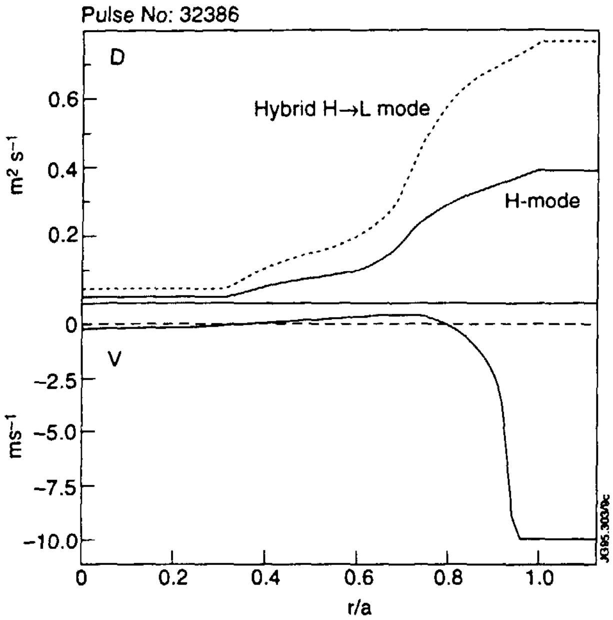

Fig.3 Transport profiles used in simulation.

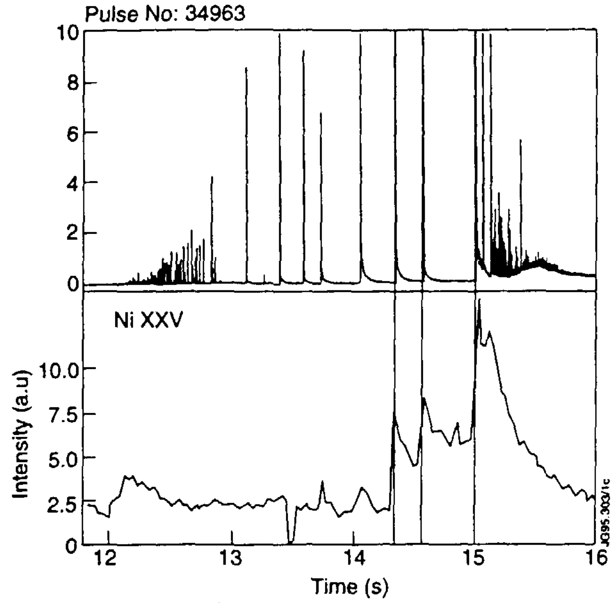

Fig.4 Time evolution of NiXXV showing ELMs

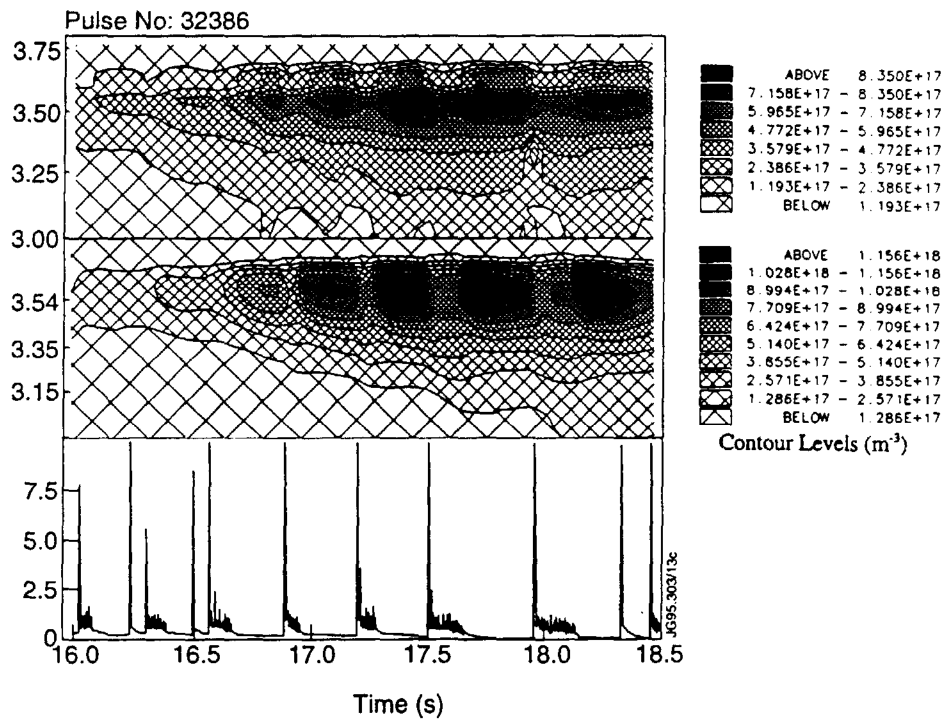

Fig.5 Comparison between Ne^{10+} profile from CXRS and simulation.

References

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