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Experimental evidence of the non-local response of transport to peripheral perturbations

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Abstract

Qualitatively novel results on non-locality phenomena in perturbative transport experiments are reported. Here, non-locality means a rapid response in the core follows an edge perturbation on a time scale far shorter than any standard approximation to the global, diffusive model confinement time. Sequential firing of supersonic molecular beam injection on the HL-2A tokamak sustained the increase in the core temperature in response to the edge perturbation. O-mode reflectometers are introduced to measure density fluctuations and show that the central turbulence is suppressed during nonlocallity, suggesting that the interpretation of the phenomenon due to the formation of an 'ITB-like' structure is plausible. ECH switch-off experiments on the HL-2A tokamak demonstrated that the non-local response is sensitive to the deposition location. Taken together, these results suggest that non-locality phenomena have several aspects in common which can be linked to certain simple, generic elements of tokamak turbulence physics.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Phenomena suggesting fast, apparently 'non-local' responses of core plasma parameters to edge perturbations have been observed in many tokamak experiments. The observation of an unusual fast heat pulse generated by the L–H transition in JET [1, 2] was the first clear non-local transport response. There are two unusual features of this heat pulse: a very fast propagation (within 1 ms) of the temperature rise and the observation that heat pulse amplitude does not decay in the core. Then later, the 'prompt' responses to ECRH have been observed in W7-AS [3]. In these cases, the core electron temperature responses were of the same polarity as the changes in edge electron temperature. The most striking evidence for non-locality is from cold pulse experiments, in which a transient core T_e rise is observed in response to peripheral cooling. From the first observation of the effect at TEXT in 1995 [4] to subsequent reports on many other tokamaks and a helical device [5–10], non-local responses induced by edge cold pulses have puzzled scientists who focus on plasma transport. This phenomenon is characterized by a simple but challenging picture: a strong cooling in the edge plasma induces significant heating in the central plasma on a timescale much shorter than a diffusive propagation time scale. This opposite response of the plasma core occurs before the edge cooling pulse reaches the central region of the plasma. Since this extremely fast response is a formidable challenge to standard transport models, the development of an understanding of the non-local effect could lead to significant new directions in research on anomalous transport.

The initial observation of non-local response to abrupt plasma edge cooling was performed by Gentle *et al* on TEXT [4]. A finite but small injection of carbon into the TEXT tokamak edge induces significant temperature perturbations throughout the plasma. Large, rapid temperature decreases are observed in the outer third, while temperatures in the inner third promptly begin to rise. The effects cannot be reproduced with transport coefficients that are functions only of local thermodynamic variables. Later in the RTP plasmas [6, 8], a transient rise of the core electron temperature was observed

