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Evidence for Electron Heat Flux – Temperature Gradient Hysteresis During Modulated ECRH Experiments on the HL-2A Tokamak

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Heat transport is a key issue in tokamak plasma research because of its crucial role in the plasma confinement, but its behavior is quite hard to understand due to its complex nature. As an example, many observations have shown that local macroscopic variables such as temperature and density gradients are not the only factors that determine heat transport level[1-6], and it remains an open question how the heat transport is related to macroscopic plasma variables, making it difficult to predict the heat transport in future devices.

Here we report observation of hysteresis between perturbed electron heat flux and electron temperature gradient in modulated ECRH experiments on the HL-2A tokamak. These results clearly show that the classical view that heat flux is determined by local plasma variables is violated, and suggests some bi-stable nature of the heat transport process as well. In the experiments, the electron heat flux is determined from a heat balance analysis of the core plasma using data from the multi-channel ECE, FMCW reflectometry, FIR interferometer and bolometer diagnostics, while the multi-channel ECE gives the spatially and temporally resolved electron temperature gradients. The plasmas are routine L-mode ones, and hysteresis are found to exist under quite a few plasma conditions, including different plasma density and ECRH/NBI heating power. We noticed that similar phenomenon had been reported on LHD[7], but to our knowledge this is the first time that such hysteresis is reported in tokamaks. The behavior of density fluctuations is diagnosed by a 2D BES system as well in these experiments, and some results concerning the relationship between turbulence intensity, temperature gradient and heat flux will also be presented in this talk.

References
[1] Laurent L. 1986 Plasma Phys. Control. Fusion 28 85.
[2] Luce T.C., Petty C.C. and de Haas J.C.M. 1992 Phys. Rev. Lett. 68 52–5.
[3] Cordey J.G. et al 1994 Plasma Phys. Control. Fusion 36 A267.
[4] Gentle K.W. et al 1995 Phys. Rev. Lett. 74 3620.
[5] Stroth U., Giannone L., Hartfuss H.-J., the ECH Group and the W7-AS Team 1996 Plasma Phys. Control. Fusion 38 611.
[6] Inagaki S. et al 2008 Plasma Fusion Res. 3 S1006.
[7] Inagaki S. et al 2013 Nucl. Fusion 53 113006.

Figure 1
An example of the q_e - ∇T_e hysteresis found in the HL-2A experiments, which shows the change of heat flux with temperature gradient in one modulated ECRH period (conditionally averaged).