Heat Transport and Plasma Rotation during Cold Pulse Experiments in Ohmic L-mode Plasmas

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Abstract

Thermal transport is studied by laser blow off impurity (CaF) reaction. The non-local effect, a cooling of the edge electron temperature with a rapid rise of the central electron temperature, which contradicts the local assumption of transport, was observed in denser higher Ohmic confinement (LOC) plasma regimes. Simulation shows this phenomenon can be explained by an inward heat convection term in the heat flux equation. In high density saturated Ohmic confinement (SOC) regimes, the thermal transport becomes local, central electron temperature drops in response to the edge cooling. The transition density is very close to the rotation reversal critical density. This indicates the possible correlation between thermal and momentum transport, which is also linked to the trapped electron mode (TEM) in ion temperature gradient mode (ITG) transition. TRANSPIR analysis shows the heat transport in the electron channel is reduced and heat transport in the ion channel is enhanced when the plasma switches from the LOC to the SOC regime.

Cold pulse experiments

Time traces of line averaged electron density (TCI), core and edge electron temperatures (ECE), core and edge ion temperatures (HiFiL, Sr). Dotted vertical line indicates time of LIO burst.

Confinement time, nonlocality and rotation reversal

LOC-LOC, nonlocal and rotation transitions happens at similar density. LOC-SOC, nonlocal and rotation transitions happens at similar density. Radius of rotation reversal angle point and electron temperature profile flex point has strong dependence on nonlocal effect.

Heat pinch in nonlocal transport

For LOC plasma, the nonlocal effect can be explained by adding an inward pinch term in the heat flux equation. Simulation result agrees well with measured data.

For SOC plasma, the pinch term is negligible.

Cold pulse modulation

Cold pulse modulation experiments are performed at different densities. LIO is operated at 10 Hz. SOC is operated at 50 Hz. FFT is used to obtain the amplitude and phase profile. For LOC, fundamental frequency amplitude increases towards the plasma center, which contradicts pure diffusive local transport. The inversion radius (where electron temperature begins to increase) is near the q=1.5 flux surface. For SOC, the amplitudes decreases towards plasma center. Transport is more diffusive like.

Conclusions and future work

• Nonlocal effect has critical density, which is close to rotation reversal and LOC-SOC transition density.
• Nonlocal effect can be explained by adding an inward heat pinch term.
• Modulation experiments also show the heat transport is not purely diffusive in LOC/co-current plasma regimes, where non-local effect exists.
• Transport analysis shows from LOC to SOC, normalized electron heat transport is reduced, normalized on heat transport is enhanced.

Linear GYRO kinetic simulations will be performed to characterize the turbulent transport in these experiments.

References


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Heat transport of LOC and SOC plasma

LOC -> SOC
• Normalized electron heat transport is reduced by ~ half.
• Normalized ion heat transport is enhanced by a factor ~ 2.
• Heat transport: electron channel -> ion channel (TEM->ITG)

Motivation

At Alcator C-MOD, it is shown that there is a strong connection between the LOC-SOC transition and the abrupt direction switch of core rotation reversal mode. The transition density has strong dependence on density, above which the transport is dominated by TEM modes, and below which the transport is dominated by ITG modes. Recently cold pulse experiments added the non-local transport effect to this connection.

TI and rotation measurement on C-MOD

High Resolution X-ray spectrometer with Spatial Resolution (150mm x 150mm) is used for ion temperature and rotation profile measurement at Alcator C-MOD. The measurement uses spherically bent crystal to provide spatial resolution of argon spectrum like and helium like-spectra.

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