Lower Hybrid Wave Neutral Excitation, Ionization and SOL Power Loss of the Alcator C-Mod Tokamak

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Abstract

Higher density (n_e > 10^{19} m^{-3}) Deuterium, T_e, diverted Lower Hybrid Current Drive (LHCD) discharges on Alcator C-Mod exhibit little to no current drive, as indicated by low levels of hard X-ray emission. Higher temperature (T_e<6 keV), high field (B>5 T) helium plasmas have shown decreased SOL modification and increased X-ray emission from the core plasma. Previous work has shown LH induced changes to the scrape-off-layer (SOL), suggesting SOL localized LH power deposition occurs, possibly through collisional absorption. However, electron-ion collisional absorption was found to be weak in full-wave simulations. In order to characterize collisional absorption as a loss mechanism, initial experiments were conducted to measure emission from neutral HXR line-losses. Results are presented on the modification of the SOL as measured using radially-resolved VUV and visible emission from regions in which field lines are connected or unconnected to the LH launching structure. Implications of the presented data will be discussed with respect to the LHCD density limit.

density limits CD efficiency

Lower Hybrid System of C-Mod

10.4 GHz klystrons and a 4x16 waveguide grill [3] launches the electric wave. Lower Hybrid wave which is asymmetrically absorbed by the electron distribution through landau-damping. The system is capable of coupling 100KW forward power to the plasma. The launching system generates fully non-inductive scenario in low average density plasmas (n_e < 10^{19}m^{-3}).

The system was designed to assist in generating advanced scenario, reversed-shear plasmas. It will also for extended length discharges in the near future.

GPI Measures Edge Dynamics

- The Gas Puff Imaging diagnostic (GPI), is a toroidally viewing camera filtered for specific atomic transition lines coupled with a localized gas puff; it is used for edge turbulence and transport studies. [6] The following discharges are operated without the gas puff, where it then can be Abel-inverted. It has been filtered for He-I (587.6 nm) line for the Helium plasma.

Key Results

- It was found that the variations in the edge He-I emission correlated with the LHCD density limit. In High Density plasmas, applied LH power shifted the emission profile outward from the LCFS. These results were seen both in Deuterium and Helium Plasmas.

- In low electron temperature plasma (T_e < 2 keV), the He-I emissivity profile increased and shifted outward in less than an energy confinement time with applied LHCD power.

- The boundary of high temperature plasmas were minimally effected by the LHCD, i.e. profile shifts did not occur. The slight increase in emissivity is likely due to an increased exhaust power transmitted though the SOL. The increased HXR emission indicated a larger fast electron population.

- Abel inversion methods proved difficult, as emissivity profile variation extended beyond the sight range of the camera.

Future Work

New Ly-α Camera View

- The power balance of LHCD in high density plasmas is currently unknown.

- A new poloidally viewing AXUV based Ly-α camera will study the effect of field line connection lengths and their correlation to the seen variations in emissivity. This could indirectly test the global position of LHCD in the SOL.

- Future work will quantitatively absorb/ionless mechanisms, which will fundamentally explain the density dependent loss of current drive.

Acknowledgements

This work was supported by the US DOE awards DE-FG02-99ER54512 and DEAC02-76CH03073. Thanks go out to the entire PPSc and the Alcator C-Mod team for their assistance on this work.

References


Scraped-Off-Layer (SOL) Power Loss of the Alcator C-Mod Tokamak

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Abstract

High density (n_e > 10^{19} m^{-3}), moderate T_e, diverted Lower Hybrid Current Drive (LHCD) discharges on Alcator C-Mod exhibit little to no current drive, as indicated by low levels of hard X-ray emission. Higher temperature (T_e<6 keV), high field (B>5 T) helium plasmas have shown decreased SOL modification and increased X-ray emission from the core plasma. Previous work has shown LH induced changes to the scrape-off-layer (SOL), suggesting SOL localized LH power deposition occurs, possibly through collisional absorption. However, electron-ion collisional absorption was found to be weak in full-wave simulations. In order to characterize collisional absorption as a loss mechanism, initial experiments were conducted to measure emission from neutral HXR line-losses. Results are presented on the modification of the SOL as measured using radially-resolved VUV and visible emission from regions in which field lines are connected or unconnected to the LH launching structure. Implications of the presented data will be discussed with respect to the LHCD density limit.

LHCD Evaluated with X-ray Camera

- The Hard X-ray Camera (HXR) measures electron-electron and electron-ion bremsstrahlung for photon energies (6keV-10keV, <35keV) [2]

- Poloidally-viewing Czerny-Turner radiation detectors allow for experimental comparison of forward-modelling fast-electron distributions.

- Measured X-ray count rate is used as a proxy for driven current and for the total fast electron population.

- Helium Plasmas were used to remove the deleterious effects of neutron induced background counts on the HXR camera.

- Emission profiles were inverted using a Tikhonov regularization technique applied to the Abel transform formula, after mapping the 64x64 pixel views to the midplane.

Density Limit Effects seen in Low-Temperature Helium Discharges

- Helium Plasmas were used to remove the deleterious effects of neutron induced background counts on the HXR camera.

- Emission profiles were inverted using a Tikhonov regularization technique applied to the Abel transform formula, after mapping the 64x64 pixel views to the midplane.

- The discharge profiles were inverted for the Abel transform.

- Sensitivity varied from pixel to pixel, introducing systematic error to the process. This can be seen by similarities in the inverted profiles.

- The discharges profiles were inverted for the Abel transform.

- Negative emissivities are an artefact of violating the ideal Abel transform.

Plasma Density Limits CD Efficiency

- It was found that high density (n_e > 10^{19} m^{-3}) diverted Deuterium plasmas exhibit little to no current drive with applied LHCD power [1].

- Limited discharges recover expected current drive density dependency (\rho < n^{-\alpha}).

- Some hypothesized causes include PDI, density and non-linear n_{\parallel} effects.

- The model LH electron distribution [5] display the strong anisotropy of Hard X-ray Emission profiles change on a fast (1ms) timescale.

- Previous results have shown that Deuterium Lyman-\alpha emissivity profiles at the edge change in high density with applied LH power (move vector from separatrix).

- The Ly-\alpha profiles change on a fast (~1ms) timescale and correlate to the applied LH power, suggesting an edge effect relating to LH.

Future Work

- New Ly-α Camera View

- The power balance of LHCD in high density plasmas is currently unknown.

- A new poloidally viewing AXUV based Ly-α camera will study the effect of field line connection lengths and their correlation to the seen variations in emissivity. This could indirectly test the global position of LHCD in the SOL.

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