Optimization of Hot Electron Diagnostics on LDX

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I. Abstract

The Levitated Dipole Experiment (LDX) is evaluating the dipole magnetic field configuration for fusion confinement with a levitated 1.1 MA, 68 cm mean diameter, 560 kg superconducting coil (F-coil) inside a 5 m diameter vacuum vessel. Highly peaked plasmas ($1/r^4$) are generated by up to 17 kW electron cyclotron resonance heating at 2.45, 6.4, and 10.5 GHz. The high magnetic field gradient around the outside of the dipole coil where the plasma is confined represents a new regime for modeling ECE diagnostics. Millimeter wave radiometers at 110, 137, and 165 GHZ in use on LDX can view ECE harmonics from the 2nd through the 55th depending on the location of the radiometers with respect to the plasma. A study of the viewable harmonics from each of the available radiometers at various positions and proximities to the plasma is necessary to determine the interpretation of the ECE in terms of the hot electron temperatures and densities and the optimum receiver placement for the best measurements.

II. Modeling

Before experiments were conducted, models were created for various pairings of millimeter wave radiometers, viewing positions, assumptions of reflections inside the LDX vacuum chamber, and assumed locations of the plasma peak. Using Bekefi's theory of radiation transport, $I=I_{BB}\alpha z$, the ratio of signals from two radiometers with different characteristic frequencies can be taken to give a ratio of their absorption/emission coefficients (α) since they both view the same blackbody and are launched from the same horn. These coefficients can be calculated for a given frequency at a given temperature. Temperature curves (Fig. 1) can be generated so that experimental ratios can be matched to a hot electron temperature.

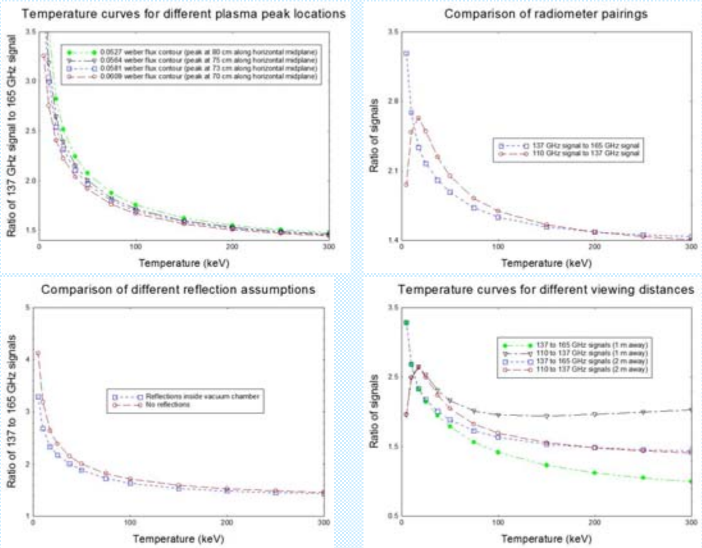

Fig. 1: Optimal temperature curves are steep because it is seen that a slight change in the position of the plasma peak significantly affects the apparent hot electron temperature. These curves were generated assuming the radiometers viewed the plasma vertically.

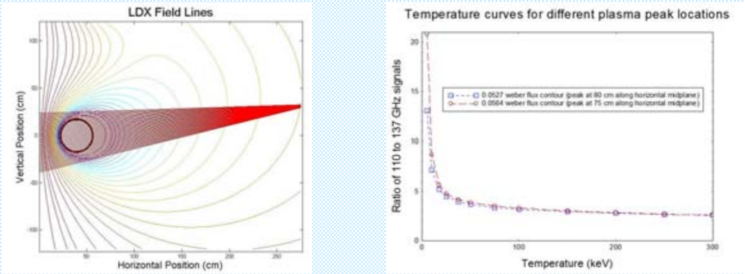

Fig. 2: When the plasma is viewed along the horizontal midplane from the chamber wall, the beam diverges above and below the F-coil and sees into the high field region. The emission from this region dominates the detected emission. From this viewing position, the position of the plasma peak has a less significant effect on the apparent hot electron temperature.

III. Results

The high magnetic field gradient that exists in levitating dipole plasmas allows for the radiometers to see out the 55th ECE harmonic. This study concluded that the emission at such a low field region is insignificant compared to the emission from the high field region. If information about the higher harmonics is to be obtained, the experiment should be altered so the beam does not diverge above and below the F-coil.

Fig. 3 shows data from a plasma shot taken during the August 2009 experimental campaign. For an assumed peak location on a flux loop at a midplane radius of 75 cm the hot electron temperature was determined to vary between 50 and 130 keV. During the six second afterglow, the apparent temperature increased above 130 keV. Significant features are apparent when the various ECRH sources are switched on and off. Sharp transitions at these times provide evidence for a dynamic plasma peak that is affected by the addition and removal of ECRH power from the system.

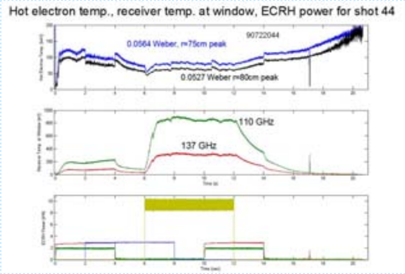

Fig. 3: The curve for peak location at 80 cm along the midplane is almost continuous with the curve for the 75 cm peak location around 2 seconds into the shot. The modeling done for this study could be used to track the movement of the plasma peak during experiments.

IV. Acknowledgments

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