Abstract - Motivation

Recent experiments in helicon plasma sources by Krümm et al. [2000] and Kwak et al. [2003] have employed mm-wave technology to investigate electron densities in a pulsed source and density fluctuations due to ion-acoustic waves, respectively. Measurement of the temporal and spatial evolution of electron densities by Krummel was accomplished with a mm-wave interferometer. The ion-acoustic waves measured by Kwak employed a collector scattering system with a heterodyne detection scheme. The WVU 300 GHz quasi-optical collective scattering diagnostic, uses a heterodyne detection method similar to the interferometer, designed to measure the "slow" wave. Experimental parameters observed to heat ions in the plasma edge in conjunction with theoretically calculated wave numbers associated with the slow wave, as seen in Kline et al. [2002], were examined for evidence of the slow wave using the mm-scattering diagnostic. Here we present initial wave number spectrum measurements of the slow wave in a helicon plasma source.


Based on the measured angular resolution of the collection optics, we can calculate the centroid of the target measurement location in the plasma for different scattering angles and position of the collection mirror. Since the collection mirror is on a linear translation stage, the spatial location associated with the maximum signal for each scattering measurement corresponds to different locations in the plasma. Even though the "slow wave" is typically considered to be an edge wave, the measurable wave number spectrum as predicted by the cold plasma dispersion relation, shows that it is possible to measure the entire plasma for certain plasma parameters. For scattering between 60° and 90°, the collection coverage is limited to only about half the plasma radius, while collection of scattered microwave signal from 70° up to 90° can be accomplished for nearly the entire plasma diameter.

Aluminum alignment wedges cut to simulate scattering angles of 0°, 70°, 80°, and 90° degrees were employed to efficiently illuminate the spatial coverage and angular resolution of the collection optics. With the collection mirror aligned to the appropriate radial location and scattering angle, the alignment wedge was moved to different locations in the incident beam across the vacuum vessel to determine the angular resolution. The measured 1°5' folding width for the collection optics is comparable to the ZEMAX optical design predictions.

Based on the radial ion density profile with $N_e = 10^{19}$ cm$^{-3}$ and typical HELIX operating parameters, an example of how the calculated wave numbers vary across the plasma radius is shown in plots A and B. As the plasma density decreases from the central peak, the magnitude of the wave numbers increases, shift to lower frequency following the lower hybrid resonance (indicated by the black lines), and narrow in the parameter space. As a point of reference, the maximum wave number of 150 cm$^{-1}$ at a frequency of 11 MHz in plot B corresponds to an ion thermal velocity ~15% of the wave phase velocity. Increases in the perpendicular ion temperature or a decrease in the collection mirror with only a single aperture for the detector potter horn, and 2 bulkhead connectors (1 for DC bias in, and 1 for IF signal out).