Motivation

Electrostatic probe measurements in pulsed, expanding helicon plasma indicate the presence of a coherent ~17 kHz wave when a double layer appears in the expansion region. Time-resolved measurements of the instability and the beam component of the ion velocity distribution demonstrate significant correlations throughout the duration of the pulse between the downstream ion beam (the ion beam is a signature of an upstream double layer) and the electrostatic wave amplitudes. This correlation is stronger than that observed between the bulk population and electrostatic wave amplitude. The ion velocity distribution (ivdd) is measured with laser induced fluorescence (LIF) and the waves with a time-of-flight probe. As the helicon source pulses, the double layer peaks and then increases in energy as the amplitude of electrostatic fluctuations increases. Once the wave amplitude decreases, the bulk and beam populations cease to undergo any further significant changes in intensity or speed. The wave measurements yield a parallel wave number of ~2.4 cm⁻¹ and perpendicular wave number of 1.7 cm⁻¹, relative to the background magnetic field. The wave phase speeds are consistent expectations for ion acoustic waves and are observed when the ion beam velocity is approximately twice the ion sound velocity.

Experimental Apparatus

The time-resolved LIF diagnostic, 200 measurements were taken over a 75.4 nm upstream. Measurements were synchronized to the repetition rate of the pulse. In total, measurements are made over the entire period of the pulse, 250 ms, repeated for different train lengths across the pulse. The interval is spaced 25 ns apart. The 10 m pulse length gives a lower frequency limit of 100 kHz. The 25 ns interval are sampled at 180 kHz, giving a Nyquist frequency of 90 kHz.

The fluctuation amplitude in the floating potential as a function of time in a 100 ns plasma pulse sampled at 90 kHz for the lower universe ratio saw the beam for a single tip. The large spikes observed are transient and don't persist. The amplitude spectra of the spikes is determined by the zero spectrum shown below.

Discussion of Observed Waves

The dispersion relation for the ion acoustic mode, for ion temperatures much smaller than the electron temperature, is

\[
\omega = \sqrt{k^2 + \frac{\omega_p^2}{m_i}} 
\]

where \(\omega\) is the frequency of the wave, \(k\) is the wave number, \(\omega_p\) is the electron Debye length, \(\gamma\) is the ratio of the specific heats, \(m_i\) is the ion mass, and \(T_e\) is the electron temperature. For large values of \(\omega\), the frequency asymptotically approaches the ion plasma frequency. For frequencies much less than the ion plasma frequency (~60 MHz, in this experiment), for values of \(k\) smaller than \(2\pi/L\) (where \(L\) is the scale length over which the phase is measured) and for values of \(\gamma\) small, the ion acoustic wave is well described by this dispersion relation. The wave phases speeds are determined by this value, \(\omega/k\). These wave phases speeds yield a parallel wave number of ~2.4 cm⁻¹ and perpendicular wave number of 1.7 cm⁻¹ relative to the background magnetic field. The wave phase speeds

Summary

- High time resolution measurements indicate strong correlation between beam fluctuations and 17 kHz frequency electrostatic fluctuations. A wave or correlation is seen with bulk ion population. The correlation fluctuates as time persist once it appears.
- Low frequency fluctuations are present in double layer and double layer-free cases.
- After the initial appearance of the 17 kHz wave, the ion beam (double layer) persists throughout discharge at a constant level.
- These experiments are consistent with previous observations that suggest an ion acoustic beam driven instability plays an important role in beam formation in expanding plasmas.