Helicon Waves in High Density Plasmas

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This thesis is entirely my own work,

except where specifically indicated.

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Abstract

This thesis investigates helicon wave propagation in a 1.5m long, 2.5cm radius, high density ($n_e > 5 \times 10^{18}$m^{-3}), high static magnetic field ($B_0 > 0.05$T) plasma, where the plasma has been produced by the helicon wave. Helicon waves launched with a double saddle coil antenna were found to consist of the first radial, $m = +1$ azimuthal mode, with no observable $m = -1$ mode under any conditions. The wave was found to propagate with the infinite plane wave dispersion relation $k_{||} \propto \sqrt{n_e/B_0}$ as if the plasma had no boundaries. Comparisons of experimental measurements of wavelength and radiation resistance with predictions of a magnetohydrodynamic numerical model show very good agreement. The numerical model also indicates that, for the conditions used in the experiment, the radiation resistance of the $m = -1$ mode is too low for it to be significantly excited.

Plasma formation by a helical antenna was also investigated.This antenna can excite $m = +1$, and $m = -1$ modes in opposite directions along the field. The helical antenna produced an axially asymmetric plasma, with the plasma density highest along the axial direction of propagation of the $m = +1$ mode. No $m = -1$ mode was again observed and the plasma extended only a short distance in the direction where the $m = -1$ mode would be expected to propagate. The helical antenna was found to produce plasma more efficiently than the double saddle coil antenna, however it had a more limited range of operating conditions due to its high $k_{||}$ selectivity.

Attempts to produce plasma using helicon waves of azimuthal modes other than $m = +1$, by means of a phased double saddle coil antenna were unsuccessful. However, by launching waves into a pre-formed plasma it was possible to control the azimuthal mode content of the wave launched. When the antenna was phased for excitation of $m = -1$, significant $m = +3$ was observed and no $m = +1$ mode, as expected.

Observations were made of the plasma formation process in the early phase of the discharge. During the initial stages of the discharge, as the plasma diffuses away from the antenna, a high density peak was observed downstream from the antenna, near the end of the uniform field region. A 1-D diffusion model was used to investigate this phenomenon, and predicted increased downstream ionisation due to a directed flux of neutrals created by the expansion of the plasma from the source region. After a period of about 10msec this density peak collapses and the plasma density drops to a uniform lower value that typifies the static phase of the discharge.

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