Continuous and Discrete Spectra of LF and HF Waves in a Helicon Plasma

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Experiments on various helicon plasma sources have revealed excitation of ion-acoustic (IA) turbulence in the megahertz range of frequencies [1-5]. Evidences have been presented that wave excitation results from parametric instabilities of helicon pump wave [2,3,5]. One more probable origin for the IA waves is the instability driven by electron drift across the magnetic field [4]. We report the results of probe measurements of low-frequency (LF) waves and high-frequency (HF) waves in pump sidebands, which were performed in a helicon plasma along with measurements of diamagnetic signal and stationary plasma parameters, in order to reveal the origin of IA turbulence.

Experiments were made on a 14-cm-diam, 36-cm-long helicon source driven at a frequency of 13.56 MHz by an azimuthally symmetric (m = 0) antenna. Plasma of density up to $2 \times 10^{12}$ cm$^{-3}$ was generated at input power of 1 kW, Ar pressure of 5 mTorr, and low magnetic fields, < 100 G. The source was operated in two modes: with uniform magnetic field and with nonuniform field growing from the antenna towards the source outlet. Measurements were made with electrostatic and magnetic, single and double probes and with a diamagnetic loop.

LF spectra have minimum amplitude on the discharge axis and include continuous noise component, in the range up to 1 MHz, and one (in the uniform magnetic field) or several equidistant (in the nonuniform field) discrete spikes, in the range 0.1 — 0.2 MHz. Noise oscillations, with relative density pulsations about 1%, were identified with IA waves which propagate obliquely in plasma cross-section (i.e., both azimuthally, along electron gyration, and radially, towards plasma periphery) with phase velocity about the IA velocity, $\sim 3 \times 10^5$ cm-s$^{-1}$. LF waves of spiky spectrum have excitation threshold on the rf power, propagate along azimuth closer to the plasma periphery, and are found to be global IA modes with high azimuthal numbers, $m = 10 - 17$. Wave propagation directions are opposite in the uniform and nonuniform magnetic field and are along streams of electron drift currents detected with the diamagnetic loop.

HF sideband spectra, both in capacitive and in magnetic signals, reproduce the structure of LF spectra, i.e., include both continuous and spiky components. Noise component measured with capacitive probes is symmetric relative to the driving frequency. However, phase measurements show that it does not relate to any potential waves and arises, most probably, from modulation of the probe signal at the driving frequency by the IA waves. On the contrary, sideband spectra measured with the magnetic probe are asymmetric, with predominance of the lower sideband, and are identified with the waves traveling azimuthally with phase velocities $(2.5 - 4.5) \times 10^7$ cm$^{-1}$. Propagation directions are opposite for the lower and upper sidebands and depend on whether the magnetic field is uniform or nonuniform. The lower sideband waves have the same lengths as the LF partners but propagate oppositely. At the same time, the phase of signal at the driving frequency is independent of azimuth, which is typical for a true $m = 0$ wave. Thus, the waves related to spiky components of HF and LF spectra satisfy matching conditions for parametric decay of the pump wave. The amplitude of magnetic signal of the "red" satellite can amount to 30% of that of the pump wave.

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REFERENCES


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