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Density Fluctuation Measurement in Helicon Plasma via mm-Wave Collective Scattering

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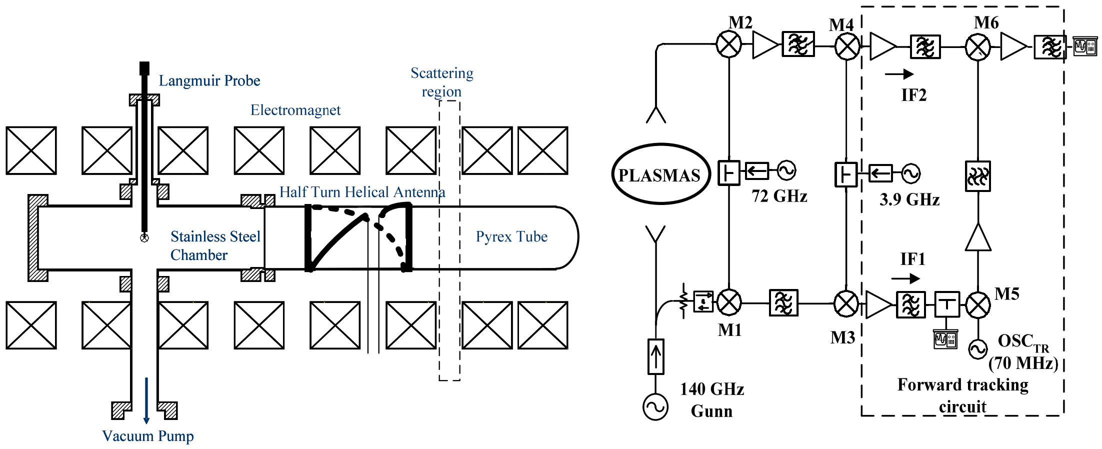
Recently studies on low-frequency fluctuations in the helicon plasmas raised the important issue of linear and nonlinear micro-processes which could alter the general characteristics of helicon plasmas. Most of the measurement results, however, have been carried out with probes in the downstream region of the helicon discharges. In this paper, collective scattering measurement results obtained from the antenna region of the helicon source are discussed as well as comparison with probe results. The scattering system operates at 140 GHz with an IF of 70 MHz, and a feed-forward tracking circuit is used to handle frequency drifts and to reduce noise. The scattering angle ranges 21-29 degree corresponding wavenumber 10.9-13.9 cm^{-1}.

1. Introduction

Helicon plasma is known to produce high density plasma and wide researches have been done to verify its production mechanism [1]. Many theoretical and experimental results were suggested and shown. Among those, high density production by TG waves is now widely accepted, however, the direct evidence has not been shown [2]. Microwave scattering is a very unique tool for the measurements of electrostatic waves or the density fluctuation in low and high temperature plasmas [3-4]. However, our preliminary measurements for TG show that the measured signal is very low so that it is not easy to discriminate it from the noise level. The main difficulty is due to that the wave frequency of detected wave is the same as that of the pump frequency and it is very hard to tell it from the pump wave or noise signal. On the other hand, recently, low-frequency density fluctuations in the helicon plasmas raised the important issue of linear and nonlinear micro-process which could alter the general characteristics of helicon plasmas and could suggest the clue for the high density discharge [5]. Altuhkov *et al.* observed ion acoustic wave like fluctuations by using the enhanced scattering(ES) method which uses backscattered waves from the upper hybrid resonance layer[6]. To perform these experiments, collective scattering measurement was modified to detect the density fluctuations and its dependence on the magnetic field was investigated.

2. Experimental setup

A schematic diagram of the helicon plasma source is shown in Fig.1(a). It consists of a 15 cm diameter, 60 and long pyrex tube and a 40 cm long stainless steel tube. Eight sets of magnets produce uniform axial magnetic field B_0 up to 2000 G inside the chamber. A 20 cm long, half –turn helical antenna is located at 40 cm downside axially from the enclosing belljar pyrex tube. The base pressure of 10^{-7} mbar is maintained by turbo-molecular pump of 350 l/s pumping speed and the typical operation pressure of Ar gas is 5 mTorr unless specified otherwise. The mm wave scattering system is basically the heterodyne system that consists of Local oscillator(72 GHz) and RF oscillator(140 GHz). The first IF frequency(70 MHz ranges) is produced via a sub-harmonic pumped mixer. The frequency noise and drift on the LO and RF are rejected on the final measured signals using the feed forward tracking circuits. RF power from the horn antenna is focused with the poly-ethelene lens whose focal length is 17 cm and reflected by rectangular mirror. The scattered signal is collected by mirror and is received by horn antenna. To avoid stray lights reflected from the wall of magnet bobbin, inner surface is covered by microwave absorbing medium, Ecosorb. The scattered wave-number varies from 10.9 to 13.9 cm^{-1} corresponding scattering angle from 21 degree to 29 degree. The resolution of wave-number is less than about 4 cm^{-1}.

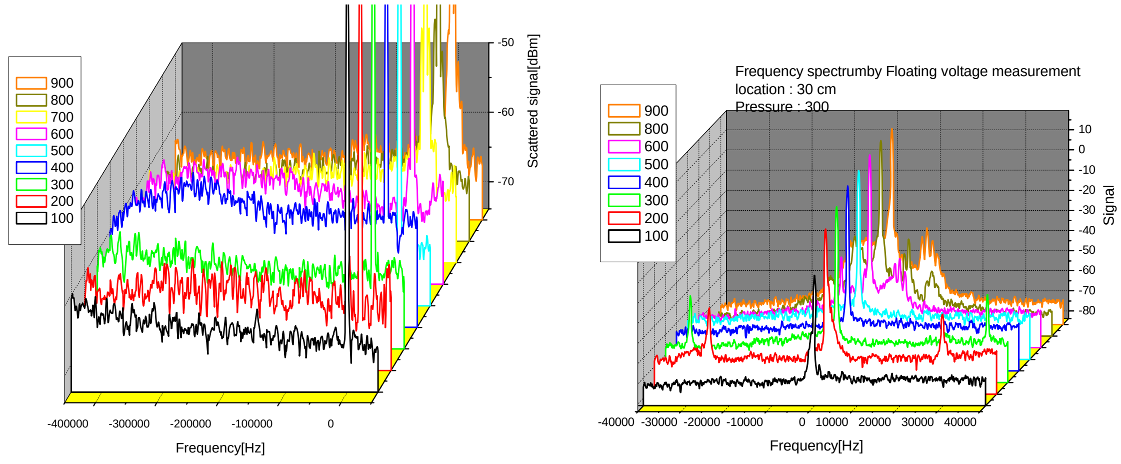


(a) (b)

Fig.1. Helicon plasma discharge apparatus(a) and the scattering measurement setup(b).

3. Results and discussions

Fig.2(a) shows the typical spectrum of the density fluctuation measured by mm wave scattering system at k=11.9 cm^{-1} for various magnetic fields. Two different kinds of fluctuations are observed. One is located on the high frequency side(H) with the broad band



(a) (b)

Fig.2. Typical fluctuation spectrum by the mm wave scattering(a) and the floating probe(b).

spectrum whose frequency range is 100-600 kHz and another is at the low frequency spectrum(L) with narrow peaks whose frequency range is within 5-10 kHz. High frequency fluctuation occurs below the saturation region of the plasma density with the magnetic field and it disappears above the saturation magnetic field. On the other-hand, low frequency fluctuation occurs above the 700 G and it does not vary as the magnetic field or the k number. The similar low fluctuation frequency is observed at the down stream region where the fluctuation is measured by a floating Langmuir probe as shown in fig. 2(b). Though several peaks are observed around 25 kHz at B_0=200 and 300 G, most of intense signals within 10 kHz are found above 700 G. The dispersion relation of acoustic waves which propagates perpendicular to the magnetic field

$$w^2 = k^2 Vs^2 + \Omega^2 \qquad (1)$$

where Ω is ion cyclotron frequency and Vs is the velocity of ion acoustic wave which is proportional to the square root of the electron temperature. Ω it is about 4 kHz at 100 G for argon gas. When B_0<1000 G, Ω can be neglected and the wave frequency is proportional to the acoustic velocity.

In order to confirm the relationship between the ion acoustic dispersion relation and the measured density fluctuation, the fluctuations are measured as a function of the wave-number by moving position of the receiving mirror and its results are compared with the calculations as shown in fig.3(b). Fig. 3(a) show the fluctuation spectrum at B_0=100G.

The scattered angle is varied from 10.9 to 13.9 cm-1. The high frequency fluctuations at B_0=100 and 300 G follow the general dispersion relation of ion acoustic waves. The assumed electron temperature is 3.0 and 1.1 eV at B_0=100 and 300 G respectively. The measurements in the down stream by Langmuir probe show the similar trends on the electron temperature. High frequency fluctuations may be generated by parametric decay instability of the helicon or TG mode though the daughter waves are not observed. However, it seems that the low frequency fluctuations come from another origin because it does not only follow the ion acoustic wave dispersion relation but there is also no dependence on the magnetic field. The measured frequency is around 5 kHz. Low frequency fluctuations are very similar to the observations by Light *et al.* and Schröder *et al.* [7-8]..

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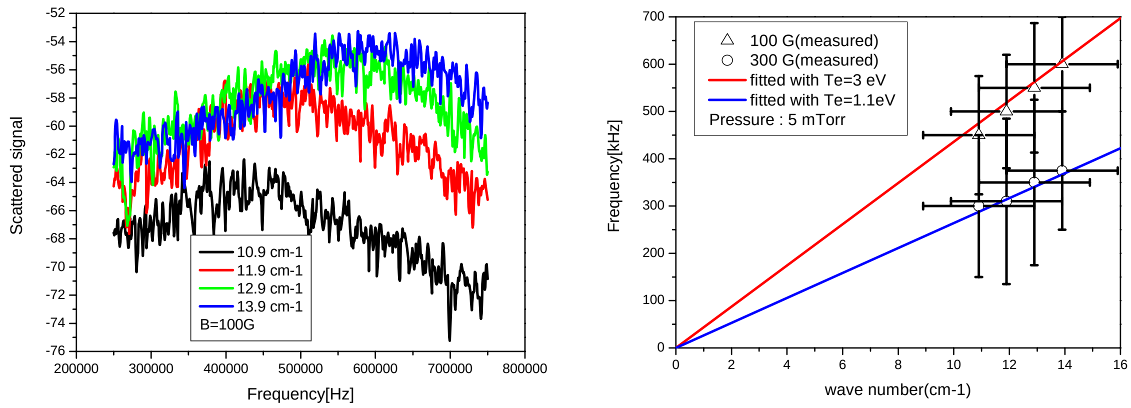

(a) (b)

Fig.3. High frequency fluctuations(a) and the dispersion relation for B_0=100 and 300 G(b).