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Effect of dust on plasma fluctuation spectra.

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The presence of charged dust particles can change the amplitude and spectrum of the plasma fluctuations. This is due to the dissipative effect of the charging collisions of plasma particles on dust which produce fluctuations of the dust charge. The discreteness of the dust particles (the natural fluctuations of the dust) also induce plasma fluctuations, different from the usual thermal fluctuations induced by electron and ion discreteness [1]. The relative importance of the two depends on the dust density, or more precisely, on the dust charge density. Measurements of plasma density and potential fluctuations *in selected parts of the spectrum* in the presence of dust can therefore be used as a diagnostics for the properties of the dust.

Here we present first observations of modification of plasma density fluctuation spectra due to dust particles. The experiment is conducted in a central region of a cusp plasma configuration, where a quiescent homogenous collisionless and unmagnetized plasma provides optimal conditions for measurements of the plasma fluctuations. The particles are formed during the discharge in Ar-CH_4 mixure due to well known effect of methane dissociation [2]. This results in a plasma with particles of different shapes and broad size distribution, a condition which is close to space and fusion (SOL) plasmas.

The experiment is performed in a cusp plasma device at Institute of Plasma Physics in Milan (for details see Ref. [3]). The static magnetic field has an intensity of 0.26 T at the point cusp and 0.156 T at the line cusp. The discharge pressure was varied between 0.07 and 0.02 Pa under a flow rate spanning from 6 to 3 sccm. The plasma source is a microwave generator at the frequency of 2.45 GHz powered at 500 W providing plasma density n_i = 10^11 per cm^3. For the pressure range studied, the central region of the discharge (up to 3 cm from the center) is *collisionless* plasma with essentially *unmagnetized* ions and weakly magnetized electrons.

For production of the dust particles, discharge in Ar-CH_4 mixture has been chosen. Such mixture decomposes mainly into Ar+, Hx+, hydrocarbons ions and condensed carbon black particles (dust) [4]. In order to verify that phenomena observed are due to the dust particles and not to different plasma composition, experiments in Ar-NH_3 mixture have been performed. The choice of NH_3 is motivated by the fact that it decomposes into ions of similar mass [5], has similar ionization cross-section and close ionization potential. All three (Ar, Ar-NH_3, and Ar-CH_4) discharges have similar density profiles that means the main difference between them is the presence of the carbon particles in the latter and also indicates that the number density of dust formed was low/modest.

Averaged plasma parameters and the density (ion saturation current) fluctuations are measured by a cylindrical Molybdenum probe of 4.7 mm length and 0.075 mm radius, located at the center of the device. The *spectral* characteristics of ion saturation current fluctuations basically reflect those of the density fluctuations. We note that if accurate *phase* measurements are desired these might not hold true anymore [6].

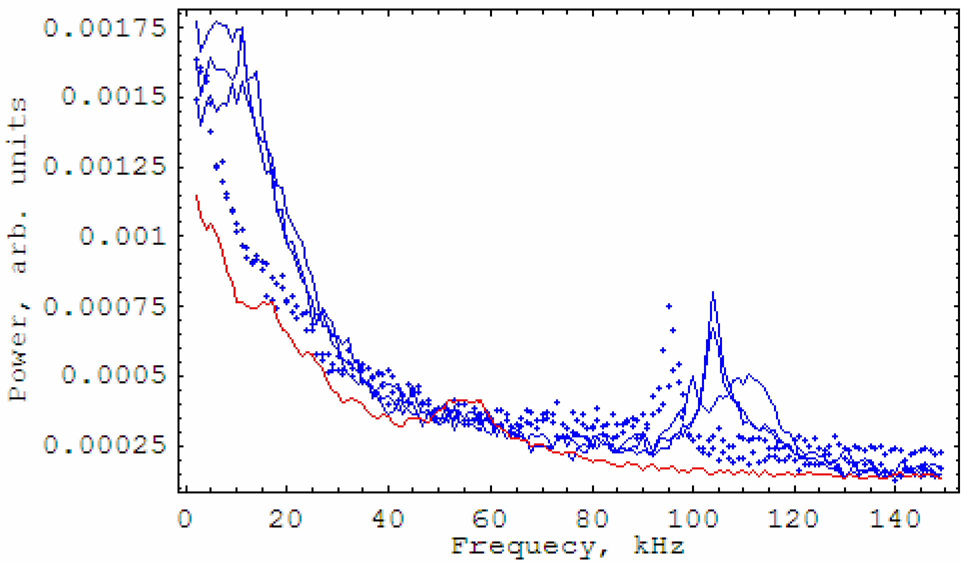

Fig. 1: *Power spectra of density fluctuations in Ar (red curve), mixture Ar+25 % CH_4 (blue dots) and Ar+50 % CH_4 (blue curves). Blue curves (dots) show statistical variation.*

The measurements in the center of Ar discharge revealed fluctuation level of 2 % and decaying power spectra, as shown in Fig.1 (red curve). Addition of 25 % of CH_4 results in the modifications of the spectra (Fig.1, blue dots), namely increase of the power at very low frequencies and appearance of peak(s) at higher frequencies. With increase percentage of methane the modifications become more pronounced (Fig.1, blue curves).

The spectrum found in 50-50 % Ar- NH_3 mixture discharge reproduces that of the pure argon, as seen from Fig.2 (violet curve) and does not exhibit any features found in Ar- CH_4 mixture spectrum. That picture was confirmed for flux rates (pressure) in a number of discharges. Thus, we conclude that changes of the spectrum are due to the dust formed in the Ar- CH_4 discharge. To summarize, the presence of the dust results in an enhancement of the very low frequency part of the spectrum and an enhancement of selected high frequency(ies). We stress that except peak(s), the power at higher frequencies is the same for Ar, Ar- CH_4 and Ar- NH_3 discharges indicating that the plasma conditions are almost identical and the comparison of these spectra is indeed meaningful.

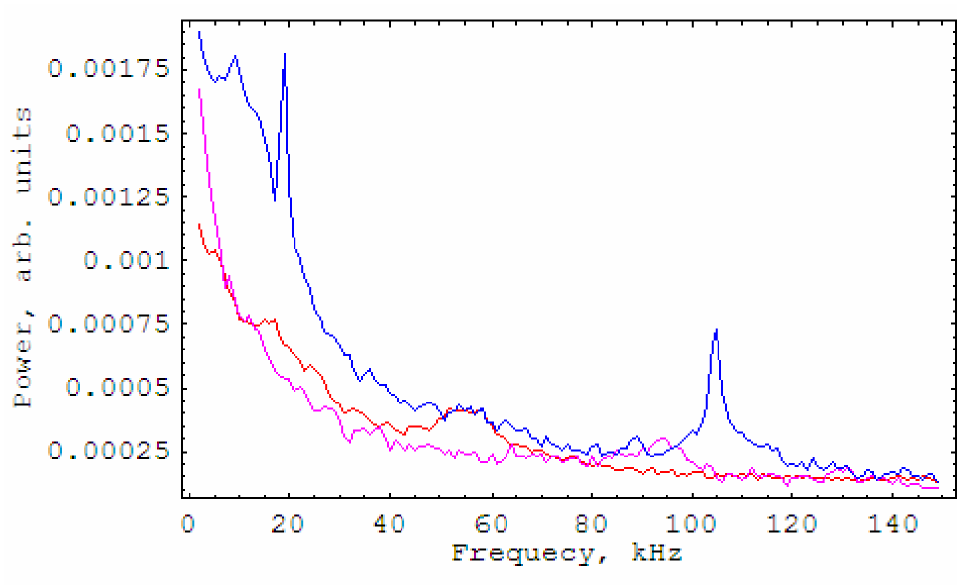

Fig. 2: *Power spectra of density fluctuations in Ar (red curve), mixture Ar+50 % NH_3 (violet curve) and Ar+50 % CH_4 (blue curves).*

For comparison with the experimental data we present here the results of the kinetic model [7]. The theory of fluctuations is developed for unmagnetized plasma where collisions of all species with neutrals are neglected and for constant dust density. The model takes into account the dust charge fluctuations due to the charging processes. This leads to modified expressions for the spectral densities of the plasma fluctuations, valid for sufficiently low dust densities (parameter $P=n_dZ_d/n_i$, where n_d is dust number density, Z_d is the particle charge). For comparison with the experimental data, which are single point measurements, the spectral density of the ion density fluctuations predicted by the model have been integrated over the range of wave numbers k corresponding to the smallest (probe dimension) and largest (dimension of plasma) wave lengths resolved in the experiment. The results are presented in Figure 3 and show a trend similar to that observed in the experiments. The model also predicts (not shown here) that for small k and large enough P the power in the peak of the ion acoustic mode is amplified. In our experiments we probably have a broad size distribution and each size can have different n_d (i.e. P). This might explain why we observe peaks in the experiment while they do not survive upon integration in the curves plotted in Fig.3. It is not reasonable to expect an absolute quantitative agreement with the experiment as the model is for monodisperse spherical dust particles, however the theoretical predictions of the change in power for frequency range where the effect was observed in the experiment, as well as overall qualitative picture is in very good agreement.

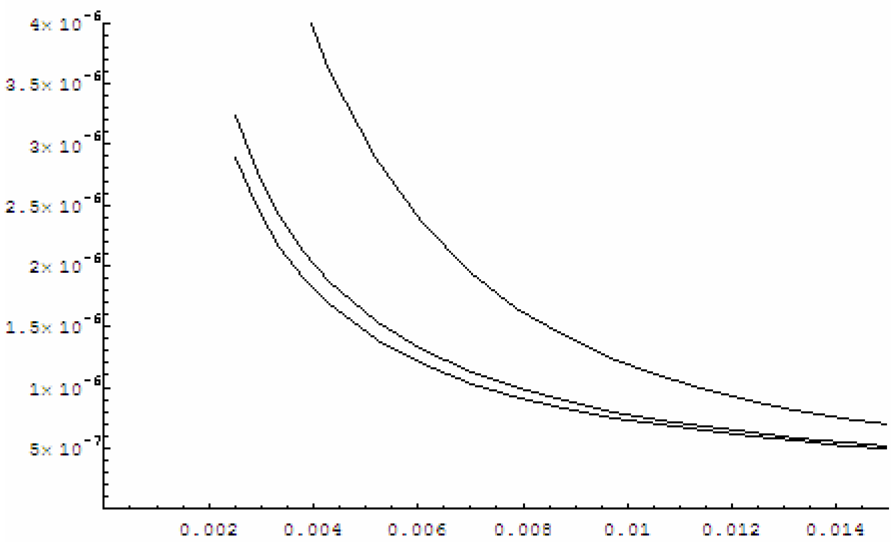

Fig. 3: *Power spectra of ion density fluctuations as a function of frequency in units of* $\omega_{pi} / 2\pi$ *(where* ω_{pi} *=66 MHz is the ion plasma frequency), without dust (lower curve, P=0) and in the presence of dust (upper curves, P=0.0001 and 0.001). The calculations are carried out for the plasma parameters corresponding to the experiment,* n_i*=10^11 per cm^3,* T_i*=0.03 eV,* T_i/T_e*=0.01 and dust particle radius a=0.01* μm.

[1]. V. Tsytovich and U. de Angelis, Phys. Plasmas, **6**, 1093 (1999).

[2]. L. Fulcheri and Y. Schwob, Int. J. Hydrogen Energy, **20**, 197 (1995).

[3]. N. Spinicchia *et al* , Surface & Coatings Technology, **200** 6434 (2006).

[4]. C.J. Liu, R. Mallinson, L. Lobban, J. of Catalysis, **179**, 326 (1998).

[5]. P.J. van der Oever *et al*, Appl. Phys., **98**, 093301 (2005).

[6]. V. Demidov, S. Ratynskaia, and K. Rypdal, Rev. Sci. Instrum, **73**, 3409 (2002).

[7]. U. de Angelis *et al*, "*Fluctuations in dusty plasmas*", these proceedings