Inverse brush cathode; a discharge for thermal fluctuation measurements

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Spectral densities of plasma fluctuating quantities are commonly used for diagnostics purposes in both laboratory and space plasmas. Typical examples include Thomson scattering in fusion plasmas [1] and Quasi-thermal Noise spectroscopy in space [2]. In dusty plasmas, a drastic enhancement of the low-frequency part of the power spectrum of fluctuations has been theoretically predicted and its use as a potential dust diagnostic has been suggested [3-5].

For experimental tests of fluctuation theory in ideal plasmas and plasmas seeded with dust, the ideal environment would be that of stable quiescent plasma. Proof of principle of the measurements of spectral modifications due to presence of dust has been provided with experiments performed in plasma confined in a magnetic cusp [3,4] but the noise level was too high for the spectral measurement in dust-free plasmas.

In most laboratory plasmas the homogeneous state of the positive column is often unstable, with the plasma exhibiting spatial fine structures and ionization instabilities. Rare exceptions are the so-called brush cathode discharges [6], where a specially manufactured cathode allows stable operation in the abnormal glow regime and the only fluctuations present are those associated with the thermal motion of the particles.

Such a device has recently been built by the KTH Complex Plasma Group in collaboration with CNR-Bari (Italy). It was constructed in a novel configuration that combines the advantages of the inverse design [7] with those of the reflex geometry [8]. It comprises of two opposite flat cathodes with a closely spaced uniform array of small holes drilled into the normal surface and two ring anodes placed symmetrically in between.

With a power of a few tens of W and voltages over 1kV, successful discharges have been obtained with plasma densities up to several $10^{10}$ cm$^{-3}$ and electron temperatures up to 0.5 eV in the field-free region between the two anodes. The densities can be further increased by modification of the set-up with reduced cathode-anode distances that will yield higher densities at lower voltages. Moreover, changing the background gas pressure and the applied voltage will allow us to achieve a wide range of plasma densities ($10^9$ cm$^{-3}$ - $10^{11}$ cm$^{-3}$) and collisionalities. Probe measurements of ion density fluctuations have revealed a noise level of the order of $10^{-4}$ and below, confirming the quiescence of the discharge.