Collective scattering on moving plasma perturbations

COLLECTIVE SCATTERING ON MOVING PLASMA PERTURBATIONS

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Collective scattering has proven to be a powerful technique to study plasma fluctuations. Heterodyne mixing of the scattered signal, using the incident beam as local oscillator increases the sensitivity several orders of magnitude. The angle between scattered and incident beam determines the k-spacing of the interference pattern in the detection volume. The i.f.detector signal is caused by the electron density perturbations moving through this interference pattern. Using a CO_2-laser and small scattering angles of 1-5°, the k-resolution varies from $1\text{-}5.10^4 m^{-1}$. Since corresponding lengths are much larger than the Debije length only collective phenomena are observed. The beat signal on the detector can be studied real time or frequency analysed. The general set up is shown in fig.1.

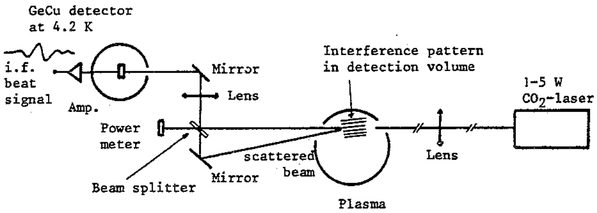


Fig.1.: Experimental set-up.

One experiment has been carried out on a continuous magnetized plasma arc with a radius of 10^{-2} m. The arc is a hollow cathode discharge in argon, current ~ 50 A, background pressure ~ 0.1 P and magnetic field ~ 0.2 T. The electron density in the arc is 10^{20} m^{-3} and the electron temperature is a few eV.
The signal generated by the density fluctuations lies in frequency range of .1-100 MHz. Spectral analysis of the signal is performed by means of a set of band filters. Measurements with optical probes have shown long correlation lengths in the direction of the arc. Long wire like electron density perturbations are assumed to be rotating at the plasma edge. From the dispersion ω→k (see fig.2) we find that the fluctuations rotate with the electron diamagnetic drift frequency, which in our case is close to the ion cyclotron frequency.

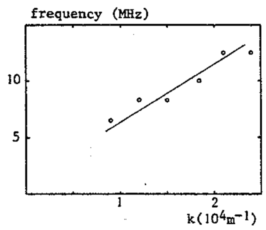


Fig.2.: Dispersion curve.

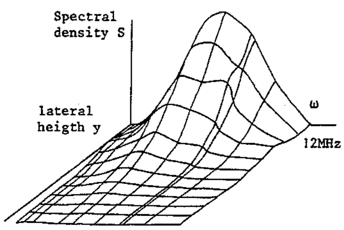
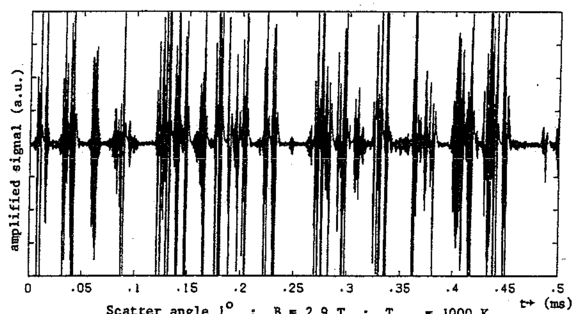


Fig.3.: S(y,ω) plot for $k = 9.10^3\ m^{-1}$.

The results can be compared with computer simulation of the signal. The measurements do not contradict the assumption of structures rotating at a radius of 3-4 mm. However, they do not prove their existence either. Real time measurements are planned in order to make final conclusions possible.
Collective scattering of CO_2-light has also been used for the determination of electron density fluctuations in a closed cycle MHD generator. In such a generator hot argon gas seeded with 0.01-0.05% cesium is send through a channel with a magnetic field (≤ 3 T) perpendicular to the supersonic flow (v ≈ 1000 m/s, gas temperature ≈ 1000 K). The Lorentz force generates an electrical current that is concentrated is so called "streamers" : discharges with a diameter in the order of a centimeter.
In these streamers electron temperatures of 5000 K and electron densities up to $5.10^{21} m^{-3}$ are reached. Measurements of line and continuum emission and high speed photography have shown that the streamers have a fine structure and consist of a number of small discharges (filaments) with a diameter smaller than 1 millimeter. To get quantitative information about the dimensions of the filaments collective scattering has been used. The application of heterodyne detection makes this diagnostic only sensitive for a certain range of spatial dimensions. While the streamers are passing the interference pattern in the detection volume a time-varying signal is generated and real time measured by means of a high speed transient recorder (fig.4). Also line and continuum radiation is recorded 8 centimeters downstream. From earlier experiments it follows that the properties of a streamer do not change over such a distance. The streamer velocity calculated from the time difference between scattering and emission signals and the velocity deduced from the frequencies in the scattering signal correspond very well. From a plot of the magnitude of the scattering signal(fig.5) versus the spatial resolution of the measurement a smallest length scale of 0.3 mm is determined. The results show the applicability by excellence of CO_2-collective scattering to determine the size of moving plasma perturbations.



Scatter angle 1° ; B = 2.9 T ; T_{gas} = 1000 K
v = 1100 m/s ; sampling frequency 32 MHz.
Fig.4.: Scattering signal of run 4282.

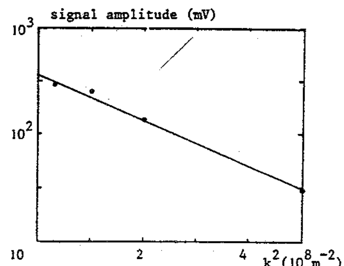


Fig.5.: Signal amplitude versus k^2.
The slope determines the length scale.

References :

1) R.E. Slusher and C.M. Surko, Phys.Fluids 23 (1980),472.

2) D.C. Schram, H.W.H. van Andel, G. le Clair and P. Brodeur, Plasma Physics 25 (1983),1133.