The study of long range electric potential correlation on the GAM frequency on the T-10 tokamak

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In the recent years there has been significant interest to Geodesic Acoustic Modes (GAM). GAMs, being the high-frequency counterpart of zonal flows, can be a possible mechanism of the turbulence self-regulations. It has been shown theoretically that GAMs manifest themselves as oscillations of plasma electric potential with $m = n = 0$ (and can weakly be seen on density with $m = 1$, $n = 0$) [1]. ExB poloidal turbulence flows (i.e. GAM) are shown at fig. 1.

GAMs have been studied with two main diagnostics: Langmuir probes and Heavy ion beam probing (HIBP), a unique method for direct measurement of the electric potential in the hot plasma core. Diagnostics are separated by half of torus of the T-10 tokamak (R= 1.5 m, a= 0.3 m, B < 2.5 T). Diagnostics arrangement and schematics of HIBP are shown at fig. 2 and fig. 3.

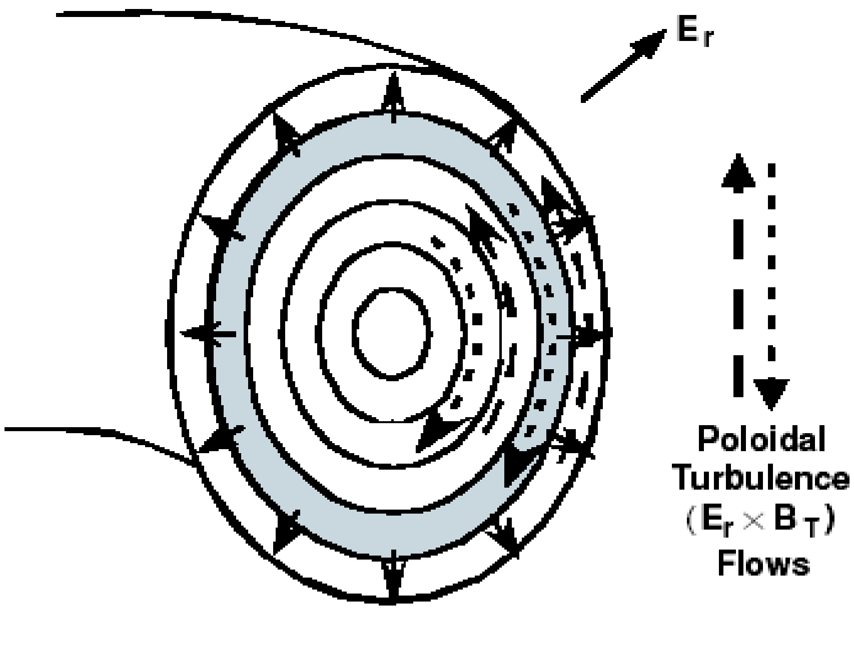

Fig. 1. Schematic of GAM oscillations.

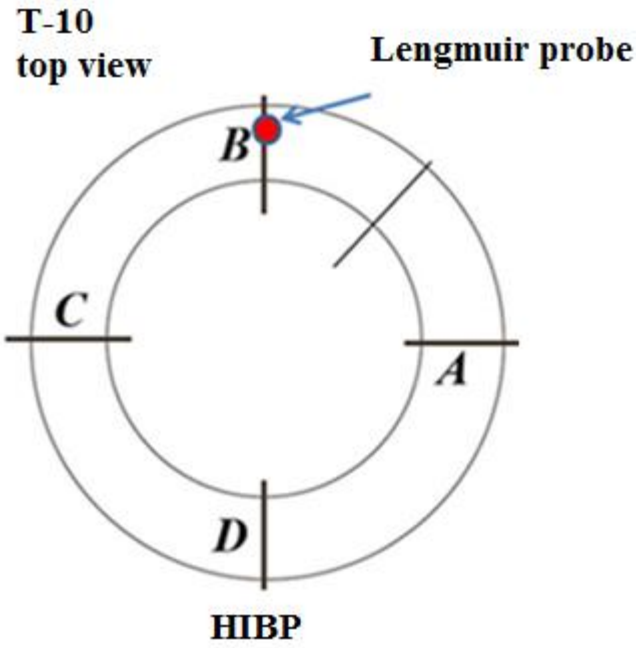

Fig. 2. Diagnostics arrangement.

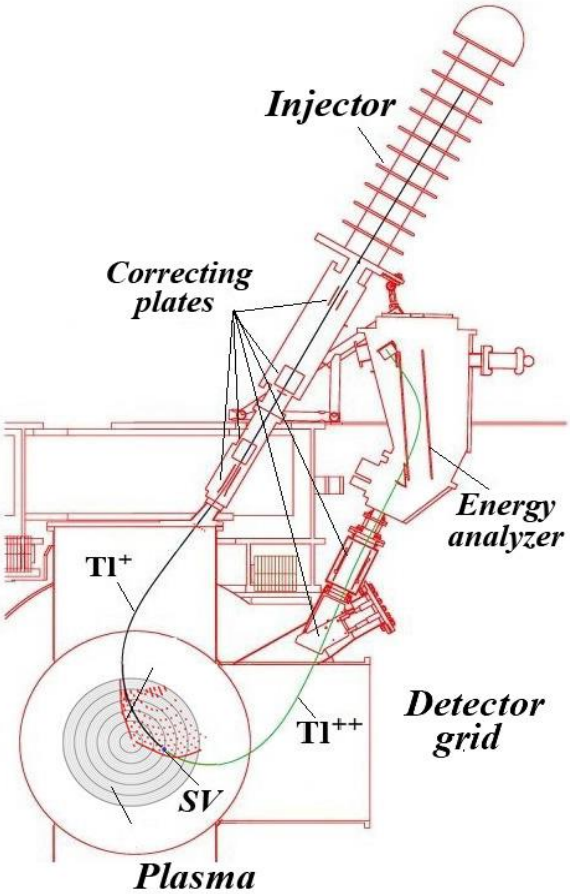

Fig. 3. Schematic of HIBP.

This work is dedicated to simultaneous measurements of plasma potential oscillations at GAM frequencies in different locations and studying of their correlation properties. It was found that coherency between signals of two diagnostics is up to 0.8 that is unexpectedly high for such a large distance between them, half of torus in toroidal and about π in poloidal direction. Such coherency appears when Langmuir probes were located at about ρ = 0.95. Also, the phase shift between potentials measured with two diagnostics has been obtained.

The value of coherency decreases with increasing in radial distance between HIBP sample volume and probes position. The phase shift between electric potential oscillation measured with HIBP and measured with Langmuir probes in the GAM frequency range was negative (about - 1.5 – 2.2 rad). Its value increases with increasing in radial distance between points of observation of two diagnostics. Spectrograms of potential oscillations measured by HIBP, – Lengmuir probe (LP), coherence and phase shift between oscillations of potential measured by two diagnostics are shown at fig. 4 (#71003, B = 2.42 T, I = 220 kA, n_e = (2 – 4)*10^{19} m^{-3}).

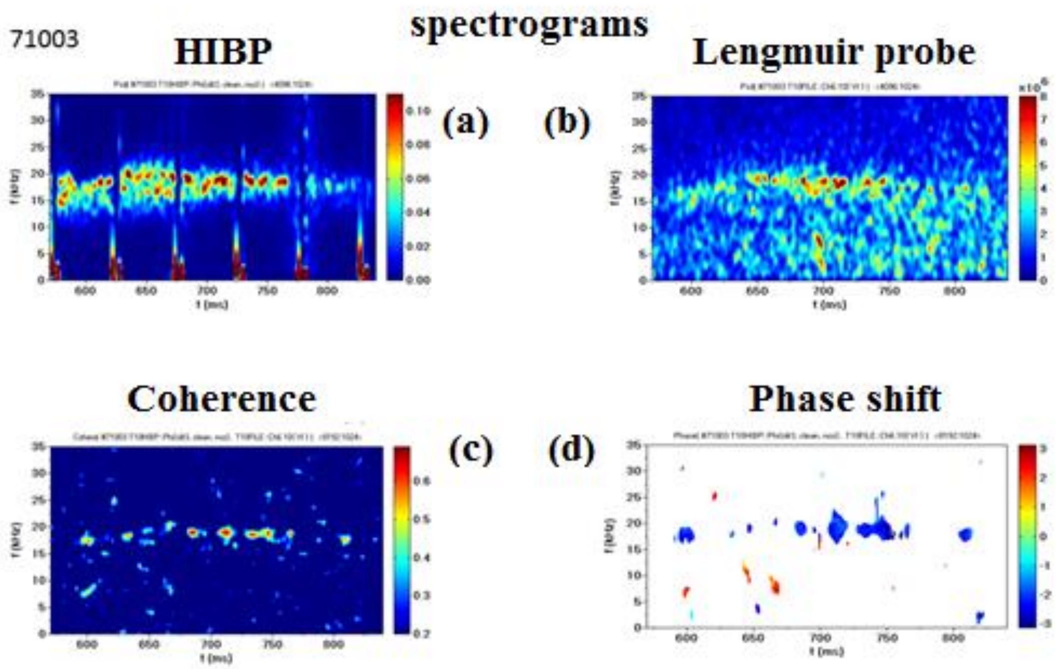

Fig. 4. Spectrograms of potential oscillations, (a) –HIBP, (b) – Lengmuir probe (LP), (c) - coherence, (d) – phase shift between oscillations of potential measured by HIBP and LP (shot # №71003).

We assume that phase shift in toroidal and poloidal directions is equal to zero because m = n = 0 for GAM. Since phase shift is negative plasma potential wave propagates outwards in examined regime. The value of phase velocity can be calculated as:

$$v = \lambda f = 2\pi f \Delta r/\Theta,$$

where λ – potential oscillations wavelength, f – GAM average frequency, Δr - the magnitude of the radial difference between the observation areas, Θ – phase shift between potential oscillations at GAM frequency, measured by HIBP and LP. The magnitude of its velocity changes from ~ 2 km/s (Δr ≈ 3 cm) to 7 km/s (Δr ≈ 11 cm). Radial distributions of averaged maximum values of coherence and phase shifts are shown at fig. 5 (shots from the same regime as shot #71003).

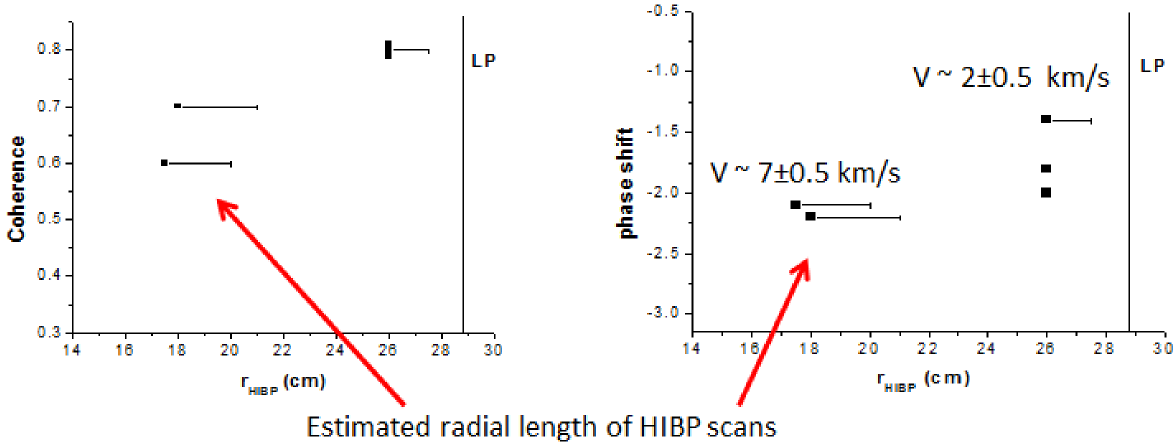

Fig. 5. Radial distributions of averaged maximum values of coherence and phase shifts Θ.

There is a some analogy with the data obtained on the tokamak TCV [2]. The GAM observed on the T-10 on the potential oscillations propagates outward, the GAM observed on the TCV on the density oscillations propagates outward.

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References

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2. de Meijere C.A. et al. Complete multi-field characterization of the geodesic acoustic mode in the TCV tokamak // PPCF. 2014. Vol. 56, № 7. P. 72001.