1.4 Characteristics of zonal flow and geodesic acoustic mode in edge plasmas of the HL-2A tokamak

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Zonal flows (ZF) are universal in turbulent systems such as magnetically confined laboratory and space plasmas as well as atmospheres of stars. The extensive studies in this field are aimed at understanding nonlinear processes responsible for the coherent structure formation and for anomalous cross-field transport induced by turbulent fluctuations.

It is widely accepted in recent years that the turbulence and the induced transport may be reduced or even suppressed by $E \times B$ sheared flows, such as mean flows and ZFs. The ZFs are induced by $m = 0, n \neq 0$ radial electric field fluctuations with finite radial scales, generated by nonlinear interactions in ambient turbulence (ATs). Here, $m/n$ is the poloidal/toroidal mode number of the fluctuations. Two kinds of ZFs have been observed in toroidal plasmas, i.e., near zero low frequency zonal flows (LFZFs), and oscillatory geodesic acoustic modes (GAMs).

Although both GAMs and LFZFs have been identified in toroidal plasmas, few experimental data of zonal flow dependence on plasma heating schemes are available.

1 Experimental arrangement

The spatio-temporal fluctuations of the floating electrostatic potential were measured with three Langmuir probe (LP) arrays distributed poloidally and toroidally (See Fig. 1) in the experiment. A 10 tip rake probe array with 4 mm tip separation was set up poloidally orientated and named poloidal probe (PP). A second rake probe array of 12 tips was mounted in the radial direction named radial probe (RP). A three step Langmuir probe (TSLP) array of 6 tips and the second rake probe array form a fast reciprocating probe set of 18 tips and a 65 mm poloidal span, which was located in a poloidal cross section of 2100 mm away from the first rake probe array in the toroidal direction. The length and diameter of each tip are 3 and 2 mm. All of the probe sets were mounted at the outside middle plane of the tokamak up-down symmetrically. The PP and RP were used to measure the floating potential fluctuations while the TSLP array was for the measurements of the electron temperature and density in the experiment.

2 Experiment results

The variation of the characteristics of LFZFs and GAMs with ECRH power of 150 kW was investigated for the first time in the edge plasma of HL-2A tokamak using multipoint measurements of floating potential and radial electric field fluctuations obtained with a Langmuir probe arrays placed toroidally and poloidally. Fig. 1 shows the typical power spectra of the floating potential fluctuations in OH and ECRH plasmas at the radial position of $z = 2.8$ cm inward from the last close flux surface (LCFS). Two distinct features are a large power fraction in low frequency range of $0 \sim 3$ kHz and a sharp peak at $f \sim 10$ kHz. The former and the latter were identified as a LFZF and GAM, respectively. The intensity of the LFZF, GAM and AT increases with ECRH power.

Fig. 1. The representative power spectra of floating potential fluctuations inside the LCFS with Ohmic and ECRH heating.

The radial distribution of the zonal flow intensity was also studied in ECRH plasmas and compared with that in Ohmic
plasmas. Shown in Fig. 2 (a) are the radial dependence of the potential power of LFZF in ohmic (squares) and ECRH (cycles) plasmas. Same profiles for the GAM are also given in Fig. 2(b). Moving from the boundary inward, the intensity of LFZF first increases slightly, and then sharply rises up at the location of $-2.5$ cm where the GAM power reaches a minimum after a maximum at the position of $-1.5$ cm.

The spatio-temporal characteristics of turbulence envelopes, induced by the LFZF, an important aspect of ATZF interactions, have been successfully demonstrated through the envelope analyses of the potential fluctuations in the experiment. The spatial properties of the turbulent envelopes, including long range correlation, poloidal and toroidal symmetries and finite radial wave number are similar to those of zonal flows themselves.

In summary, intensive LFZF was found to coexist with GAM in the edge plasma of a tokamak. The characteristics of LFZF and GAM in ECRH plasmas were analyzed and compared with those in Ohmic plasma. The spatio-temporal structures of the AT envelopes, similar to those of the ZFs indicate that zonal flows in fact impacts the AT.