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Experimental observation of the localized coupling between geodesic acoustic mode and magnetic island in Tokamak plasmas

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Zonal flow is a ubiquitous phenomenon in nature and the laboratory. In toroidal plasmas, two branches of zonal flow exist, e.g. the stationary (or low frequency) zonal flow and the geodesic acoustic mode (GAM). Both stationary zonal flow and GAM have been proved to be mainly electrostatic in the zonal flow-drift wave system. Tearing modes (TMs) is one of the magnetohydrodynamics instability in tokamak plasmas, which can lead to the formation of magnetic islands. Beta-induced Alfven Eigenmodes (BAEs) locate inside the shear Alfven continuous spectrum gap, which is caused by the finite thermal plasma compressibility that close to the frequency of GAM. The BAEs during TMs are counter-propagating waves, and form standing wave structure in the island rest frame.

The interplay between BAEs and TMs has been reported on EAST before [1, 2]. Two theoretical models have been proposed for the excitation of BAEs, i.e. the subtleties of the Alfven continuum inside magnetic islands [3–5] and the magnetic islands induce free energy [6, 7]. The models are difficult to verify directly for the limitation of diagnostics, which is motivated for the finding of new reasonable mechanism by the localized measurement.

The nonlinear interaction among GAM, TMs and BAEs is reported experimentally in HL-2A [8], which is investigated theoretically in Ref [9]. The experimental observation of the localized coupling among GAM, TMs and twin counter-propagating BAEs waves have been investigated in EAST tokamak. The GAM has weak magnetic component of m/n = 2/0 (standing wave), while the BAEs are dominated by electromagnetic components with mode numbers of $m/n = \pm 4/1$, where m, n are poloidal and toroidal numbers respectively, '-' means electron diamagnetic drift direction. The GAM, magnetic islands and BAEs are located at the same region of q = 4 rational surface, where the burst of GAM is ahead of TMs and BAEs. Moreover, as the intensity of magnetic island increasing, the electrostatic GAM decreased while the electromagnetic BAEs increased. Our localized measurement provided another reasonable excitation mechanism for BAEs, i.e. the BAEs is excited by the nonlinear coupling between GAM and magnetic island, which is fully different in comparison with Ref [9]. The results strongly implied that the energy could be transferred from zonal flow to magnetic field through local couplings between GAM and magnetic island, which would be conducive to the understanding of energy conversion process between electrostatic and electromagnetic fields.

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