§2. Bursting Behavior of Alfvén Eigenmodes

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It was reported that recurrent bursts of the toroidicity-induced Alfvén eigenmodes (TAEs) and drop in neutron emission that indicates fast ion loss were observed in neutral-beam-injection (NBI) heating experiments [1,2]. We have successfully reproduced the recurrent TAE bursts and fast-ion losses with four-dimensional Fokker-Planck-magnetohydrodynamic (MHD) simulation. It is found that the key processes of the recurrent burst are creation and collapse of the stepwise structure in the fast-ion distribution.

A kinetic-MHD hybrid model, which was used in the Vlasov-MHD and particle-MHD simulations [3], is employed. In this model plasma is divided into two parts, the background plasma and fast ions. The background plasma is described by the MHD equations and the electromagnetic field is given by the MHD description. Time evolution of the fast ion distribution is followed by the Fokker-Planck simulation method directly solving the distribution function in the phase space.

We consider a four-dimensional phase space (R,φ,z,v), where v is the parallel velocity and (R,φ,z) are the cylindrical coordinates. Fast-ion source with a Gaussian profile in minor radius and collisional slowing down are taken into account. The initial condition is an MHD equilibrium where B_0=1[T], n=3×10^{19}[m^{-3}], R_0=2.4[m], and a=0.8[m]. These parameters are similar to the NBI experiment at TFTR [1]. In the initial condition there is no fast ion and the switch of fast-ion source is turned on. The fast ion gradually accumulates and at the end of simulation the volume-averaged fast-ion beta value reaches to 0.6% which is similar to the experimental value. The slowing down time is set to 2000τ_A, where τ_A is the Alfvén time.

Four TAEs with toroidal mode number of 1-4 are destabilized. Time evolutions of the total energy of four TAEs and the peak value of fast-ion distribution at $v=v_A$ and at the mid-plane are shown in Fig. 1. It can be seen that the recurrent bursts of TAEs and the drop in the peak value of fast ion distribution take place. In Fig. 2 the bird's-eye view plot shows time evolution of the fast-ion distribution as a function of the major radius at $v=v_A$ and at the mid-plane. The distribution function is averaged in the toroidal angle. Bright parts correspond to the regions flattened by TAE activity. Stepwise structure is recurrently created by the fast-ion source and by four TAEs which are localized at different minor radii, and it collapses around t/τ_A =600, 1340, 2030, and 2710. We should notice that collapse takes place at a constant level of TAE energy. This is consistent with the theory of resonance overlap [4].

In Fig. 3 shown are time evolutions of the total fast-ion energy and the TAE energy. Drops in the fast-ion energy indicate that the TAE-induced fast-ion losses are reproduced in this simulation.

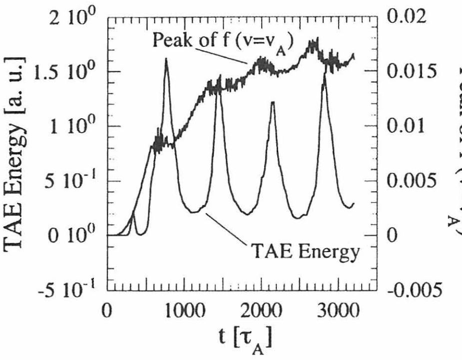

FIG. 1. Time evolutions of TAE energy and the peak value of the fast-ion distribution.

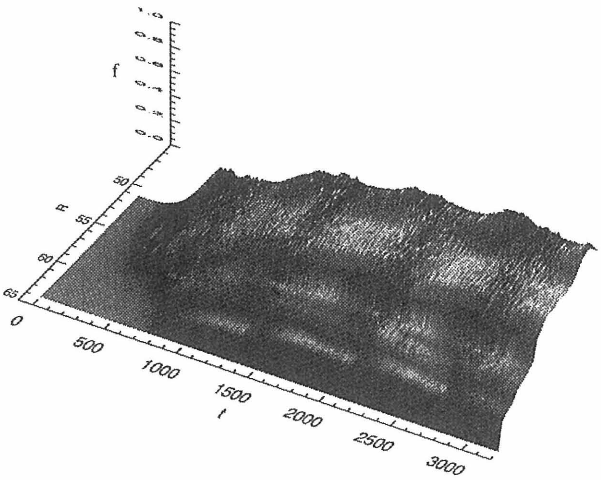

FIG. 2. Bird's-eye view plot of time evolution of the fast-ion distribution.

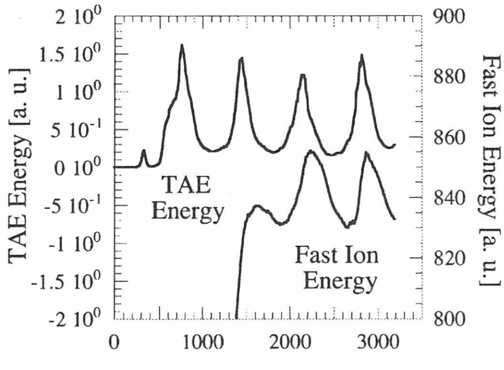

FIG. 3. Time evolutions of the TAE energy and fast-ion energy.

References

[1] K. L. Wong *et al.*, Phys. Rev. Lett. **66**, 1874 (1991).

[2] H. H. Duong *et al.*, Nucl. Fusion **33**, 749 (1993).

[3] Y. Todo et al., Phys. Plasmas **2**, 2711 (1995); Y. Todo and T. Sato, Phys. Plasmas **5**, 1321 (1998).

[4] H. L. Berk, B. N. Breizman, and M. Pekker, Phys. Plasmas **2**, 3007 (1995).