**Invited Abstract Submitted for the Thirteenth Topical Conference
on Applications of Radio Frequency Power to Plasmas
April 12–14, 1999, Annapolis, Maryland**

Plasma Rotation Induced by RF*

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Plasma roation has many beneficial effects on tokamak operation. Toroidal rotation in tokamaks has been demonstrated to be necessary for stablization of low n MHD modes by resistive wall in order to sustain high beta equilibria. Radial electric field shear generated by sheared rotation, either toroidal or poloidal, has been shown to suppress turbulence and allow improvement in energy confinement. In present-day tokamaks, rotation is mostly driven by unbalanced neutral beam injection (NBI), which may not be effective in the reactor regime. Hence, experimental and theoretical investigation of radiofrequency (RF) induced plasma rotation is of great interest.

A variety of RF effects on toroidal rotation has been reported from TFTR, JET, DIII–D and Alcator C-Mod tokamaks. In dominantly NBI-heated discharges, addition of RF heating usually reduces toroidal rotation in the direction parallel to plasma current; this has been observed on TFTR, JET, and DIII–D. In the case of purely ICRF-heated plasmas, counter-current rotation generated through an RF-induced ion orbit loss mechanism was reported in an early TFTR experiment. On the other hand, co-current rotation has been observed in H–mode discharges with ICRF heating alone on JET and C-Mod. While the co-current rotation observed in the JET experiment appears to be correlated with an increasing ion pressure gradient associated with the L-H transition, significant core rotation observed on C-Mod cannot be accounted for by this explanation. Experimental evidence on RF induced poloidal rotation is less readily available. Localized sheared poloidal flow generation has been observed in IBW heated discharges on PBX-M and TFTR.

Theoretical explanations of RF induced rotation can be categorized under different ways of breaking the toroidal symmetry in momentum space. Direct momentum input from waves and the presence of loss cones are examples. Another promising physical mechanism for understanding the diverse phenomena is non-ambipolar RF induced radial transport of minority or beams ions, which gives rise to radial electric field and $J \times B$ torque for both torodial and poloidal acceleration. Finite gyro-orbits play a significant role. A theoretical framework, including moment and gyrokinetic approaches will be introduced to discuss the physical processes and clarify the issue of toroidal momentum conservation. Key signatures for testing the different models will be identified.

*Work supported by U.S. Department of Energy under Grant No. DE-FG03-95ER54309.
†In collaboration with S.C. Chiu, Y.R. Lin-Liu, and Y.A. Omelchenko