# Intrinsic Rotation and Zonal Flow Generation in a Simple Laboratory Plasma System

George R. Tynan[a,c] Patrick H. Diamond[c,d], Christopher Holland[a], Stefan H. Mueller[a], Min Xu[a], Zheng Yan[a,b],

[a]*Center for Energy Research & Department of Mechanical and Aerospace Engineering, 9500 Gilman Drive, UCSD, La Jolla, California, USA*
[b]*Department of Engineering Physics, University of Wisconsin-Madison, Wisconsin, USA*
[c]*Center for Momentum Transport and Flow Organization,UCSD , 9500 Gilman Drive, La Jolla CA 92093*
[d]*Center for Astrophysics and Space Science & Department of Physics, 9500 Gilman Drive, UCSD La Jolla, California, USA*

**Abstract**:
The nonlinear interaction between drift turbulence and zonal flows plays a key role in determining the turbulence amplitude, spatiotemporal scale and subsequent transport and is therefore of significant interest in magnetic fusion research. We summarize the status of laboratory plasma experimental studies of this problem using multipoint time-domain probe studies, frequency-domain studies, and direct visualization studies. The mean fluctuation-induced Reynolds stress is consistent with the observed time-averaged shear flow and estimated damping profiles. Velocimetry applied to fast camera measurements permits simultaneous zonal flow and drift fluctuation imaging. The results show that the drift instability generates isotropic vortex structures at the maximum pressure gradient region which then propagate azimuthally and slowly drift radially outwards towards the shear layer located at the plasma boundary. As the vortex structures approach the shear layer they are stretched and thinned and eventually incorporated into the shear layer, thereby maintaining it against damping. Radially resolved Fourier-domain measurements show these merger events as an indirect nonlinear energy transfer process that can amplify a preexisting shear layer. This region is defined by the external heat input profile into the system and characterized by a rapid change in the magnitude of the plasma pressure gradient, neutral gas temperature and density. When combined with strong flow damping outside of the plasma column due to ion-neutral collisions, a central plasma rotation without any external momentum input occurs. This intrinsic rotation can be interpreted as an being generated by an effective residual stress operating in concert with a no-slip boundary condition at the plasma edge. The outward flux of turbulent vortices thus acts like a heat engine which transforms a radially directed heat flux into a mechanical rotation of the central plasma.