**Key Mechanism for Fast Magnetic Reconnection identified in a Laboratory Experiment**

*The Magnetic Reconnection Experiment at Princeton Plasma Physics Laboratory has improved our fundamental understanding of magnetic reconnection, a key process in magnetized plasma in the universe. Recently a quadrupole magnetic field has been clearly observed during the reconnection process in MRX, demonstrating that Hall MHD physics plays an important role in fast reconnection. This is an important step for understanding the key mechanisms for anomalously fast reconnection observed in the universe.*

*[Sessions LP1-96-100 (Oct.26,2005), BI-2(Oct.24), Adam's Mark Hotel, Denver CO]*

Magnetic reconnection, a topological rearrangement of magnetic field lines, occurs ubiquitously both in laboratory and space and astrophysical plasmas. During magnetic reconnection a conversion of magnetic energy to plasma kinetic energy occurs by way of acceleration or heating of plasma particles. Recently magnetic reconnection phenomenon have been recognized to have wide-ranging importance in space and astrophysical plasmas, as a key process in the interaction of the solar wind with the dipole field of the earth's magnetosphere, in the evolution of solar and stellar flares and in the formation process of stars. One of the most fundamental questions is why reconnection occurs much faster than predicted by the classical MHD (Magnetohydrodynamic) theory, which treats the plasma as a single electrically conductive fluid.

The extensive theoretical and numerical work over the past decade has revealed that two-fluid effects (separate electron and ion fluids, instead of a single fluid) are important within the small, critical layer where reconnection occurs. This leads to the different behaviors of large orbit ions and magnetized (gyrating) electrons, a Hall effect. The magnetized electrons flow differently from ions in the reconnection region and pull magnetic field lines towards the direction of electron current. This pulling of the magnetic field lines results in an "out of reconnection plane" quadrupole component to the magnetic field (where there are two distinct regions of positive field and two distict regions of negative field). This out of plane field is considered to be a key signature of two-fluid effects in magnetic reconnection. As demonstrated by the recent two-dimensional numerical simulations at University of Maryland, the Hall effect is considered to increase the reconnection speed when coupled with some dissipation. Although this quadrupole field has been measured in a few occasions in the magnetosphere plasma, it has not been verified in laboratory plasmas.

In Magnetic Reconnection Experiment (MRX) at PPPL, the fundamental physics of magnetic reconnection has been extensively studied by creating magnetic reconnection in a controlled, repeatable, and easily measurable manner. Recently the quadrupole magnetic field component has been clearly measured, confirming the presence of two-fluid effects. It was experimentally demonstrated in MRX that magnetized electrons flow differently from ions in the reconnection region and pull magnetic field lines towards the direction of electron current. As a result, an out-of-reconnection plane field of quadrupole profile, a signature of Hall effects, is created as demonstrated in Figure 1. The data from MRX is the most conclusive demonstration of the Hall effects to date and is in good agreement with the two-dimensional simulation results by University of Maryland. This is an important step for identifying the key physics mechanisms for anomalously fast reconnection almost always observed in laboratory and in the universe. These effects can possibly explain the observed fast reconnection in the Earth's magnetosphere, stellar flares and extra-galactic radio lobes. In particular, MRX experimental data has a striking similarity to magnetospheric measurements, in which the quadrupole component has also been detected.

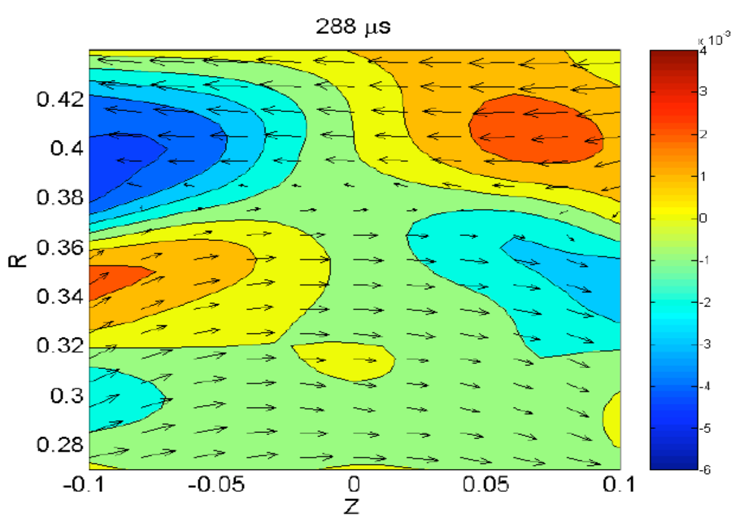


Figure 1 Color-coded contours of out-of plane quadrupole field superposed on vectors of reconnecting field in the neutral sheet (reconnection region) of MRX. The two large positive (red) regions and two large negative (blue) regions show the quadrapole out-of-plane magnetic field. Opposing fields are reconnecting at the center simultaneously creating out-of-plane magnetic fields of quadrupole profile seen in the color contours.

**Contacts**:
Masaaki Yamada, PPPL Princeton University : myamada@pppl.gov, 609-243-2566
Hantao Ji, PPPL Princeton University: hji@pppl.gov, 609-243-2162
James Drake, University of Maryland: drake@plasma.umd.edu, 301-405-1471
Forrest Mozer, University of California: fmozer@ssl.berkeley.edu, Berkeley, 510-642-0549