Thermal Transport Control by Magnetic Shear of Core Island Structure

P.W. Terry, I.J. Mckinney, J. Boguski, S. Munaretto,
M.D. Nornberg, B.E. Chapman, and J.S. Sarff
University of Wisconsin-Madison

Helical distortions of toroidally symmetric plasmas, whether spontaneously occurring or forced by 3D field perturbations, are increasingly being linked to improvement of transport and stability of important MHD modes. Examples include the maintenance of $q_0 > 1$ in high-beta hybrid tokamaks and the thermal transport barrier at the edge of the helical core of the quasi single helicity (QSH) state of the RFP. Here we describe theoretical and experimental investigations that probe the way the magnetic shear of the dominant island structure affects transport barrier physics in the QSH state.

Theoretically we show how magnetic and flow shear suppress the coupling between a dominant core resonant tearing mode and higher toroidal-mode-number tearing modes that are resonant at larger radial values. When the suppression physics is included in a time dependent MHD mode coupling theory it leads to a predator-prey system whose limit cycle oscillations match those of experiment, particularly in the scaling of QSH persistence with plasma current or Lundquist number. The addition of a temperature evolution equation subject to magnetic-fluctuation-induced thermal losses and the shearing effect of the dominant coherent island yields a thermal transport barrier whose properties are probed by the temperature gradient oscillations induced by the QSH limit cycle. These oscillations have relative phasing and amplitudes in the magnetic and thermal fields that agree well with experiment. The analysis suggests that the suppression by magnetic shear does not just apply to fluctuation amplitudes, but must include as well the cross phase between the radial magnetic field perturbation and the temperature fluctuation.

Experimentally in MST, measurements of temperature, density, and soft x-ray emission are used with V3FIT to reconstruct the 3D field structure at different stages of the QSH onset cycle. The reconstruction shows that the magnetic shear can be very large and strongly localized at the edge of the helical core in the ramp up to the QSH state while maintaining significant but smaller values at later times. Measurements of the plasma flow are also being undertaken, both to determine the role of its shear in the transport barrier physics, and to expose the anticipated dynamo effect associated with the helical core.