Topic: OV

Overview of Results in the MST Reversed-Field Pinch Experiment

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We report on results achieved in the MST reversed-field pinch in the following three key areas. In the area of plasma confinement and beta we have achieved improved-confinement plasmas with simultaneously high $T_e \approx 2$ keV and high $T_i > 1$ keV at MST's highest current capability ~ 0.5 MA. Both temperatures increase with plasma current. In addition, we have achieved plasmas with simultaneously high n_e and high β_{tot} up to 26%, which exceed local and global MHD stability limits. In the area of auxiliary heating and current drive we report on two complementary rf approaches, using lower hybrid and electron Bernstein wave injection at the power level 250 kW. In the area of transport and fluctuation studies we report on experimental and theoretical results of particle and momentum transport resulting from MHD tearing fluctuations. The results indicate that the Maxwell and Reynolds stresses are both important for momentum transport. We also report on experimental and theoretical studies of anomalous ion heating from magnetic reconnection.

Inductive control of the plasma current profile in the RFP enables reduced MHD tearing and its consequent fluctuation-induced transport. To date, this has provided as much as a ten-fold improvement in energy confinement in MST. Recent efforts have focused on optimizing control at MST's largest current, resulting in plasmas with high electron temperature $T_e \approx$ 2 keV over more than half of the plasma radius (Fig. 1). In addition, judicious timing of the current profile control initiation relative to spontaneously occurring magnetic reconnection allows the magnetic energy released at the reconnection to be captured in the form of well confined thermal ions with T_i exceeding 1 keV (Fig. 1). Thus, the synergetic use of spontaneous magnetic self-organization and active reduction of plasma transport results in well confined plasmas with hot electrons and ions. This is the first time both T_e and T_i have been produced simultaneously at these high levels in an RFP. Total thermal beta (electrons and ions) is 10%. Both electron and ion temperatures and stored energy increase with plasma current. This is important for scaling, but also provides a continued test of the robustness of magnetic fluctuation suppression. The combination of active current profile control and deuterium pellet injection results in higher density and higher β improved-confinement plasmas (Fig. 2). This technique allows us to attain an RFP record high β_{tot} up to 26%. The large pressure gradient exceeds the Mercier limit for local interchange in the core and creates pressure-drive for global tearing, a new regime for the RFP. No evidence for interchange modes degrading plasma performance is observed. A modest increase in the tearing mode amplitudes relative to low density plasmas suggests pressure-driven tearing might be important at high beta.

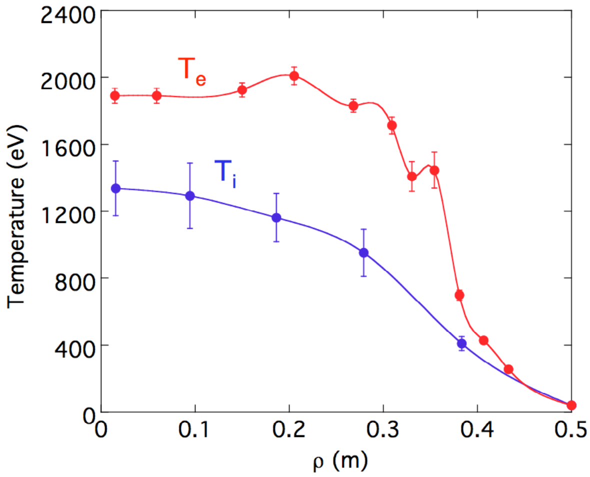

FIG. 1. Radial profile of electron and ion temperatures

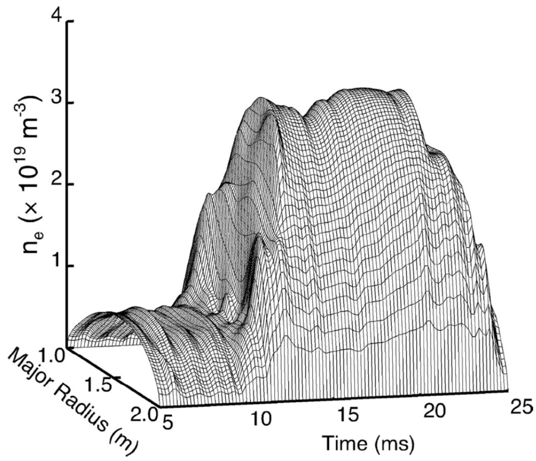

FIG. 2. Time evolution of density profile after pellet ablation during t = 10 to 13 ms

Two RF techniques for current drive and electron heating - lower hybrid (LH) and electron Bernstein wave (EBW) injection - have been applied at a source power level exceeding 200 kW. Ray tracing and Fokker-Planck calculations predict good absorption and directional control for both waves. For LH injection about 125 kW has been coupled to the plasma.

Substantial progress has been made in understanding the momentum transport and anomalous ion heating. We have investigated magnetic fluctuation-induced momentum transport through detailed measurements of Maxwell and Reynolds stresses. A somewhat surprising finding is that the both stresses are large, much larger than the rate of change of the plasma inertia. However, they are similar in magnitude and opposite to each other, providing a net balance approximately equal to the plasma inertial term. Theoretically, we report quasilinear, analytical calculation of the tearing mode stresses for a flowing plasmas and full MHD computation of the stresses from nonlinearly coupled tearing modes, and their effect on the flow profile. The combined experimental and theoretical studies establish that tearing modes transport momentum, and that the transport is enhanced through nonlinear coupling between modes. We have also investigated the dynamic of ion heating during spontaneous magnetic reconnections. A large fraction of the magnetic energy released during reconnection is converted into the ion thermal energy, with impurity ions being somewhat hotter than the bulk ions. The location of reconnection is important. The strongest heating is observed when the reconnection zone spans the entire plasma minor radius. When reconnection is limited to the plasma edge, the ion heating is not as strong and is edge-localized as well. Several models for the ion heating process are developed, including resistive heating from tearing flows and ion cyclotron heating.