13^{th} International Stellarator Workshop

Overview of Recent Results from HSX*

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HSX, the first stellarator in the world with an axis of symmetry in the magnitude of the magnetic field, is completing its first year of plasma operations. Well-formed nested magnetic surfaces have been measured in HSX using an electron beam and fluorescent mesh technique. A method has been developed and applied to experimentally measure the spectral content of the magnetic field in Boozer coordinates by analyzing the orbits of passing electrons. The method is especially useful in detecting spectral components nearly resonant with the rotational transform. The results confirm the expected reduction of the toroidal curvature component in HSX to near-negligible levels. Second harmonic ECH at 28 GHz has been used to make plasmas with energetic electrons. A set of auxiliary coils has been used to add a toroidal mirror term to the magnetic field spectrum. Breakdown studies show improved confinement of the ionizing electrons with quasi-symmetry, as compared to the mirror configuration, through reduced plasma formation times. Minimum breakdown times are achieved for all configurations with resonance on the magnetic axis, with a symmetric (low-field/high-field) dependence in the QHS case and a strong increase for the mirror case with low-field side resonance. At low densities (2-5 x 10^{11} cm^{-3}) temperatures inferred from SX and diamagnetism are on the order of 1-1.5 keV and peak for the quasi-helically symmetric field structure with on-axis resonance. Factors of 4-6 decreases in the stored energy are observed for the energetic electron plasmas when the quasi-symmetry is broken with the addition of a toroidal mirror term. Differences in the stored energy between the quasi-helically symmetric and mirror configuration diminish with an increase in the collisionality. Peaked plasma density profiles, determined by inversion from a 5-chord 288 GHz array, are observed for the QHS mode. With a mirror term that subtracts from the main field at the ECH antenna location, resulting in a deep ripple at the ECH beam waist, significant broadening of the density profile is observed.

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The Effects of Symmetry Breaking on Plasma Formation in the Helically Symmetric Experiment (HSX) *

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A 28 GHz ECH system has been used at 2nd harmonic to examine the effects of the magnetic field spectrum on the confinement of the breakdown electrons in HSX. The breakdown time (τ_b) is defined as the time it takes the density to rise to a small, detectable level (2 x 10^{11} cm^{-3} line-averaged density) at fixed RF power (~50 kW) and fill pressure (3 x 10^{-5} torr). A set of auxiliary coils can add a toroidal mirror term to the magnetic field spectrum to break the symmetry of the quasi-helically symmetric (QHS) configuration. Scans of τ_b as a function of the magnetic field strength were made in the QHS and mirror modes. The breakdown time is plotted as a function of distance of the resonance location from the magnetic axis. Both curves show a minimum with the resonance near the magnetic axis. On the high field side, where trapping is not significant, the data are similar. As the resonance is moved to the low field (outboard) side, where trapping is significant, τ_b increases significantly for the mirror mode, indicative of more rapid electron loss. The QHS τ_b appears symmetric between high and low field side heating. When the phase of the toroidal mirror term is changed to provide the deepest magnetic ripples at the toroidal launch location of the ECH, the breakdown time increases even more. This indicates that the ripple structure at the ECH launch position is important in the breakdown process.

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ASTRA Modeling of ECH Plasmas in HSX at 0.5 T*

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Initial Electron Cyclotron Heating experiments at the second harmonic with a 28 GHz gyrotron at low power have demonstrated, at low densities, a difference in the stored energy and confinement time between the QHS (quasihelically symmetric) configuration and one in which the symmetry is broken, the Mirror mode. Numerical results using the one-dimensional transport code ASTRA indicate that the difference in neoclassical transport between the two cases is likely to be the cause of the difference. An improved analytic form of the monoenergetic diffusion coefficent, based on a 6 parameter fit to Monte Carlo calculations, makes it fairly easy to integrate over moments of the distribution function and solve for the self-consistent radial electric field for the Mirror configuration. The improved confinement with quasisymmetry is examined over a range of densities and absorbed power and compared to the experimental results.

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Initial Results from Biased Electrode Experiments in HSX*

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HSX is the first stellarator in the world to possess a direction of symmetry in the magnitude of the magnetic field. Hence, the parallel viscosity in this direction is small compared to a conventional stellarator. This quasi-symmetry in the helical field can be broken by the addition of a toroidal mirror field. With this additional field, there are mod(B) variations in all directions on a flux surface and large parallel viscosity in all directions. Calculations show that in this "Mirror" mode, the viscous damping rate is 1-2 orders of magnitude larger than in the base quasihelically symmetric configuration.

To study the physics of radial electric fields and their associated flows in HSX, we will draw a radial current from the plasma edge with a biased electrode. We have built a biased electrode system capable of applying 300V of bias and drawing up to 400A of current. The bias can be applied and turned off quickly (≈10μs) and the system is capable of positive or negative bias. For edge measurements, we will use a Langmuir probe to directly measure the floating potential and T_e to determine the structure of E_r. We will utilize Doppler spectroscopy to measure core flow of impurities. To study any changes in global energy confinement with biasing, we will use a diamagnetic loop. Density and temperature profile effects with biasing will be studied using a multi-chord interferometer and an array of surface barrier diodes. Initial data from these experiments will be presented.

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