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Research Subjects: High Temperature Plasma Physics Experiments, Spherical Tokamak, MHD Stability, RF Heating and Wave Physics, Advanced Plasma Diagnostics Development, Fluctuations and Transport

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Experimental studies of high temperature magnetically confined plasmas for fusion application are being pursued. A new spherical tokamak (ST) device, TST-2 (major radius 0.36 m, minor radius 0.23 m, toroidal field 0.3 T, plasma current 200 kA) was constructed and produced its first plasma in September 1999. The ST is a highly promising plasma confinement device because of its potential for stable high β (β = plasma pressure / magnetic pressure) operation with good confinement. TST-2 has a greatly upgraded capability of the central solenoid compared to its predecessor TST-M, and has already produced plasmas with currents of up to 90 kA with less than 1/3 of the full capability of the solenoid. Initial results indicate that plasmas with 50 kA plasma current has an ion temperature of 50–100 eV and a density of greater than $3 \times 10^{18}\,\mathrm{m}^{-3}$.

The position and the shape of the plasma can be determined from magnetic measurements. Typical plasmas have an aspect ratio (major radius / minor radius) of 1.6 and an elongation (plasma height / width) of 1.5. An MHD instability peculiar to the ST called the internal reconnection event (IRE) is frequently observed. Magnetic measurements indicate that a coherent rotating mode with a toroidal mode number of $n = 1$ exists prior to an IRE.

The ST can confine high density plasmas at low magnetic field. Consequently, ST plasmas have unusually high dielectric constants compared to conventional tokamak plasmas. Some waves that are commonly used for heating and current drive, such as the lower hybrid wave and the electron cyclotron wave, cannot propagate to the plasma core. Understanding of wave physics in such a regime is very important. Excitation, propagation, and absorption of the high-harmonic fast wave (HHFW), which has good accessibility to high dielectric constant plasmas, are being studied in TST-2. The HHFW is excited by a combline antenna, and the wave fields are detected using magnetic probes distributed on the vacuum vessel wall. Initial measurements indicate good agreement with the results of a full-wave code calculation.

Noninductive plasma initiation and plasma current ramp-up are critical issues for the eventual success of the ST concept as an attractive fusion reactor. Reliable plasma initiation is achieved by 1 kW of 2.45 GHz microwave power. Ionization is achieved by resonant wave absorption by electrons gyrating in the magnetic field. Noninductively driven currents of up to 1.2 kA was obtained. The generated current increases as the neutral pressure is decreased down to 1.5×10^{-6} Torr, suggesting that this current is driven by the pressure gradient of the plasma.

HHFW heating and current drive experiments were performed on the JFT-2M tokamak at Japan Atomic Energy Research Institute (JAERI). The measured soft X-ray energy spectrum indicated significant electron heating and an upshift of the wavenumber parallel to the magnetic field. A reciprocating Langmuir probe array was used to measure the plasma density, electron temperature, and plasma potential. The measurements indicate the existence of a poloidal electric field. Detailed investigation of the electric field with good spatial and temporal resolutions may clarify the physics of an important bifurcation phenomenon observed as a transition to the high confinement mode (H-mode).

A current drive antenna is being developed for use on the LHD device at National Institute for Fusion Science (NIFS). This antenna will be used to excite a traveling wave in the plasma in order to control the rotational transform profile. Design was made based on the results of mock-up antenna measurements and model circuit analysis. A prototype antenna consisting of 4 modules was fabricated. After final optimization with the prototype antenna, the complete antenna consisting of 10 modules will be fabricated.

A multi-layer mirror soft X-ray spectrometer aimed at making soft X-ray energy spectrum measurement on a fast time scale was developed and tested on the CHS device at NIFS. Novel microwave-based measurements such as a frequency-swept microwave transmission measurement for density profile diagnostic, and a low-cost multiple-channel interferometer system using fast switching instead of multiple oscillators and detectors, are being developed.

NSTX at Princeton University Plasma Physics Laboratory and MAST at UKAEA Fusion are state-of-the-art ST devices which are one rank larger than TST-2. Our group maintains close contact with these groups. In particular, our group is responsible for coordinating US-Japan collaboration activities on NSTX, and participate actively on experiments focusing on RF heating and on the development of a new electron temperature diagnostic based on electron Bernstein wave emission.