Plasma diagnostics in the stellarator TJ-II with a detailed description of the experimental method and data analysis used to determine local magnitudes and pitches of its magnetic field components.

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Interest in magnetically confined fusion has increased in recent years due to a developing awareness of the growing energy supply problem as well as to the launch of the ITER project which is aimed at demonstrating the scientific viability of fusion as a viable future energy source. ITER is based on the tokamak concept, one of two scientific-technological solutions that have been developed to confine high temperature plasmas in equilibrium in a torus. In tokamaks, equilibrium is achieved by a combination of magnetic fields produced by external coils and by inducing a current through the plasma. In contrast, the stellarator concept relies on external coils with complicated geometry to generate a stable equilibrium. Although both concepts share common physics and technology, their development has not been parallel. Whilst the stellataror concept is further from the final objective, due mainly to the complexity of construction, it has the advantages that it is intrinsic stability and it can be operated continuously, thereby simplifying both control and security. Indeed, while the tokamak may be an ideal prototype to demonstrate the viability of fusion it is possible that the stellarator will become the favored configuration for future commercial power plants.

Since fusion research began in the 1950's, magnetically confined plasma devices have been built in many countries, including Spain, where the TJ-II stellarator has been operated since 1998. In all cases, progress has required diagnostics to provide insights into the physical processes taking place within the plasma and to measure its parameters. TJ-II is a heliac type device with a major radius of 1.5 m and an average minor radius of ≤0.2 m. Its magnetic field ($B_0 \leq 1$ T) is generated by a system of poloidal, toroidal and vertical field coils. Plasmas created with hydrogen are heated using 2 gyrotrons operated at 53.2 GHz, the 2nd harmonic of the electron cyclotron resonance frequency ($P_{ech} \leq 600$ kW), and central n_e and T_e up to 1.7×10^{19} m^{-3} and 2 keV respectively are achieved. Additional heating by the injection of accelerated neutral hydrogen atoms from 2 neutral beam injectors provides up to 1 MW for ≤100 ms so $n_e \leq 5\times10^{19}$ m^{-3} is attained. Finally, it possesses a complicated vacuum-vessel geometry, a bean-shaped plasma cross-section and a fully 3 dimensional plasma structure.

The TJ-II has excellent access (96 portholes) and is equipped with a large set of modern diagnostics. One system is a spectrally resolved Motional Stark Effect diagnostic used to quantify the magnitude and pitch of components of its magnetic field. It includes a compact diagnostic neutral beam injector that provides a short pulse of accelerated neutral hydrogen atoms to stimulate Doppler-displaced Balmer Hα emissions, which are the basis for this diagnostic. Measurement of the wavelength separation of the Stark splitting of the Hα spectrum, as well as of the relative line intensities of its components, allow the local magnitude and direction of the internal magnetic field components to be measured at 10 positions across the plasma. After outlining the principles of this technique and the diagnostic set-up, magnetic field measurements made during ECR heating phases are explained for a representative magnetic configuration and are compared with vacuum magnetic field estimates in order to evaluate the capabilities and limitations of this diagnostic.