(3) Diagnostic Systems

For the precise measurement of plasma parameters in a three dimensional helical plasma, an extensive set of diagnostics has been developed with national and international collaborators, and routinely operated in the Large Helical Device. The present status is that the total number of diagnostics is over 60 owing to the continuous efforts for the development of new diagnostic instruments by researchers.

The YAG laser Thomson scattering system and the ECE system have proven as reliable diagnostics for the temporal evolution of the electron temperature profile. The YAG laser TS system works routinely to provide the electron temperature profile with a flexible repetition rate (from μs to hundreds of ms). In order to obtain absolute electron density profiles, Raman and Rayleigh calibrations using gaseous nitrogen were conducted before and after each experimental campaign. In the 14th LHD experiment campaign, electron temperatures (T_e) of more than 20 keV were observed by the YAG Thomson scattering system. Since electron density (n_e) is low in usual high-T_e experiments, both the signal intensity and the signal-to-noise (S/N) ratio are also low. To accurately determine T_e in the high-T_e, low-n_e experiments, we tried to increase the effective laser pulse energy, and to apply three signal accumulation methods.

A 13-channel far infrared laser interferometer and a CO_2 laser imaging interferometer have been routinely operated for the precise measurement of the electron density profile in the LHD. The two dimensional phase contrast imaging diagnostic is employed to measure the spatial profile of the density fluctuations with the wave number in the range of 1-30 cm^{-1}. From the 2D image it is possible to identify the propagation direction of the fluctuations and their location. Most of the fluctuations exist at $\rho > 0.5$. The fluctuations propagate in the ion diamagnetic direction in the core plasma region ($\rho < 0.7$) and in the electron diamagnetic direction in the edge region ($\rho > 0.7$). The effects of magnetic configuration on micro-turbulence are also investigated.

In order to obtain the fine structure of the density profile, a new type of reflectometer using an ultra-short sub-cycle pulse has been developed. A new impulse source, whose amplitude is -2.0 V and FWHM pulse width is 18 ps, is utilized as a source. From this impulse to obtain the desired frequency components, we utilize the base-band waveguide and get each chirped wave. In order to measure the perpendicular velocity of the electron density fluctuations, the radial electric field and perpendicular wave number, Doppler reflectometry has been developed. The system is a unique technique combined with the backscattering method and reflectometry, and will provide useful information for the understanding of plasma turbulence and confinement transition phenomena.

Far infrared laser diagnostics using short wavelength laser sources around 50 μm are under development for future high–performance LHD plasmas. A new type of two color laser (47.6/57.2-μm CH_3OD) interferometer has been developed and its original function, vibration subtraction, was confirmed. For the application of this laser source to polarimetry a new photoelastic modulator was developed. The achieved angular resolution is 0.05 degrees with a time constant of 1 ms. Another approach to establish a reliable density measurement is the development of a CO_2 laser dispersion interferometer, which is free from phase errors due to mechanical vibrations.

The plasma potential profile is an important quantity in a helical system since the radial electric field plays an important role in particle orbits and their losses. A heavy ion beam probe (HIBP) is being developed to measure potential and density fluctuation in high temperature plasmas. The HIBP system is composed of a negative ion source, a tandem accelerator of 6 MeV, beam lines, and a tandem energy analyzer. In the 14th campaign, several coherent fluctuations, which are referred to be reversed–shear induced Alfven eigenmode and geodesic acoustic mode, are observed directly in core plasmas, and their spatial distributions are revealed.

For multi-dimensional measurements of the non-axisymmetric LHD plasma 2-D or 3-D imaging diagnostics are under intensive development with national and international collaborators. A 3-D imaging system has been developed in collaboration with Kyushu University for the measurement of an electron temperature profile and its fluctuations and for the density fluctuation measurements. The 2D microwave imaging detector is a key device in this diagnostic. A 2D (7x7) imaging detector array was developed, which has a frequency bandwidth of 20 GHz. A 3-D MIR image of the edge harmonic oscillation (EHO) is successfully detected. The EHO is observed in the VH mode plasma in DIII-D when the ELM is absent.

A data acquisition system with parallel processing technology has been developed for diagnostics with a 3 minute cycle during LHD operation. In the 14th campaign, the total number of the data acquisition nodes went up to 90, and more than half of them are stady-state operable digitizers. The data amount of the LHD plasma diagnostics has grown 4.6 times larger than that of three years before. In the last campagin, the maximum acquired amount has increased up to ~11 GB/shot.

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