(5) Diagnostics Systems

For the precise measurement of plasma parameters in the three dimensional helical plasma, an extensive set of diagnostics have been routinely operated. 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. The achieved calibration factors are valid as far as all optical components are completely stable. However it is so hard to fix whole system at the initial condition for a long time. A new method, a laser beam scanning system, was applied to obtain correction factors to the errors originated from misalignment.

A 13-channel far infrared laser and a CO_2 laser imaging interferometers have been routinely operated for the precise measurement of the electron density profile in the Large Helical Device. The two dimensional phase contrast imaging diagnostic is employed to measure the spatial profile of the density fluctuation 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 fluctuations and their location. The most of fluctuation exists at $\rho > 0.5$. The fluctuation propagates in the ion diamagnetic direction in the core plasma region ($\rho < 0.7$) and in the electron diamagnetic direction in the edge region ($\rho > 0.7$).

In order to obtain a fine structure of a 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. The system has 3 frequency bands; X-band, Ka-band, and U-band. This technique is found to be useful for the study of a magnetic island structure. In order to measure the internal structure of density fluctuation, a new type of reflectometer has been developed, which is the broadband frequency tunable system and has the ability of fast and stable hopping operation. During one plasma discharge, the launching frequency increases step by step, and this operation is called as frequency hopping. One of the important issues of this measurement is the study of energetic particle driven magneto hydrodynamics instability.

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.

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 an energy analyzer. In the 11th campaign, the Au^- beam current of the plasma spatter-type negative ion source is improved to extend the diagnostic range in high density and high temperature plasmas.

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 (4x4) imaging detector array was developed, which has a frequency bandwidth of 20 GHz. Each detector element consists of a Yagi-Uda antenna, a beam lead type GaAs Schottky barrier diode, two RF amplifiers and a SAW filter. The system was firstly applied to the reversed field pinch (FRP) plasma in TPE-RX for the measurement of density fluctuations.

A data acquisition system with parallel processing technology has been developed for diagnostics with a 3 minute cycle during LHD operation. Data of most diagnostics is acquired by the CAMAC system. The total number of CAMAC modules and channels are about 300 and 2000, respectively. The data values of the LHD plasma diagnostics has grown 4.6 times bigger than that of three years before. In 11th campagin, the maximum acquisition amount has increased up to 6.79 GB/shot, constantly having about 180 shots per day.

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