(5) Diagnostic 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 the 10th campaign the central density reached more than 10^{21} m^{-3} by the formation of the Internal Diffusion Barrier (IDB). In such high density plasmas we sometimes observe a peculiar electron temperature and density profile in TS data. In order to solve this problem a new system was developed for monitoring plasma light, since this problem was thought to be due to intense background light, resulting in large error in both measured electron temperature and density. As a result the intense background light is found to be observed in only specific polychromators that see divertor plates.

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 2-D phase contrast imaging diagnostic is employed to measure the spatial profile of the density fluctuation with the wave number in the range of 1-10 cm^{-1}. The spatial resolution $\Delta\rho$ is nominally of the order of 0.1. 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. In LHD 10th experimental campaign, 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; those are X-band, Ka-band, and U-band. Each frequency component is amplified by corresponding microwave power amplifier and combined to one transmission line. A newly designed multiplexer was developed, improving insertion loss compared with the conventional directional coupler.

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 CH3OD) interferometer has been developed and its original function, vibration subtraction, was confirmed in a test stand.

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 10th campaign, changes of the plasma potential have been measured during ECRH heating on the NBI target plasma. In this discharge ITB is created by the injection of ECR wave into the NBI plasma. The observed increase in temperature at the center of the plasma is about 3keV, which is the same order of the potential increase measured with HIBP.

A tracer-encapsulated solid pellet (TESPEL) has been developed for impurity particle and heat transport studies. A TESPEL ball consists of polystyrene polymer as an outer shell in diameter of 300 – 900 μm and tracer particles as an inner core. This fiscal year, the TESPEL was applied to the pellet charge exchange system (PXC) to measure the helium ion profile. It is very important to measure the helium ion profile in a plasma, since the helium/hydrogen ratio is a key parameter for minority heating in ion cyclotron resonance frequency heating , and it is dispensable to investigate the α particle heating mechanism in future fusion reactors.

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 ECE imaging system has been developed in collaboration with Kyushu University for the measurement of an electron temperature profile and its fluctuations. This fiscal year a VUV telescopic camera was newly developed to study the fluctuations in addition to the soft X-ray tangentially viewing camera. The effective brightness of the new system is 10^4 times larger than the previous one, resulting in the improvement of the time resolution.

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. The raw datesize is 4.6 GB/shot, with having about 170 shots everyday.

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