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 since 1998. The total number of diagnostics is over 60 owing to the continuous efforts for the development of new diagnostic instruments by researchers.

An absolute calibration of the Thomson scattering (TS) system has been carried out by using Rayleigh scattering and Raman scattering in gaseous N_2 in order to estimate precious electron density profile. Two calibration results show that Rayleigh scattering calibration provide better results than the Raman calibration because polychromators of the TS system are optimized to Rayleigh scattering wavelengths. The calibrated data, which is obtained by using new ADC system, is in agreement with the electron density measured with MMW interferometer.

To realize high accurate measurement of electron temperature profile, ruby laser beam is applied in addition to YAG laser. It is confirmed that this system contributes to reduction of the measurement error compared to the present system.

A new 2D Thomson scattering system for measuring anisotropic electron temperature using multi-reflection of a single lase light and its time-of-flight effect has been developed. The single filter spectromator was tested by using multi-angle injections of scattered light in 2015.

We have developed a coaxial laser beam combing device based on the terbium scandium aluminum garnet (TSAG) crystals based Faraday rotator for the beam combiner of the Thomson scattering system. The TSAG crystals have large magneto-optic coefficient, good thermal properties and ease of the fabrication, which are suitable for the high average power beam combiner. It is verified through the experiments.

The collective Thomson scattering (CTS) system has been developed in order to investigate characteristics of confined bulk and fast ions. The CTS spectra obtained in the experiments shift compared to calculated spectra, and the direction of the shift depends on the direction of injected neutral beam. Also, the anisotropy of the spectrum was observed, which is considered to be the tail component originated from fast ions.

The InfraRed imaging Video Bolometer (IRVB) is useful for understanding the complicated radiative structures existing in the 3D magnetic geometries of helical devices, which has been applied for study of radiative cooling of the divertor by impurity gas seeding. With N_2 seeding, strong poloidal asymmetries are observed in the radiation profiles, and the radiation enhancement was also observed to be around 20%, while the reduction in divertor heat load indicated by ion saturation current was more than 50% in some locations. For the application of IRVB to the neutron environment in fusion plasma devices, in-situ calibration of the themal characteristics of the detector foil is available recently.

Euclid distance minimization has been studied for improving 3D plasma image reconstruction of 4 IRVB's. The modified Tikhonov method has been applied to the 3D tomography of radiation profiles recently. The results show that noisy artifacts diminish and the profiles of edge and core radiations become clearer compared to previous results.

The Digital Correlation Electron Cyclotron Emission (DCECE) measurement technique with Giga Hertz sampling digitizer has been developed. One of advantages of the DCECE is to be able to choose the spatial and temporal resolutions after the plasma experiment, which is useful for the study of the multiscale dynamics. Also, ECE imaging system with LO-integrated Antenna array (LIA) has been installed into LHD. The LIA is separated from LHD to avoid the neutron effect.

The ECE signal is separated into two radiometer systems with different local frequency in order to cover its wider frequency, while this causes a decrease in signal. An original high frequency dichroic filter has been designed and tested to realize more sensitive ECE measurement. The characteristics of filters with different thicknesses have been numerically investigated.

The correlation ECE radiometer (cECE) has been developed to investigate the plasma turbulence. To increase the amplitude of signals, the number of channels is decreased and bandwidth of RF bandpass-filters is extended, which leads to successful detection of the turbulence-like signal.

Modulation of electron cyclotron resonance heating (MECH) technique is well used for investigating plasma heat transport. For the observation, both the ECE and Thomson scattering system is applied for measuring electron temperature, whereas time resolution is different. The conditional averaging technique for reconstruction of Thomson scattering system has been developed for solving this problem, and it was found that this technique is useful for the heat pulse propagation analysis.

A dispersion interferometer (DI) with CO_2 laser has been developed. Although the DI is free from the mechanical vibrations, the phase-modulated DI has a disadvantage in the time resolution. In order to solve this problem, a heterodyne technique with an acousto-optics modulator (AOM, 40MHz) has been applied. This system has been tested in General Atomics in US. To solve the fringe-jump problem of conventional interferometer, the Nd:YAG laser dispersion interferometer has been developed and it has been confirmed in experiments that the density resolution with $\pm 1.2 \times 10^{19}$ m^{-2} was realized for 200s. On the other hand, it is verified that the full digital processing phase detector is expected to be valid for solving the problem on fringe jump of interferometer, which will be tested using FIR interferometer of the Heliotron J.

The heavy ion beam probe (HIBP) measuring electrostatic potential in core plasma has been well used for turbulence study. In order to reduce electric noise and to construct multi-channel data readout system, the electronics of the front-end circuit with the specific integrated circuit (ASIC) has been designed and tested. The increase in beam current also increase the signal-noise ratio and makes the measurement in high-density regime possible. The experiments for optimizing the gas cell for high charge exchange efficiency has been made at Kobe University. Then the dependence of the beam current on the gas thickness was clarified.

A new beam emission spectroscopy (BES) was designed to detect the high frequency fluctuation in the peripheral region of the plasma. This system is expected to improve the signal intensity by aligning the line of sight along the magnetic flux surface, and planned to install 6O port of the LHD.

The microwave imaging system has been developed for study of plasma fluctuations in LHD. The ultra-wideband microwave-modulated laser radar was designed and fabricated for the improvement of spatial resolution. In the experiments using a prototype, 3D image of object by scanning a laser beam in two dimensions was successfully obtained.

The system for “Doppler-free” saturation system at the Balmer-alpha line of atomic hydrogen has been developed because the structure of Zeeman-splitting is masked by the Doppler broadening in hydrogen plasma, which has been tested at Hokkaido University. The obtained results are consistent with the calculation.

The Angular Resolved Multi-Sight (ARMS) line measurement and Compact Neutral Particle Analyzer (CNPA) have been applied to investigate characteristics of neutral particles. One of the experimental results shows that the particle loss in high density regime is larger than the low-density case in the range with < 30 keV.

Technical verification on high-performance long distance data transfer methods has been continued for several years. Actual verification tests between NIFS Toki and IFERC Rokkasho sites, massively muti-connection file transfer protocol (MMCFTP) has acieced over 8 Gbps effective speed by using SINET Layer-2 VPN.

The camera system for monitoring plasmas has been upgraded for deuterium experiments. The system consists of six CCD cameras (2-O, 4-O, 6-O, 10-O×2 and 6-T) installed in the inside of specially designed 19-inch racks. Six radiation resistant bundled image fibers are used for transmitting the plasma images to the cameras.

In order to confirm the tolerance of highly integrated electronic components such as a programmable logic controller (PLC) to neutron and gamma-ray generated in deuterium experiments, gamma-ray irradiation on equipment has been done at the Cobalt 60 irradiation facility of Nagoya University. The experimental results show that the electronic components on the torus hall should be considered to be rearranged.

The radiation field in the torus hall has been evaluated by using Monte Carlo neutronics code (MCNP-6) with three dimensional modeling of LHD. The gamma-ray absorbed dose for Si is 20-70 Gy during nine years of LHD operation. Also, MCNP-6 is used to estimate energy dependent sensitivity of the neutron flux monitor (NFM). An in-situ calibration of the LHD NFM is planned in Nov, 2016, by using ^{252}Cf neutron source rotation in LHD vacuum vessel, which will be compared to the calculation. The fast neutron detector and the neutron spectroscopy were designed and installed in LHD. The Associated Particle Coincident Counting neutron energy spectrometer, APCC-NES, was installed at KSTAR and successfully demonstrated the measurement of DD neutron energy spectrum.

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