Interferometer Systems on KSTAR

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Interferometry is based on the phase measurements, which means that its values should be tracked from zero density but are free from the intensity modulation error. It guarantees reliable absolute density measurements with a proper fringe-jump compensation scheme. Depending on the electron density, frequency of the beam source should be carefully selected. Low frequency system makes too many fringe-jump on the high density plasma, while high frequency system suffers from the mechanical vibration. Well-designed vibration compensation system is crucial for the high density fusion plasma measurements. On Korea Superconducting Tokamak Advanced Research (KSTAR), several types of interferometer systems were developed through its operation stage, including a radial millimeter-wave interferometer (MMWI)[1], a vertical far infra-red laser interferometer (FIRI)[2], a multi-channel tangential two-color interferometer (TCI)[3,4] and a vertical single crystal dispersion interferometer (SCDI)[5].

The MMWI system uses two 280GHz voltage controlled Gunn oscillators that differ by 60MHz for the heterodyne measurements. The microwave is radially injected onto plasma via oversized waveguides, rectangular horn antennas and concave mirrors to minimize the beam power loss. The beam is reflected on a plasma facing carbon tile, which is specially shaped to focus the beam on the plasma center. Although the MMWI was designed for the first plasma of KSTAR that was expected to reach the peak electron density of several 10^{19} m^{-3}, it was operated on the high density H-mode condition of KSTAR with support of in-situ fringe jump compensation techniques[6] up to 10 years. Now the system was dismounted, and a new 1 THz interferometer system (THI) using microwave sources based on an amplifier-multiplier chains (AMC) technique was designed[7]. The THI will use quasi optics dielectric lens and will share the optics with KSTAR ECEI system via specially designed wire grid beam splitter. The THI will be used to measure radial line-integrated density with high precision and to analyze high frequency fluctuation components on the line density.

The FIRI is 119μm CH_3OH laser interferometer that measures vertical line density. A vibration compensated corner-cube mirror was installed on the top end of vertical beam line. The measured density showed excellent agreement with the MMWI via comparison using rtEFIT reconstructed flux surface. An H-mode real-time density feedback control system was developed based on the FIRI signal. The system successfully controlled electron density up to 4.5 x 10^{19} m^{-3} during H-mode condition and up to 55 s of long pulse H-mode plasma. The FIRI was replaced to a tangential TCI, which has better stability and multi-channel measurements capability. To compensate phase error comes from mechanical vibrations, the TCI uses two frequency sources: one is a 10.6 μm CO_2 laser and another is a 660nm diode-pumped solid-state (DPSS) laser. Relatively short source wavelength removes a risk from fringe-jumps during fast density changing events such as edge localized modes (ELMs) during H-mode operation. Increased vibration effect is compensated by a two-color method. In addition, supported by improved wavelength stability of CO2 laser and a phase comparison algorithm using field programmable gate array (FPGA), the TCI shows extremely robust operation during entire KSTAR campaign without issues from the fringe-jump and the signal drift. The TCI has 5 tangential channels, the system provides information on the density distribution over core and edge region of plasma. All 5 channels have real-time measurements capabilities and combined on the plasma control system (PCS). The TCI is used for average density feed-back control, and even more, could be used for the separated density control on core and edge region with proper actuators. Second TCI system that adds 5 channels is planned. With total 10 tangential channels, the density profile can be reconstructed from the TCI data.

The SCDI is a 1064nm Nd:YAG laser interferometer based on dispersion technique using a nonlinear crystal that makes second harmonic beam sharing same beam path. With this technique, severe vibration error on short wavelength interferometer could be effectively compensated. While even TCI with the short-wavelength of 10 um suffer from a pellet injection experiment that makes extremely high density change over several 10^{21} m^{-3} within milliseconds range, the SCDI successfully followed these events. The SCDI therefore became an essential diagnostic for one of the most important topics for the next generation tokamaks such as ITER on disruption mitigation technique using shattered pellet injections.

References

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