Ion Doppler Spectroscopy System on the SUNIST-2 Spherical Tokamak

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Ion temperature diagnostic methods typically involve Charge Exchange Recombination Spectroscopy (CXRS) and X-ray imaging Crystal Spectrometer (XCS) in plasma research in tokamaks. However, the former relies on Neutral Beam Injection (NBI), which is both costly and cumbersome, while the latter requires extended optical paths to achieve high-resolution dispersion and to get reliable results. To address the spatial constraints inherent in compact concept devices, an Ion Doppler Spectroscopy (IDS) system has been developed on SUNIST-2(Sino-United Spherical Tokamak-2) for 1D ion temperature profile measurement, offering high spatial and temporal resolutions (22 mm and 2 ms, respectively). The system is capable of estimating the radial ion temperature profile throughout a discharge, as shown in Fig.1, with typical fitting errors remaining within 10%. Through optimized optical design and an improved spectral fitting method, the Doppler broadening of the 529 nm CVI spectral line at specific points can be directly obtained, rather than being inferred from line-integrated measurements, as shown in Fig.2 and Fig.3. This approach avoids errors associated with the symmetry assumption required by Abel inversion. Additionally, an iterative algorithm based on neighborhood denoising was developed to effectively filter out noise from ionizing radiation and electronic interference under high-gain conditions, thereby enabling accurate and automated analysis of Doppler broadening. A model incorporating numerical parameters also accounts for the influence of the Zeeman effect on the spectral line in strong magnetic fields. The results indicate that the Zeeman effect decreases with increasing temperature, with the correction rate ranging from approximately 15% to 5% across the ion temperature range.

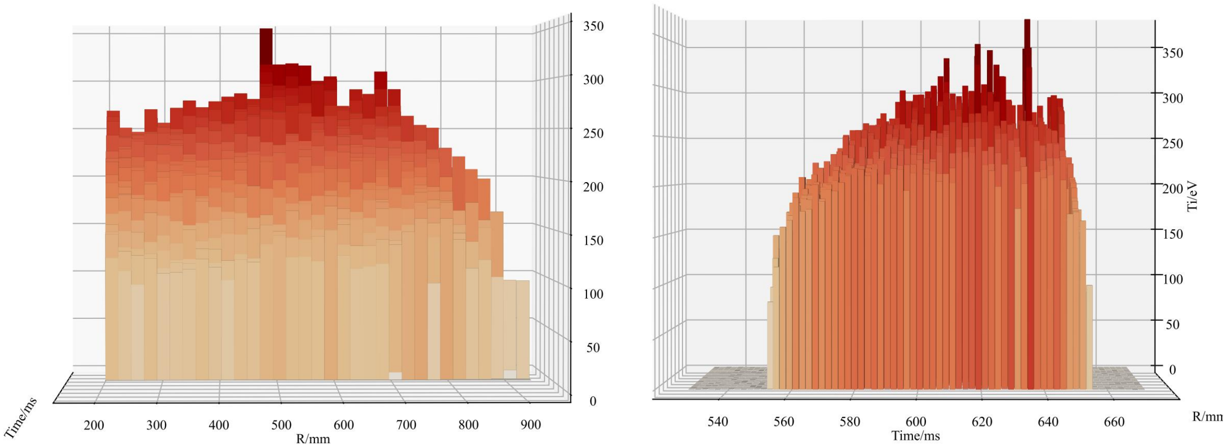

Fig.1 Measured ion temperature profile by radial (left) and by time (right)

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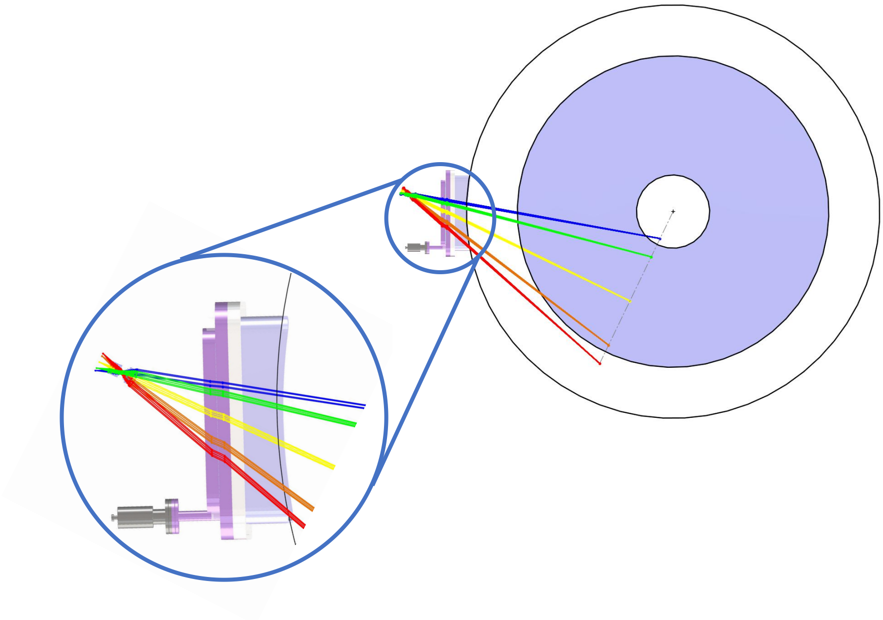

Fig.2 Schematic diagram of light receiving optical system

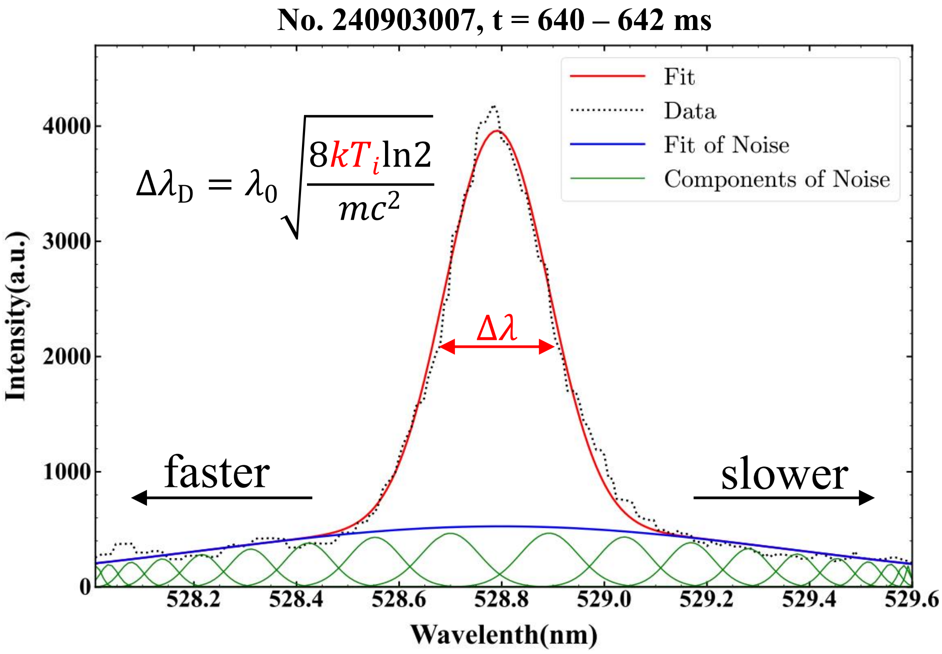

Fig.3 A brief rendering result of the spectral fitting method