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Fast ion diagnostics by collective Thomson scattering

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Controlled fusion reactors require knowledge of the behavior of energetic charged particles produced by auxiliary heating and fusion reactions. Energetic charged particles are transported due to wave-particle interactions such as MHD activity, and as a result, the energetic charged particles are lost from the confinement region. In severe cases, it causes damage to the vacuum vessel. Auxiliary heating produces and sustains high-temperature plasmas, which contain energetic particles with an anisotropic velocity distribution. These charged particles slow down to become bulk particles. The velocity-space analysis becomes important to understand a substantial origin of physical phenomena such as wave-particle interactions provoked by anisotropy.

A collective Thomson scattering (CTS) diagnostic with a +/- 3 GHz band around a 77 GHz gyrotron probe beam was developed to measure the velocity distribution of bulk and fast ions in the Large Helical Device (LHD) [1]. The CTS diagnostics in the millimeter-wave range for fusion devices have been performed in TEXTOR [2], ASDEX Upgrade [3], Wendelstein 7-X [4], and FTU [5], and designed for ITER [6] to diagnose bulk and fast ions and induced instabilities. The CTS diagnostic at LHD uses a heterodyne receiver to detect electromagnetic radiation in the radio frequency (RF) range from 74 to 80 GHz. The RF signal is down-converted to an intermediate frequency signal from 0 to 6 GHz in a mixer for more accessible treatment. The frequency characteristics for each channel of the heterodyne receiver need to be calibrated for a precise reconstruction of an asymmetric spectrum. We proposed a new in-situ calibration method for a CTS diagnostic system combined with a raytracing code [7] to compensate for a shift of a measurement position due to the refraction of probe and receiver beams. The CTS spectrum was measured successfully with the *in-situ* calibrated CTS receiver and responded to fast ions originating from a tangential neutral beam with a beam energy of 170 keV and from a perpendicular beam with an beam energy of 60 keV, both in the LHD [8].

To comprehend the spectrum asymmetry observed by the CTS diagnostic, we need to analyze the particle distribution in velocity space based on the modeling in [9]. We have recently reported a velocity space reconstruction from a CTS spectrum using a machine learning method [10]. In this case, velocity space distributions as training data are prepared from TASK/FP [11] to obtain a rule between a forward and inverse transform. Finally, the rule for inverse transformation is applied to tomography. This new velocity space analysis elucidates that fast ions cause the measured anisotropic CTS spectrum. The methods and studies demonstrated lead to a new era and are essential for CTS, millimeter-wave diagnostics, and electron cyclotron heating required under fusion reactor conditions. This presentation contains a concise review of CTS, millimeter scattering, and related research topics.

References

[1] M. Nishiura *et al.* Nucl. Fusion **54**, 023006 (2014).
[2] H. Bindslev *et al.* Phys. Rev. Lett. **97**, 205005 (2006).
[3] S. K. Nielsen *et al*. Plasma Phys. Control. Fusion **57**, 035009 (2015).
[4] D. Moseev *et al*. Rev. Sci. Instrum. **90**, 013503 (2019).
[5] B. Baiocchi *et al*. J. Instrum. **15**, C01046 (2020).
[6] S. B. Korsholm *et al*. Nucl. Instrum. Methods Phys. Res. 623, 677 (2010).
[7] N. B. Marushchenko *et al*., Comput. Phys. Comm. 185, 165 (2014).
[8] M. Nishiura *et al*. Rev. Sci. Instrum. **93**, 053501 (2022).
[9] M. Salewski *et al*. Nucl. Fusion **51** 083014 (2011).
[10] M. Nishiura *et al*. J. Instrum. **15**, C01002 (2020).
[11] H. Nuga *et al*. Nucl. Fusion **59**, 016007 (2019).