

Gaussian process tomography for soft x-ray array and MHD mode analysis on HL-3 tokamak

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A new soft X-ray (SXR) array system based on ceramic circuit boards has been installed on HL-3 tokamak to provide line-integrated measurements of the plasma emissivity in the energy range of 0.1–20 keV, which contains important information for the study of magnetohydrodynamic (MHD) activity. The lines-of-sight of this diagnostic cover a substantial portion of the poloidal cross-section, creating favorable conditions for two-dimensional tomographic reconstruction of the SXR emissivity. To investigate MHD behavior in HL-3, a Bayesian-based Gaussian Process Tomography (GPT) method has been developed to reconstruct local emissivity profiles from a limited number of noisy line-integrated measurements. To enhance the accuracy and reliability of the tomographic reconstruction, the non-negativity of emissivity is enforced in GPT using truncated Gaussian by Gibbs sampler, and knowledge about equilibrium magnetic geometry is incorporated into the construction through an anisotropic covariance matrix. The singular value decomposition (SVD) technique is employed to analyze the SXR emissivity and to extract the spatial and temporal features of MHD activity. The GPT method has been validated using both synthetic and experimental SXR data from HL-3 plasmas. For example, a growing $m=1$ mode localizing near the $q=1$ surface was observed as a precursor to a sawtooth oscillation, appearing before the crash and rapidly vanishing afterward. MHD activity under high- β_N conditions has also been investigated. During a discharge with $\beta_N \sim 2.1$, both 2/1 and 1/1 modes were simultaneously observed, which exhibited the same frequency but were located at different radial positions.

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