

Seminar

Institute for Plasma Research

Title: Absolute Calibration of Michelson Interferometer Diagnostic with an Upgraded Dry Cryogenic Detection System for Broadband ECE Measurements

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Abstract

Broadband electron cyclotron emission (ECE) measurements using Michelson interferometers (MI) provide a unique capability for absolutely calibrated electron temperature diagnostics in magnetically confined plasmas. At the SST-1 tokamak, the MI-based ECE diagnostic has recently been upgraded and absolutely calibrated to improve measurement reliability, accuracy, and sensitivity. A major hardware upgrade has been implemented by replacing the conventional wet cryogenic cooling detection scheme with a closed-loop dry cryogenic detector system, enabling cryogen-free operation, improved thermal stability of the detector, and uninterrupted long-duration experimental campaigns.

The dry cryogenic detection system employs an InSb hot electron bolometer integrated with a dual-stage pulse tube cooler, enabling cryogen-free operation and stable cooling down to ~4 K. Detailed procedures covering cryostat pumping, detector cool-down, resistance verification, and diode-based temperature measurements confirm that all operating parameters meet design specifications. This is illustrated in Fig. 1.

Following the system upgrade, a full absolute calibration of the MI diagnostic has been performed using a hot-cold source methodology, in accordance with calibration standards implemented on well-known tokamak devices. Absolute calibration of the upgraded MI system is carried out using a two-step methodology comprising in-laboratory characterization followed by in-situ calibration in the SST-1 experimental hall. The in-lab calibration employs cold, ambient, and hot radiation sources to determine the intrinsic diagnostic sensitivity under controlled conditions. Subsequently, absolute calibration is performed by probing hot-cold sources placed in front of the diagnostic antenna, thereby incorporating the full transmission line and system transmission losses. Long integration times with repeated source switching are used to achieve high signal-to-noise ratios.

Signal processing forms a critical component of the calibration procedure. Interferograms are acquired over a 20-min period with sequential switching among hot, ambient, and cold sources, followed by digital filtering and coherent averaging based on reference marker alignment. Difference interferograms are generated to suppress background contributions, and phase-corrected Fourier transformation is applied to recover broadband spectra. Spectral calibration factors are derived using the Rayleigh-Jeans approximation, enabling absolute conversion of interferometer response to ECE spectral intensity and radiation temperature.

The successful transition to a closed loop dry cryogenic MI system, combined with an absolute calibration, represents a significant advancement for broadband ECE diagnostics on SST-1. The upgraded diagnostic provides a reliable platform for routine absolute electron temperature measurements, cross-validation with other diagnostics, and future studies of profile evolution and long-pulse plasma operation.

References:

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