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Development of Coherence Imaging Measurements for Ion Temperatures in the Scrape-off-Layer of Wendelstein 7-X

D. Gradic[1], V. Perseo[1], D.M. Kriete[2], M. Krychowiak[1], R. König[1], A. Pandey[1], M. Otte[1], M. Jakubowski[1], T. Sunn Pedersen[1], D. Zhang[1] and the W7-X Team[1,*]

1) Max-Planck-Institut für Plasmaphysik, Greifswald, Germany

E-mail : dgradic@ipp.mpg.de

2) Auburn University, Auburn, USA

A spatial-heterodyne Coherence Imaging Spectroscopy (CIS) instrument was used to produce 2D ion temperature images in the SOL of the Wendelstein 7-X (W7-X) stellarator for the first time. Coherence imaging is a powerful new interferometric method that has very high wavelength resolution, higher light throughput than traditional spectrometers and the ability to make ion flow velocity and ion temperatures images for single atomic emission lines. Ion temperatures are derived from the Doppler line broadening, however in the SOL of large magnetic fusion experiments, additional broadening effects such as Zeeman splitting complicate the analysis. This is why CIS T_i measurements have not been performed in the SOL of tokamaks or stellarators before. The CIS measurements at W7-X were cross-calibrated with a multi-channel Echelle spectrometer of long focal length and very high spectral resolution, that shared several sightlines with the coherence imaging diagnostic. The spectra demonstrated that, the effective broadening by intermediate field Zeeman splitting ($B \approx 2.5$ T) is indeed on the same order of magnitude as Doppler broadening in the cold scrape-off-layer ($T_i \lesssim 100$ eV) of W7-X. The CIS fringe contrast analysis was successfully expanded to account for Zeeman splitting, thus enabling the evaluation of 2D ion temperature measurements in the 3D magnetic island chain of the W7-X SOL.

The CIS and spectrometer T_i measurements reveal ion temperatures ranging from 10 to 20 eV for the C^{2+} impurity species close to the divertor targets. During the transition from an attached to a detached plasma state, only a small drop in ion temperatures was observed, simultaneous to a movement of the C^{2+} radiation zone further away from the targets.

* See author list: T. Klinger et al 2019 Nucl. Fusion 59 112004