Soft x-ray imaging and inversion techniques for measurements of edge magnetic topology in the DIII-D tokamak

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We are developing novel imaging/analysis techniques to examine the role of externally produced resonant magnetic perturbations (RMPs) on the plasma equilibrium. A new tangential 2D soft x-ray imaging system (SXRIS) is being designed for DIII-D to measure the edge island structure in the lower X-point region. Application of RMPs has shown control of edge localized modes (ELMs). Control of ELMs is crucial for next step devices where the energy expelled can damage plasma-facing components.

RMPs are thought to induce overlapping island chains in the pedestal region that change the pedestal pressure gradient (and hence the stability of ELMs) by altering the density and/or temperature profiles. Initial calculations assume that the structure of RMP fields inside the plasma is similar to that in vacuum. In principle, however, the response of the (often rotating) plasma to externally imposed RMPs should shield (or amplify) the different RMP spatial harmonics.

Experiments on the DIII-D tokamak demonstrate full ELM suppression with this method. Paradoxically, experiments with lithium-wall-conditioned plasmas and a different RMP mode spectrum on the NSTX spherical tokamak show the reverse effect: the application of the RMP triggers ELMs. Furthermore, experiments on stellarator/heliotron devices (W7AS, Heliotron-J, and LHD) also show that resonant magnetic structures in the plasma edge play a role in ELM stability. Measurements of the island structure inside the plasma are thus needed to validate models for the effects of RMPs on ELM stability.

Soft x-ray (SXR) imaging yields information on the magnetic topology of the edge plasma. Core MHD studies have used tangential viewing with visible cameras, pinhole optics and a scintillator plate on both tokamaks and stellarators, but interpretation of the images is complicated by the 3D chordal integration, and requires advanced inversion techniques [1]. We use a synthetic diagnostic calculation based on 3D SXRIS emissivity estimates calibrated against NSTX data as a tool to assess signal levels and aid design efforts. Using this tool, a signal-to-noise ratio (SNR) of 10 with 1 cm edge island resolution for a 25 ms integration time is expected. Impurity puffing is expected to increase the SNR even further.

The image inversion in this scenario is ill-posed and requires a regularization method. We can exploit advances in dental imaging, where high spatial resolution from limited-angle measurements is needed. The inversion methods are based on Bayesian statistics and Tikhonov regularization. These methods are examined in the context of noise, spatial sensitivity and symmetry assumptions. Modeling with the DIII-D synthetic diagnostic and core NSTX SXR imaging are used to assess the inversion methods and optimize the geometry of the SXRIS on DIII-D.

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[1] S. Ohdachi, et al., Plasma Sci. Technol. **8**, 45 (2006).