Development of NBI modulation experiments in the TCV tokamak

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Modulation techniques have often been exploited in tokamaks to estimate transport parameters. Here, modulated neutral beam injection (NBI) power is used to induce perturbations to the plasma toroidal angular momentum in the TCV tokamak for the purpose of assessing the momentum transport coefficients and residual stress. Similar experiments have been performed on other tokamak devices, for example ASDEX Upgrade, DIII-D and JET. These experiments were designed to study the scaling of the experimental Prandtl number, Coriolis momentum pinch, and residual stress with theoretically relevant plasma parameters including the normalized gradients of plasma profiles (T_e, T_i, n_e), plasma collisionality, normalized gyro-radius (ρ^*), and plasma shape. However, the operational range of each device intrinsically limits the results that can be obtained, making cross-machine comparisons essential for reliable extrapolation to future devices. Measurements from TCV are of particular interest due to its extreme shaping capabilities and naturally higher ρ^* values.

The development of an equivalent NBI torque modulation scenario at the TCV tokamak, however, faces several challenges. At TCV, the torque modulation is provided by a tangentially injecting neutral heating beam (NBH), which passes through the plasma twice and, even at the lowest power/voltage settings, significantly perturbs the plasma. This makes it unsuitable for small-perturbation experiments. However, it is possible to change the applied power during a plasma discharge such that a base-level of NBH power can be maintained in addition to the applied power modulation. This scenario significantly reduces the temperature and rotation perturbations, providing a possible route forward. The CXRS measurements at TCV are performed on a diagnostic neutral beam (DNB) and, due to the low active signal to background ratio, dedicated modulation of the DNB at multiples of the CXRS integration time is required to obtain rotation and ion temperature profiles of sufficient quality. Moreover, the present power supplies of the DNB limit the "on-time" of the beam to 400ms, constraining the total number of CXRS measurements that can be made per discharge.

A viable modulation scenario therefore requires simultaneous modulation of the NBH and DNB at different frequencies and duty cycles, effectively sweeping the CXRS measurements across the applied torque modulation, such that a single, high-resolution picture of the modulation cycle can be assembled. The plasma behavior during this time period must be kept stable to ensure the reproducibility of the modulation cycles. This contribution will present the progress that has been made towards the development of such a scenario together with a preliminary analysis of the obtained modulation data.