Contribution ID: **296** Type: **Oral**

Demonstration of Power Exhaust Control by Impurity Seeding in the Island Divertor at Wendelstein 7-X

Friday, October 26, 2018 5:00 PM (20 minutes)

Effective power exhaust by impurity seeding and its dependence on the gas species used was demonstrated in island divertor configurations for the first time at Wendelstein 7-X (W7-X).
A systematic set of experiments has been conducted during the first island divertor campaign which show that switching from Neon (Ne) to nitrogen (N2) as seeding gases enables switching from global to more localized edge cooling. In case of Ne seeding significant enhancement of edge radiation with slow decay after end of the injection is observed due to the high recycling properties of this noble gas. The N2 seeded discharges show immediate response of local plasma parameters at the divertor target correlated to the puff duration. Fast Te recovery and drop of Prad after end of the puff suggest a rather low recycling coefficient for this impurity species. These effects are analysed by 3D modeling with EMC3-EIRENE for high and low recycling coefficients.
The impact of the 3D edge magnetic structure on radiation is investigated experimentally by changing island size and connection lengths with the island control coils in the 5/5 configuration for scenarios with ne˜1.8e19m-3 at PECRH˜2.9MW. A 22ms Ne puff causes enhancement of Prad by ˜1.6MW. Application of full control coil currents, Icc=2.5kA, yields a reduction of intrinsic Prad level from ˜0.7MW to 0.3MW and an reduced increase of Prad by 1.1MW in response to Ne seeing. The change of island geometry results in a faster decay of total impurity radiation measured by an effective time constant \tau_{Prad}.
The presented findings on power exhaust control by impurity seeding in the W7-X island divertor are the basis for implementing radiative cooling as means to protect plasma facing components as performance levels at this new HELIAS stellarator are rising. With increasing performance, equilibrium effects will impact on the 3D magnetic structure, which is addressed by equilibrium reconstruction with V3FIT and the 3D MHD code HINT. Investigation of the link between the magnetic structure, the appropriate gas species, the injection location and the impurity transport is of critical importance for the high level goal of HELIAS divertor optimization. The experimental and numerical studies presented here represent a first-time consistent exploration of this field in the new island divertor configuration.

Country or International Organization

United States of America

Paper Number

EX/9-2

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Session Classification: EX/9-TH/7 Divertor & Exhaust Physics

Track Classification: EXD - Magnetic Confinement Experiments: Plasma–material interactions; divertors; limiters; scrape-off layer (SOL)