First observation of a stable highly-radiative divertor regime at stellarator W7-X

D. Zhang[1], R. König[1], Y. Feng[1], S. Brezinsek[2], M. Jakubowski[1], R. Burhenn[1], B. Buttenschön[1], H. Niemann[1], M. Krychowiak[1], A. Alonso[3], J. Baldzuhn[1], S. Bozhenkov[1], M. Hirsch[1], L. Giannone[4], S. Kwak[1], F. Penzel[4], K. Rahbarnia[1], J. Svensson[1], H. Thomsen[1], V. Winters[5] and the W7-X team

[1]*Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany*

[2]*Forschungszentrum Jülich GmbH, IEK-4, D-52425 Jülich, Germany*

[3]*Laboratorio Nacional de Fusión – CIEMAT, 28040 Madrid, Spain*

[4]*Max-Planck-Institut für Plasmaphysik, Garching, Germany*

[5]*University of Wisconsin – Madison, Wisconsin 53706, USA*

Shortly after the first successful operation with five inboard limiters, the stellarator Wendelstein 7-X (W7-X) was upgraded by installing ten up/down-symmetrically-paired test divertor units (inertially cooled) and already conducted divertor experiments late last year. The first divertor experiments have shown significant differences in radiation behavior of impurities (carbon and oxygen as major intrinsic impurities) in comparison with the previous limiter plasmas. First, the region of intensive radiation, which was typically several cm inside the LCFS of the limiter configuration, shifted outwards towards the separatrix of the divertor configuration or even into the Scrape-Off layer (SOL) depending on the radiation strength. Secondly, for certain plasma scenarios the radiated-power fraction is significantly increased without serious degradation of energy confinement.

Most importantly, a stable highly-dissipative divertor regime was discovered for an ECR-heated hydrogen discharge in which the total radiation power (measured by the bolometer) approached 95% of the total 3MW input power and the edge bolometer channel signals remained almost unchanged over several energy confinement times. Despite this high radiation, there was no remarkable loss of the diamagnetic energy. In consistence with the bolometer measurement, the IR-cameras monitoring the divertor targets revealed reduced heat load on all ten divertor units down to a remaining fraction which might be assigned to contributions from photons and CX-neutrals. This experimental finding motivated a careful survey of all relevant divertor plasmas as well as a dedicated divertor program in the last two weeks of the past campaign for its reproducibility. This plasma state turned out to be well repeatable. Based on bolometer measurements, this paper presents a systematic analysis of this regime, including the radiation strength and location in the island divertor as well as their dependences on divertor configuration and plasma parameters.