Prototype-Material Plasma Exposure eXperiment

The Importance of Plasma-Material Interactions for Fusion

The scientific demonstration of magnetic fusion energy as an environmentally sustainable and economically competitive energy source will require mastering the science of plasma material interactions (PMI) and the development of plasma facing components (PFCs) that exhibit unprecedented erosion resistance and self-healing capability during prolonged exposure to high particle/heat fluxes and intense D-T fusion neutrons. The limited lifetime of PFCs will impact the availability of a fusion reactor and hence its economic viability. In addition, PMI impacts the performance of the core fusion plasma, for example, through the release of impurities leading to dilution of the plasma fuel and increased radiative power losses. Even before the lifetime of a PFC is reached, stringent controlled in-vessel inventories of dust and tritium could stop the reactor operation due to PMI in the nuclear environment. An improved understanding of the degradation mechanisms associated with PMI is needed in order to identify potential PFC materials and operational regimes.

New devices to study Plasma-Material Interactions for Fusion Reactors

Linear plasma generators are cost effective facilities to simulate divertor plasma conditions of present and future fusion reactors. They are used to address important R&D gaps in the science of PMI and towards viable PFCs for fusion reactors. Next generation plasma generators have to be able to access the plasma conditions expected on the divertor targets in ITER and future devices. The Material Plasma Exposure eXperiment (MPEX) is planned to address this regime with electron temperatures of 1 – 10 eV and electron densities of 10^{21} – 10^{20} m^{-3}. The resulting heat fluxes are about 10 MW/m^2. MPEX is designed to deliver those plasma conditions with a novel Radio Frequency plasma source able to produce high-density plasmas and heat electron and ions separately with Electron Bernstein Wave (EBW) heating and Ion Cyclotron Resonance Heating (ICRH) with a total installed power of 800 kW.

Fig. 1. Proto-MPEX in Building 7625

Proto-MPEX

The linear device Proto-MPEX (Fig. 1), forerunner of MPEX consisting of 12 water-cooled copper coils, has been operational since May 2014. Its helicon antenna (100 kW, 13.56 MHz) and electron cyclotron (EC) heating system (200 kW, 28 GHz) and ion cyclotron (IC) heating system (30 kW, 8-12 MHz) have been commissioned. The operational space was considerably expanded in the last year. More than 10 MW/m^2 has been delivered on target, fulfilling the minimum heat flux requirements for MPEX. Furthermore, electron temperatures of about 20 eV have been achieved in combined helicon and Electron Cyclotron Heating heating schemes at low electron densities. Overdense heating with EBW was achieved at low heating powers. Record high electron densities of $n_e > 8 \times 10^{19}$ m^{-3} were achieved in deuterium helicon plasmas with magnetic fields of ~ 1 T. At the target electron densities in excess of 1×10^{20} m^{-3} were measured. First ion heating with ICH in a linear plasma device with ion temperatures of more than 10 eV was obtained.

PMI research in Proto-MPEX. Proto-MPEX will allow for material sample exposures, albeit for short pulse duration. First tungsten sample exposures have been carried out for those transient conditions.

Code validation. The experimental results from Proto-MPEX are used for code validation (B2-Eirene, COMSOL, VORPAL, AORSA, GENRAY) to enable predictions of the source and heating performance for MPEX.

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