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GENERATION AND ACCELERATION OF STEADY-STATE PLASMA IN PLM-M DEVICE FOR TESTING OF FUSION MATERIALS

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ABSTRACT

•The PLM-M plasma device at the National Research University "MPEI" is used to test in-vessel components of a fusion reactor with steady-state plasma high heat fluxes (HHF) up to 5 MW/m^2 having parameters similar to the tokamak edge and divertor plasma.

•The results of generation and acceleration of steady-state plasma fluxes in the PLM-M device and analysis of in-vessel components are presented.

BACKGROUND

•Fusion materials (tungsten, graphite) under HHF plasma-load have been studied in experiments on tokamaks JET, EAST, WEST, AUG, T-10, Alcator C-Mod, the LHD stellarator, linear plasma devices, pulsed plasma accelerators like QSPA-T, in electron- and ion-beam devices, and in laser experiments.

•Linear devices with magnetized plasma – divertor simulators are useful for testing in-vessel reactor components. The linear plasma device PLM-M was constructed at the National Research University "MPEI". In 2023-2025, The PLM-M was upgraded using the RF plasma heating for testing fusion materials.

• To predict the erosion of tungsten divertor plates in a fusion reactor (ITER, FNS, and DEMO) steady-state HHF tests of tungsten are needed.

METHODS / IMPLEMENTATION

THE PLM-M DEVICE

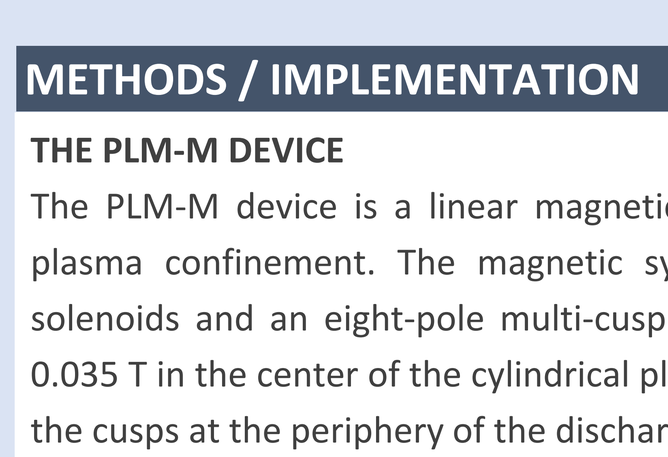
The PLM-M device is a linear magnetic trap with a multi-cusp magnetic plasma confinement. The magnetic system of PLM-M consists of two solenoids and an eight-pole multi-cusp system. The magnetic field up to 0.035 T in the center of the cylindrical plasma discharge 4 and up to 0.2 T in the cusps at the periphery of the discharge chamber.

PLASMA SOURCES

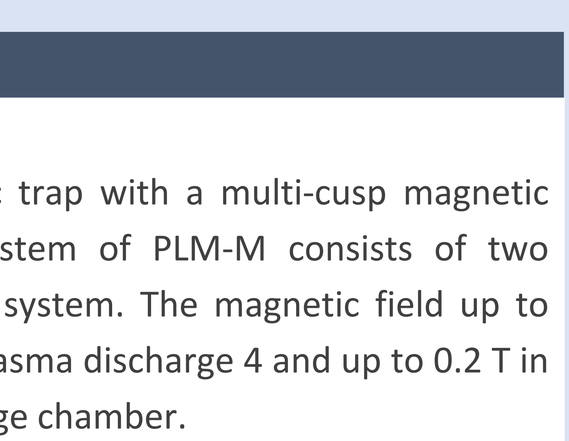
Two plasma sources are used: (1) a beam source with ionization of injected atoms by electrons accelerated by a CD electric field between the cathode and anode, and (2) a helicon source with ionization of atoms and RF plasma heating, the cooled helicon antenna is used.

IRRADIATION REGIME

$He^+ \rightarrow W$, E=80 eV, J=0.2 A/ cm^2, fluence ~ 3.6×10^{21} ion/cm^2, T~1100 K.



3D schematic of the PLM-M : 1,2 – solenoids; 3 - eight-pole multi-cusp system; 4 - center of the cylindrical plasma discharge; 5 - cusp zone; 6 - cathode; 7 - anode; 8 - cooled helicon antenna; 9- quartz tube



The systems of the PLM-M device

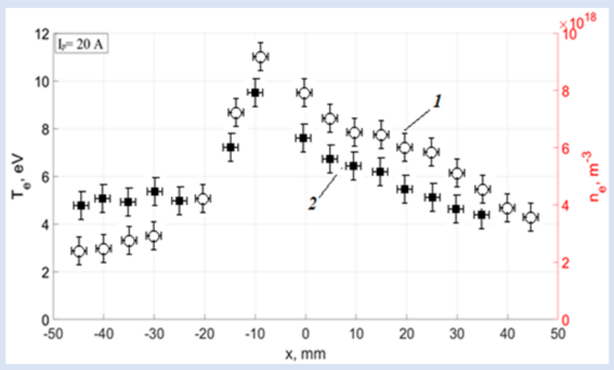
OUTCOME

THE PLM-M DEVICE FOR FUSION MATERIALS TESTING

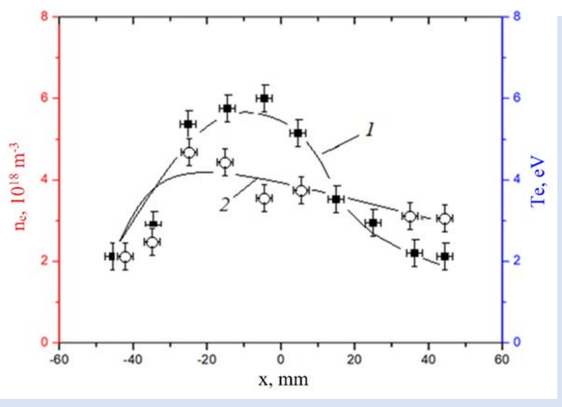
The PLM-M device with RF plasma heating using the helicon antenna allows obtaining a steady-state plasma flux with an electron concentration of ~10^{19} m^{-3}, electron temperature ~10 eV, depending on the plasma current. Such powerful plasma flux can be used to test fusion materials and in-vessel components of thermonuclear reactor. Experiments on PLM-M allow to develop plasma technologies and for creating an electric jet engine.

TESTS OF THE TUNGSTEN MOCK-UPS

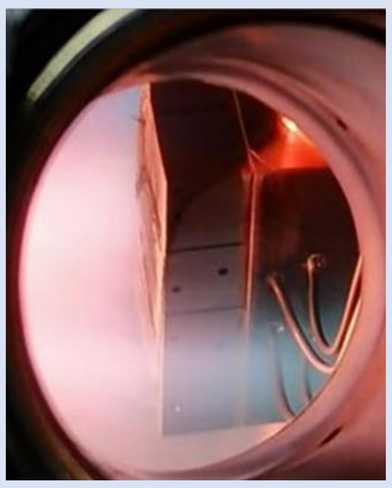
To apply additional load to the tungsten during plasma tests in PLM-M, a neodymium laser was used, simulating the ELM load. After plasma tests of the tungsten mock-ups in the PLM-M device, no large-scale destruction or melting of the mock-ups were observed. No significant macroscopic changes of the tungsten surface (initially smooth), no large-scale cracks or spalling on the surface, no significant erosion of the tungsten module were observed after two hours of plasma testing in PLM-M.



Plasma parameters in PLM-M: (1) radial dependence of electron temperature T_e , (2) - electron density n_e, plasma current of 20 A. RF heating power 950 W



Plasma parameters in PLM-M: radial dependence of (1) - electron density n_e, plasma current 8 A , (2) - electron temperature T_e



Tungsten mock-ups during plasma test in PLM-M

Tungsten mock-ups surface after plasma test in PLM-M

CONCLUSION

•The steady-state multi-hour operation was achieved on the PLM-M device to test fusion materials with magnetized plasma.

•The tests of the cooled tungsten mock-ups in PLM-M with steady-state loads on the material surface from 1 to 5 MW/m^2 have been done. Tests of cooled tungsten mock-ups are planned in PLM-M to assess their erosion in ITER and to develop designs for the FNS .

ACKNOWLEDGEMENTS

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