Overview of Fusion Research Activities in the Republic of Kazakhstan

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ABSTRACT

- The main experimental results obtained during the physical launch of the KTM tokamak in November, 2019.
- The results of the studies on the hydrogen isotopes interaction with structural and functional materials of fusion facilities under reactor irradiation;
- The results of reactor tests of optical fiber temperature sensors and optical fibers with various coatings (polyamide, acrylic, copper, aluminum)
- The results of irradiation of concrete samples of the ITER reactor and the content of various elements in concrete

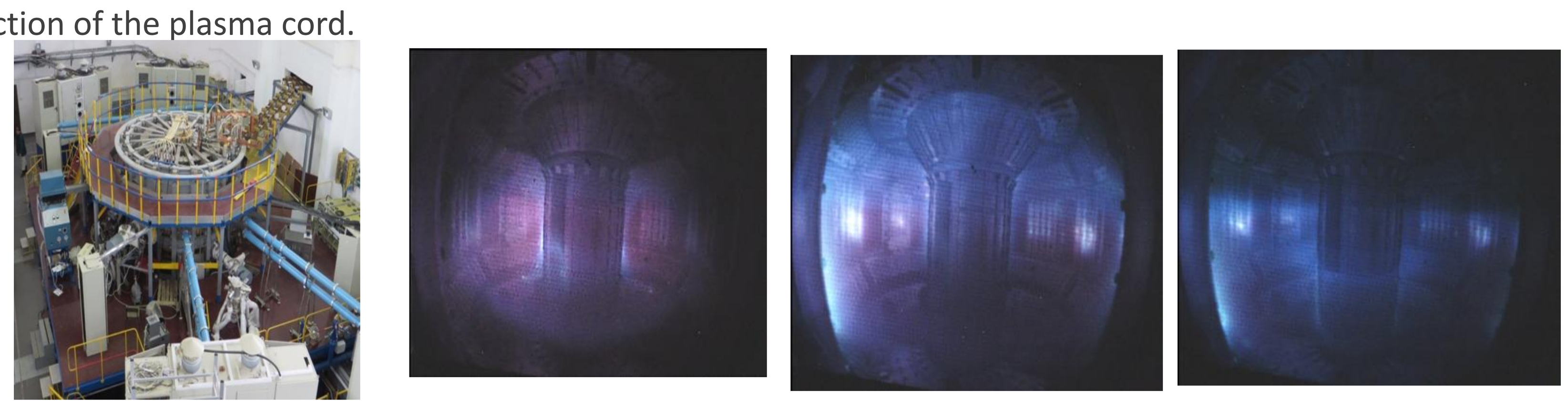
The main areas of RK fusion activities

- Research in plasma physics using KTM tokamak, improvement of plasma diagnostic methods and control system for collecting and processing of the experimental data
- Simulation studies of plasma-wall interactions using a plasma-beam facility
- Study of hydrogen isotopes interaction with structural and functional materials of fusion reactors under reactor irradiation
- Study of lithium-containing materials (ceramics, eutectics) of fusion reactor blanket and the promotion of lithium technologies for protection of plasma-facing materials
- Studies in support of ITER project

The physical launch of KTM tokamak

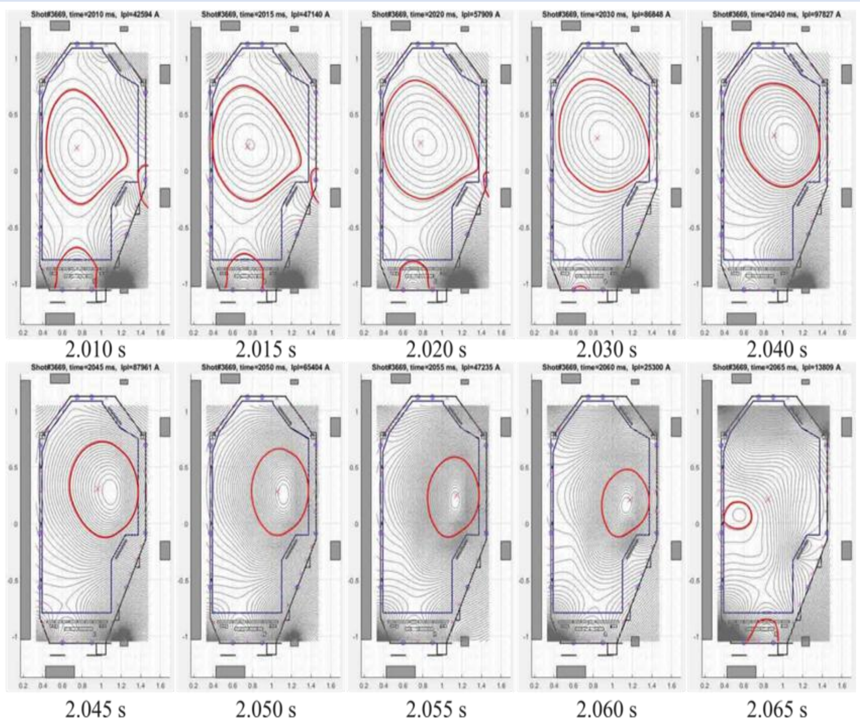
The physical launch of KTM tokamak was carried out in the end of 2019 by the joint efforts of RK experts from National Nuclear Center (NNC) and Institute of Atomic Energy (IAE NNC) and Russian experts (NRS "Kurchatov Institute" and Efremov Institute of Electrophysical Apparatus (NIIEFA)) in the framework of the joint scientific-research program of the Common-wealth of Independent States (CIS).

In accordance with the developed scenario, the following plasma discharge parameters were obtained: plasma current of 100 kA, toroidal magnetic field of 0.9 T, discharge duration of about 70 ms, and a circular cross section of the plasma cord.



The appearance of the KTM tokamak and video frames of the plasma discharge captured by the standard color camera operated at 30 fps.

- The plasma current growth rate in discharge was about 2.5 MA/s (the plasma current reached value about 100 kA within 38 ms). The loop voltage at the time of plasma breakdown was 7 V.
- The plasma linear electron density measured by a microwave interferometer with the maximum value of $8{\cdot}10^{18}$ m^{-2}.
- Obtaining the plasma in the ohmic mode at the reduced parameters was demonstrated .
- In 2020 CIS Working Group was developed new joint Research Program and in March, 12, 2021, CIS Economical Council approved a new 2021-2023 joint research program for the KTM tokamak in the framework of ATOM-CIS Commission.



The plasma shape reconstruction frames, discharge No. 3669

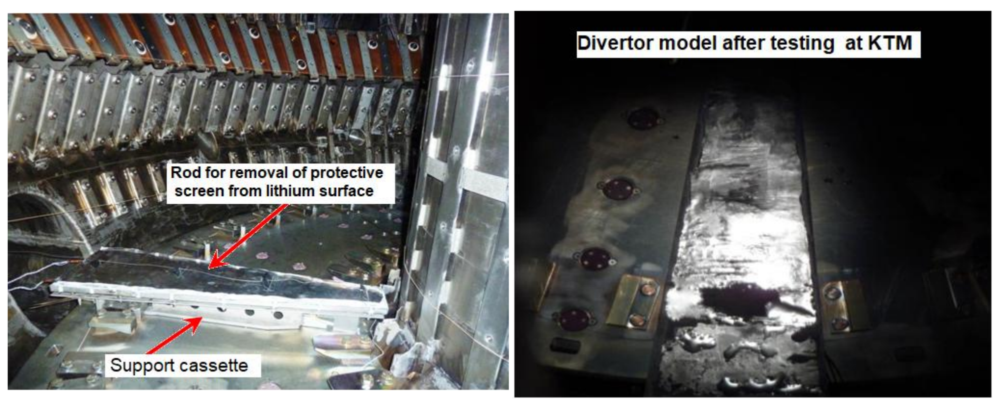
USE OF KAZAKHSTAN REACTOR BASE FOR MATERIAL SCIENCE STUDIES IN SUPPORT OF ITER PROJECT

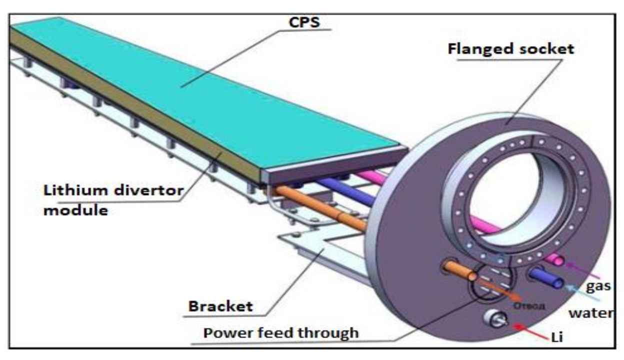
Kazakhstan has a well-developed reactor base (IVG.1M and IGR reactors in NNC RK, Kurchatov, and WWR-K reactor in INP, Almaty) and materials science base. During many years, the following materials were studied in out-of-pile and in-pile experiments: beryllium of various grades (production of RK and USA); graphites, including FP-479 (Germany), which is used as coating in KTM vacuum chamber; molybdenum; tungsten of various grades made in Germany (project CRP IAEA); stainless steels; low activated alloys and steels , as well as Li-based materials considered as the candidate structural and functional materials for fusion reactors.

CPS-based lithium divertor

The mockups of NaK-cooled and uncooled lithium divertor based on a lithium capillary-porous system (CPS) were created and then tested at the KTM experimental complex.

Requirements to improve the safety and compatibility of the divertor design with other water-cooled in-chamber elements of the tokamak, and to limit the temperature of the lithium receiving surface at <600°C under the heat flows of 10-20 MW/m² led to the development of a new design solution for the experimental divertor module and the use of a fundamentally new coolant – a gas-dispersed water flow (gas-water spray).

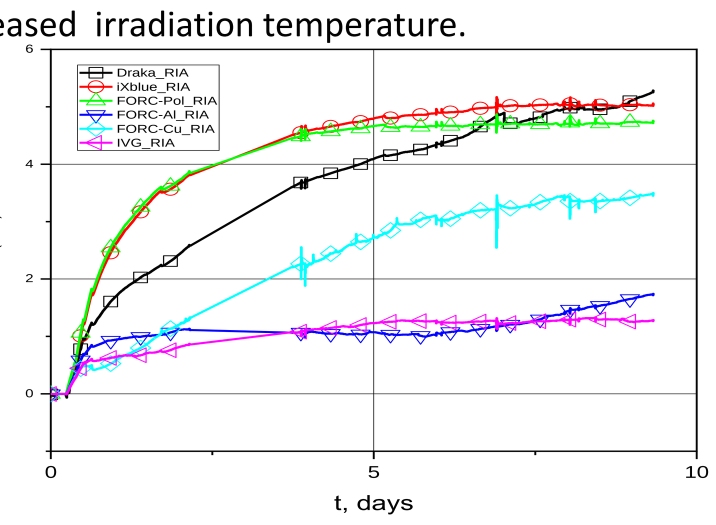




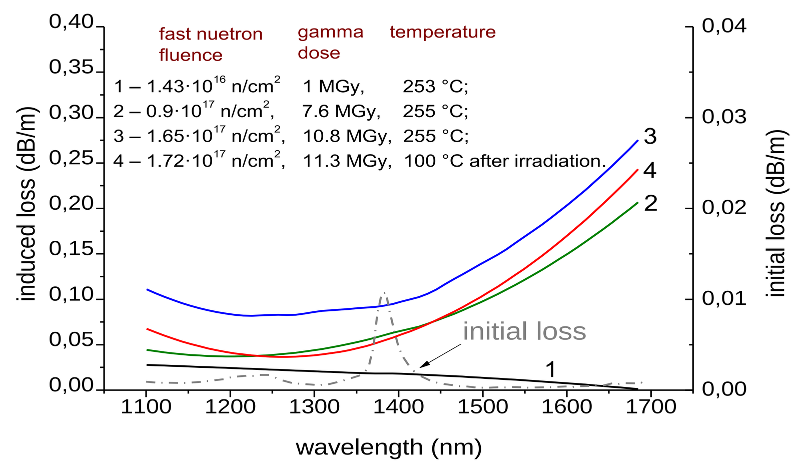
Lithium divertor module with steam-gas mixture cooling system

Testing of radiation resistance of fibers and fiber optic sensors to study the behavior of sensors in ITER conditions

The reactor experiments included the following: measurements of radiation-induced attenuations in optical fibers, registration of the time dependence of the change in the spectrum of transmitted light from the selected source, measurements of the shift of the resonant wavelength and its amplitude in the temperature sensors. The total accumulated fluence for fast neutrons was $1.76{\times}10^{24}$ m^{-2}, temperature of the samples was 185-206 °C. Based on the test results, the effect of reactor irradiation on the parameters of optical fibers and fiber-optic temperature sensors was evaluated, which will allow to select the optimal material for use In the ITER reactor. An important result of this study was the identification of irreversible destruction of polyimide and acrylate coatings in the process of reactor irradiation due to the combined effect of high neutron fluence, vacuum, and increased irradiation temperature.



Dependence of changes in radiation-induced attenuations for different fibers on the irradiation time

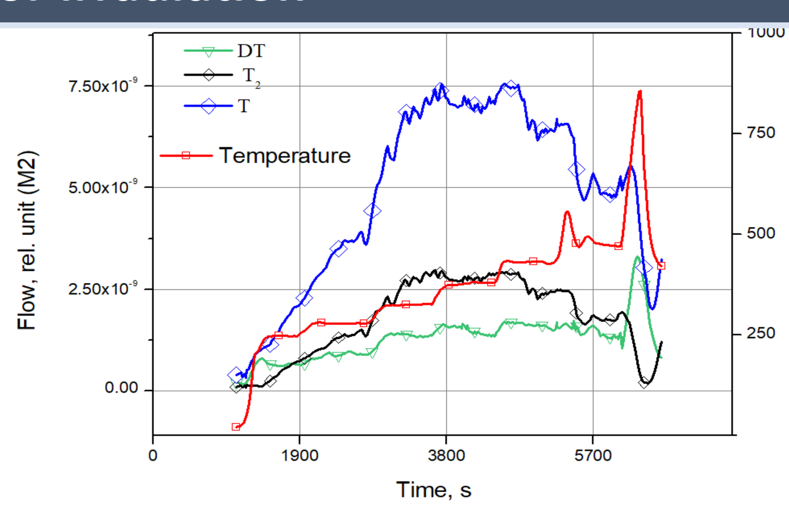


Spectrum of initial and radiation-induced optical losses in optical fibers with an undoped silica core and fluorinated cladding in a protective polyimide coating under reactor irradiation at a fast neutron flux of 2.4 10¹³ n / cm² s and a dose rate of 1.57 kGy / s.

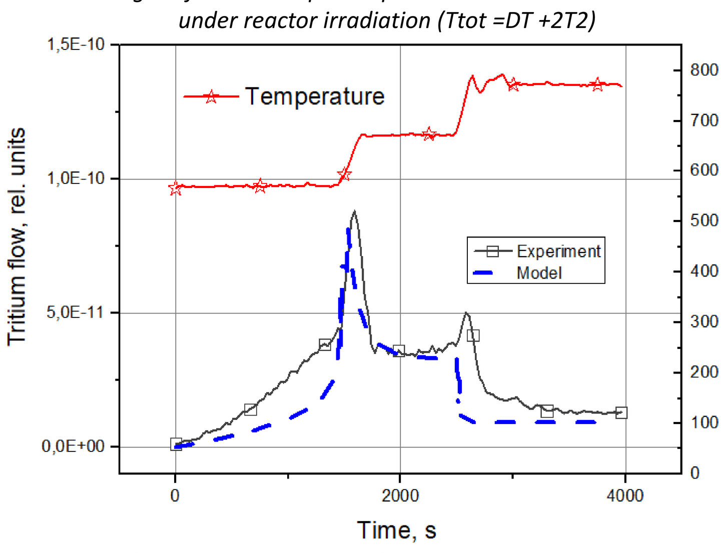
Study of the processes of T and He release from the lead-lithium eutectic Li15.7Pb under reactor irradiation

For the first time there were obtained the dependences of the tritium molecules release from lead lithium eutectic Li15.7Pb under conditions of neutron irradiation at different temperatures with a constant supply of deuterium in the inlet chamber with the eutectic's sample and continuous pumping from the back side of the sample. Modeling made it possible to obtain good agreement between the calculated and experimental values for quasi-equilibrium fluxes of tritium release from the lead-lithium eutectic and to determine the parameters of the interaction of tritium with lithium in the eutectic. The absorption constants of tritium by lithium are determined

k_(cap)~4,5·[10]^5 exp(-50000/RT)



Changes of DT and T2 partial pressures in Li15.7Pb eutectics under reactor irradiation (Ttot =DT +2T2)



Results of modeling the release of tritium in reactor experiments

Determination of trace contaminants in the chemical composition of ITER concrete samples by gamma spectrometry after neutron irradiation

The concentrations of basic and impurity elements were determined for the samples prepared from "normal" (27 elements) and "heavy" (24 elements) concrete cores.

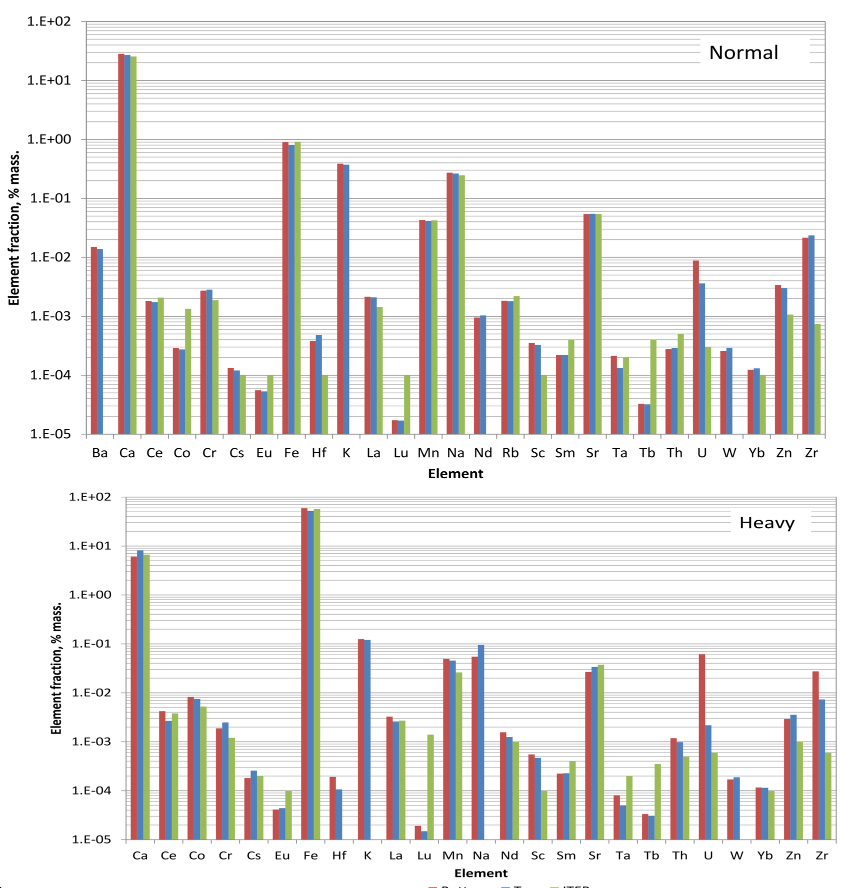
Gamma-spectrometric measurements of the samples prepared from "normal" and "heavy" concrete cores were performed after irradiation in IVG.1M research reactor at thermal neutron fluence of $5.3{\times}10^{16}$ n/cm² with different sample aging from one day to one month.

The determination of the elemental composition of the upp and lower parts of the "normal" unit showed coincidence within the accuracy of determination error;

and the elements' content In the upper and lower parts of "heavy" sample in general is the same, except for some elements such as U, Zr, Fe.

A significant content of iron in the form of FeO-Fe2O3 (magnetite) up to 59 wt% was determined in the "heavy" concrete samples.

Thus, as a result of the work, the content of the elements (Cs, Eu, Sm, Tb, TA) that can make the main contribution to the radiation situation during ITER reactor decommissioning was determined.



Composition of the elements in the "normal" (picture above) and "heavy" (at the bottom) concrete samples, wt.%

CONCLUSION

The conducted researches allow us to accumulate the extensive experience, train the personnel, and create a methodological and hardware base for future experiments on the interaction of hydrogen isotopes plasma with the structural materials at the experimental complex based on the spherical tokamak KTM.

The simulation experiments to study the effects of reactor irradiation on the hydrogen isotopes interaction with structural materials of fusion reactors, as well as on the characteristics of structural elements and measuring equipment of the ITER reactor will help to establish a correlation and synergistic effects between the effects of fission and fusion reactors on the materials and components of thermonuclear reactors.

ACKNOWLEDGEMENTS

We express our gratitude to the ATOM-CIS Commission and the ITER Organization for the opportunity to work together and for the assistance provided under CIS Intergovernmental Agreement and ITER Executive Agreements I0 REF-4300001800, LGA-2018-A-114 and LGA-2017-M-86. The work was carried out as a part of MES project AP05131677/GF5.