TESTS OF ULTRASONIC LITHIUM INJECTOR WITH EXTERNAL LITHIUM SUPPLY SYSTEM ON TOKAMAK T-11M

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The use of liquid lithium to protect the first wall and divertor plates of the tokamak from the effects of high-temperature plasma is being actively studied at many fusion devices, and seems to be the most promising idea for use in future tokamak-reactors [1]. One of the methods for introducing lithium to the periphery of the plasma column is the method of lithium injection. Outstanding results had already been achieved using such devices at tokamaks, for example, in the TFTR using DOLLOP technology (supershot discharge; more than 10 MW of thermonuclear power [2]) and in the EAST using the lithium dropper (the record plasma discharge duration of 1056 s [3]).

Since 2021, in addition to lithium limiters used to organize a closed lithium circulation loop to protect the first wall of the tokamak, an ultrasonic injector of finely dispersed lithium has been tested at the T-11M tokamak to introduce lithium into the plasma. The main operating principle of this injector is to generate droplets on the surface of a thin liquid layer under the influence of ultrasonic vibrations. Tests of such an injector [4] have demonstrated a decrease in the level of impurities in the tokamak chamber, an increase in the discharge duration, suppression of accelerated electron beams, and an increase in the power of radiation losses at the periphery of the plasma column. To use such injectors in tokamaks operating in stationary and quasi-stationary modes, for example, T-15MD and TRT, a prototype of a finely dispersed lithium injector with an external lithium refueling system without breaking vacuum conditions was developed and manufactured. Additional advantages of such an injector include the ability to regulate the parameters of liquid lithium injection and control the start of the lithium particle injection process relative to the moment of discharge ignition.

Since 2024, a prototype of a finely dispersed lithium injector with an external lithium supply system, developed for the T-15MD tokamak (NRC "Kurchatov Institute"), has been tested on the T-11M tokamak in plasma discharges with the following parameters: I_p = 60-70 kA, B_T = 1.2 T, n_e = 2-5·10^{19} m^{-3}, Δt = 200 ms. The typical sizes of lithium microdroplets are 50 μm, the velocity of the injected microdroplets in the experiments was from 1.5 m/s to 7 m/s. The flow of injected lithium during the experimental series varied in the range from 10 to 70 mg/s. Lithium was injected through the equatorial branch pipe of the tokamak. A graphite limiter was used to limit the plasma column. The lithium flow from the injector in the plasma was estimated using the Baumer HXG 20C high-speed video camera data during the discharge. Figure 1 shows the images from the video camera of the interaction of injected lithium droplets with plasma at different discharge stages, as well as the evolution of the lithium flow during injection, where the red color corresponds to the glow intensity of neutral lithium, and the green color corresponds to the glow intensity of singly ionized lithium. The effect of lithium microdroplet injection on the plasma discharge parameters was studied.

Tests of the injector with external lithium supply under plasma conditions of the T-11M tokamak demonstrated its successful operation without refueling for at least 193 plasma discharges with a total injection time of about 203 s. During the experimental campaign, three injector refills with liquid lithium from an external reservoir were successfully carried out without breaking the vacuum conditions in the tokamak chamber.

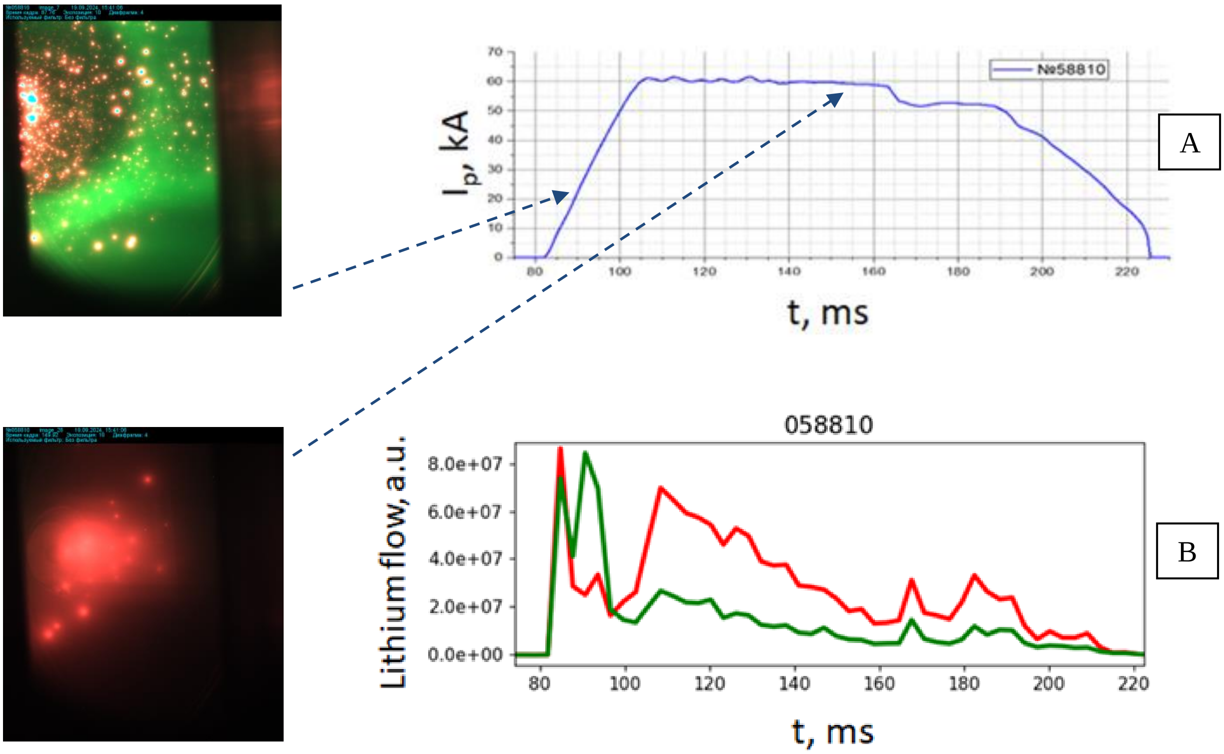

Figure 1. A – the evolution of the plasma current during discharge; and B – the dynamics of lithium flow during operation of lithium injector (the red color corresponds to the glow intensity of neutral lithium; the green color corresponds to the glow intensity of singly ionized lithium). Video images of interaction of injected lithium droplets with plasma at different discharge stages on the left.

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