System of high-speed video and infrared cameras for joint control of the lithium limiters behavior on tokamak T-11M. First results

A. Prishvitcyn[1,2], A. Djurik[1], V. Lazarev[1]

[1] *SSC RF TRINITI, Troitsk, Moscow, Russia*

[2] *NRNU MEPhI, Moscow, Russia*

1. Introduction

Lithium is the most perspective material for plasma facing components (PFCs) in tokamaks. It was experimentally shown, that the lithium application in thermonuclear facilities leads to increasing of pulse duration, decreasing of impurities in plasma and decreasing of hydrogen retention from the tokamak wall. The experimental work on tokamak T-11M is devoted to creation of closed lithium loop in tokamak vessel to escape the problem of hydrogen isotopes accumulation [1]. For the program, it is necessary to determine heat load on PFCs, particularly on longitudinal lithium CPS limiters during the tokamak discharge. In this paper, the first results of unique diagnostic system with two IR and two visible cameras from T-11M are shown. The current location of IR cameras and high-speed visible cameras on tokamak is presented in section 2. Experimental results from diagnostic system especially determined heat load on PFSs are shown in section 3. In the section 4, there are discussion about results and conclusion.

2. Tokamak T-11M, IR and visible camera location.

Tokamak T-11M is the Soviet tokamak with round crossection, working in limiter configuration. In 2018, the configuration of plasma facing elements was changed. The second ("new") longitudinal limiter-collector was installed symmetrically to the first ("old") one. It was shown, that new configuration of collectors decreased the irrevocable losses of lithium to the vessel wall in 4 terms [2]. Meanwhile, there was no information about heat load on the collectors during the discharge, and how it depends on lithium temperature. That is why unique diagnostic with two IR and two visible cameras has created.

The diagnostic system is consists of:

- two high-speed visible cameras Baumer HXG20C (get data about processes on two longitudinal limiters or one different views, framerate is 340Hz)
- two high speed infrared cameras Infratec VarioCam HD Head 680 and 880 (operating wavelength range is 7.5 - 14 microns, frame rate is 256Hz).

The launch of all cameras is synchronized.

. There are 4 diagnostic ports on tokamak T-11M, where cameras could be installed. In experiments described below, the configuration did not change. Visible cameras was installed at port №1 and №4, IR cameras was installed at ports №2 and №3 (fig.1).

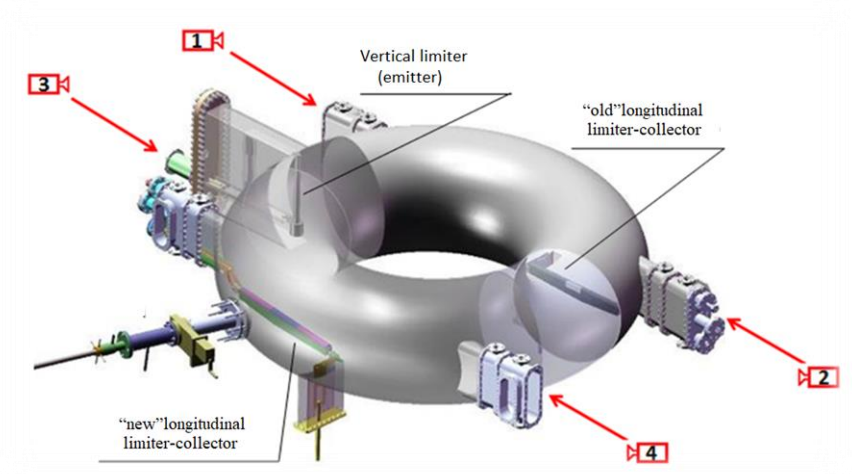

Figure 1. Tokamak T-11M and its diagnostic ports.

Data from all cameras analyzing by created MATLAB code. As a result, we get time evolution of temperature distribution (from IR camera) and luminosity distribution (from visible camera). Usually we use averaged values to simplify showing data.

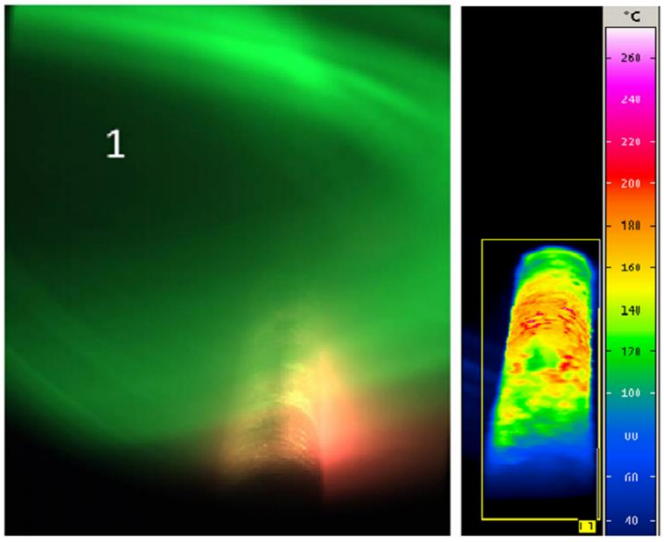

Figure 2. Example pictures from IR (right) and visible camera (left).

3. Experiments

On the T-11 M tokamak during the experiments, described below, the 2nd longitudinal limiter was placed closer to plasma then the "1st one (Figure 3) for 2cm. The 1st limiter was kept at the room temperature (15 °C) for all shots. We get data about surface temperature and luminosity near the surface for both limiters during the discharge. The heat flux on the limiters was reconstructed using temperature data.

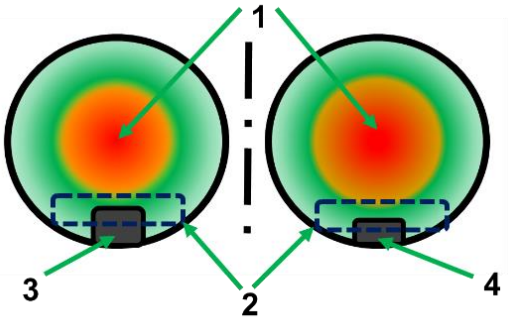

Figure 3. The configuration of tokamak limiter system during experiments. 1 - Plasma; 2 - projection of vertical limiter; 3 – 2nd longitudinal limiter; 4 – 1st longitudinal limiter. The 1st limiter is placed in the shadow of the 2nd one, which placed closer to plasma on 2cm.

a. Experiments with changing initial temperature of 2nd limiter.

During the spring 2019 experimental campaign on T-11M, experiments with changing initial temperature of second limiter were provided (shots #47851 - #47865).

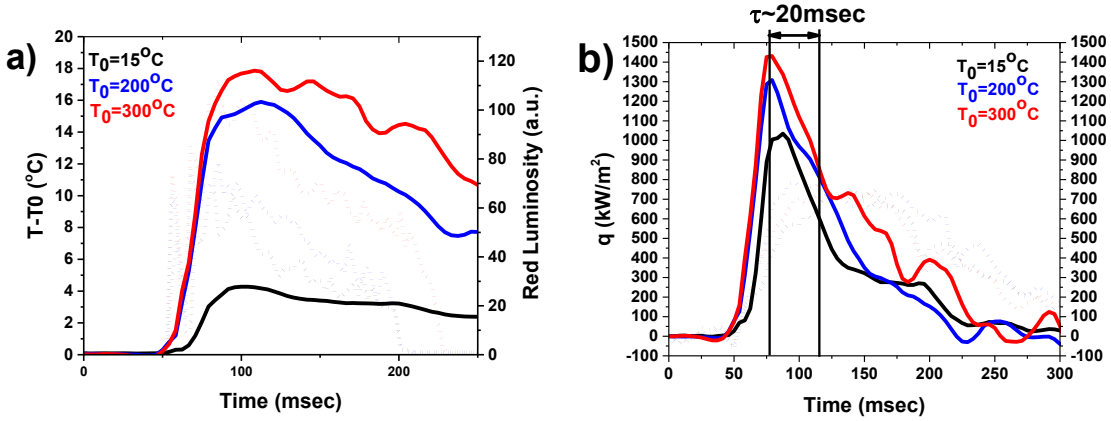

Figure 4. Time dependence of neutral lithium radiation and temperature of the 2nd limiter surface (a). Time dependence of the heat fluxes on the 2nd and the 1st limiters (b).

When the surface temperature of lithium limiter increases, the sputtering yield and evaporation rate also increase. That is shown by increasing of intensity of red luminosity (neutral lithium) signal get from visible cameras. We should note, that there is a time delay (~20msec) between, heat load arriving on the limiters (firstly on the 2nd, then on the 1st) due to its location.

b. Experiments with plasma current change

A series of experiments (# 48397-48412) with different plasma currents from 30-90 kA were carried out to study the behavior of the surface of the longitudinal limiters at various flows coming to them during the discharge process. Limiters were exposed at temperatures of 200°C and 20°C for the 2nd and the 1st, respectively. As can be seen from the obtained dependences,

with a plasma current of 30 kA, the heat flux coming to both limiters is almost equal. However, when the plasma current increases to 90 kA, the flux coming to the 2nd limiter is about 2 times higher than the old one. (Fig.5 (a)). We have determined which part of ohmic heating, during the stationar phase of the discharge, came to the limiters (Fig.5 (b)). All values less then 10%. For 2nd limiter there are two parts: slow increasing part (I_p<70kA) and constant part (Ip>70kA). The one of explanations could be the appearing of vapor shielding effect.

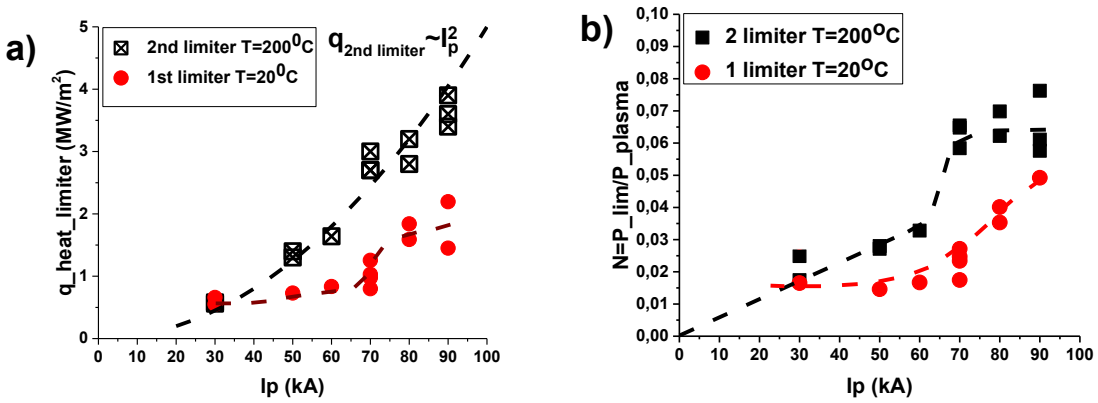

Figure 5. The dependence of averaged heat flux on the limiters vs the plasma current (a). The relation between power of heat flux on limiters and power of plasma ohmic heating for different plasma currents (b).

4. Conclusion

The observation of two longitudinal collectors in tokamak T-11M is carried out simultaneously in the visible and IR wavelength ranges. Cameras operating in the infrared range are used for recording the temperature distribution on the surface of lithium collectors. This allow to determine the distribution of heat load on the collectors surfaces.

Acknowledgment

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References

[1] S. V. Mirnov *et al.*, “Experimental test of the system of vertical and longitudinal lithium limiters on T-11M tokamak as a prototype of plasma facing components of a steady-state fusion neutron source,” *Nucl. Fusion*, vol. 55, no. 12, p. 123015, Nov. 2015.

[2] V. B. Lazarev et al., “Development of fast video recording of plasma interaction with a lithium limiter on T-11M tokamak,” *Fusion Eng. Des.*, pp. 1–5, 2016.