CONTROL OF THE RUNAWAY ELECTRON FLOW IN TORSATRON

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The possibilities of stimulation and complete suppression of the runaway electrons flow in the experiments at Uragan-2M setup were investigated. The flow stimulation was carried out by producing additional free charged particles during the runaway electrons flow formation. The runaway electrons flow suppression was carried out using the peripheral electrode with negative or positive potential. The supposed mechanisms of influence and possible use come into question in some fusion devices.

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INTRODUCTION

The possibilities of both stimulation and complete suppression of the runaway electrons flow in the experiments at Uragan-2M (U-2M) torsatron were investigated. The flow stimulation was carried out by producing additional free charged particles during the runaway electrons flow formation. The source of additional charged particles in U-2M was secondary electron emission realized due to interaction of the ion beam of the heavy ion beam probing (HIBP) diagnostic system with constructive elements inside the vacuum chamber of the device.

The runaway particles flow suppression was carried out by applying electrostatic potential to the probes located just outside the plasma confinement volume. The reason of the high-energy particles emergence in the confinement volume is vortex electric field which appears due to the temporal variation of the magnetic field. The high-energy electron flows are forming and accelerating at the magnetic field pulse edges. The flux intensity is sensitive to the variation of the working gas pressure.

EXPERIMENT ON THE U-2M

The magnetic field strength was B_0=4 kOe. The working gas pressure was $(5…8)\cdot10^{-6}$ Torr. At the magnetic field back pulse edge the stable X-ray emission was observed. The intensity of X-ray radiation was increasing with the increase of the magnetic field and decrease of the working gas pressure. The accelerated electrons due to their interaction with metallic wall of the vacuum chamber are the source of radiation (Fig. 1).

Also there were experiments on stimulation of runaway electron flow by the additional injection of electrons and suppression of runaway electron flow by the peripheral potentials.

The magnetic field of 4 kOe, working gas pressure of $(5…8)\cdot10^{-6}$ Torr. Hard X-ray emission at the magnetic field back pulse edge.

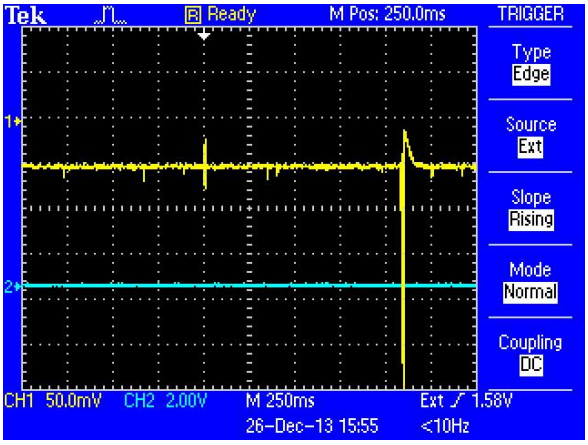


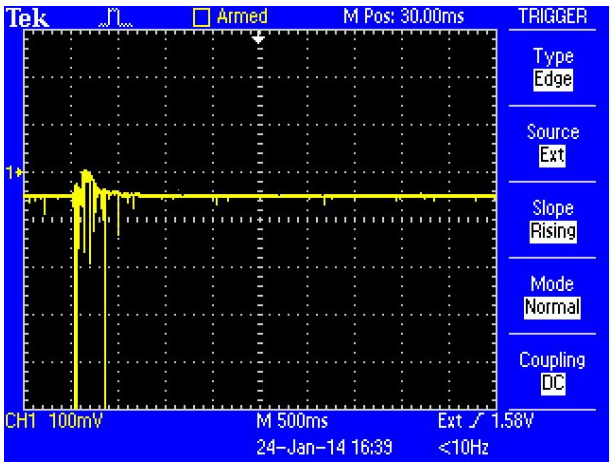
Fig. 1. X-ray emission at the magnetic field back pulse edge in the torsatron U-2M

The intensity of X-ray radiation increases with the increase of the magnetic field and decrease of the working gas pressure.

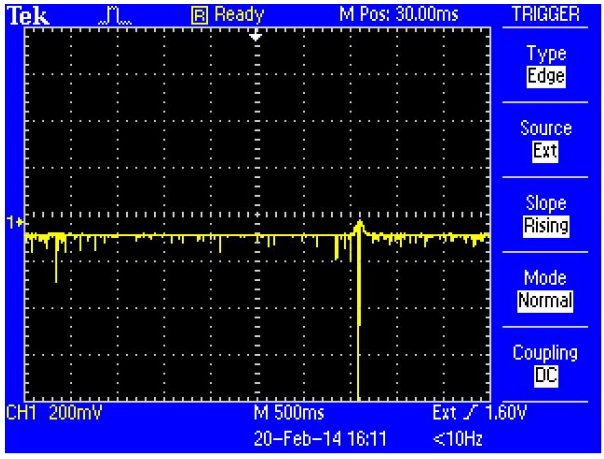
The stimulation of the runaway electron flow was realized by the ion beam which are intended for plasma diagnostics. It acted as an electron source by secondary ion-electron emission appeared during the interaction of the ion beam with the structural elements of the vacuum chamber (Figs. 2,a,b,c).

SUPPRESSION OF THE RUNAWAY ELECTRON FLOW

It is known that the formation of high-energy runaway electron flows is the most dangerous consequence of the development of the breakdown instability in tokamaks. When interacting with elements of construction such particles can cause damage and destruction. There are some methods of dealing with breakdown. The simplest way is to decrease the discharge current. Unfortunately this method is not



a



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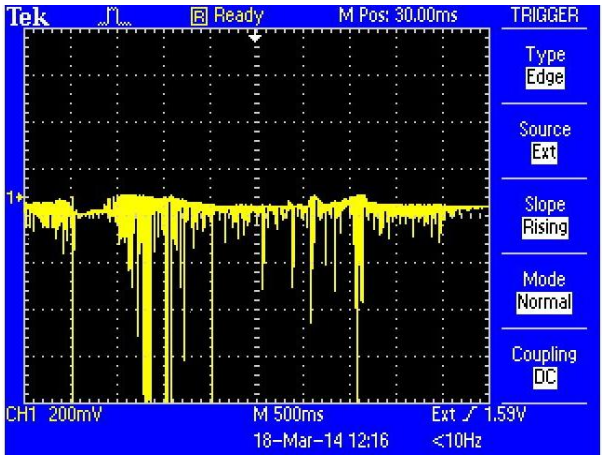

c

Fig. 2. The stimulation of the runaway electron flow during the injection of the heavy ion beam into the confinement area of the torsatron U-2M. The magnetic field strength 4 kOe. Heavy ion beam parameters: current, energy and pressure of the working gas (hydrogen).
a. 60 μA, 80 kV, 8·10 $^{-6}$ Torr;
b. 100 μA, 70 kV, 5·10 $^{-5}$ Torr;
c. 75 μA, 100 kV, 5·10 $^{-6}$ Torr

effective because the conditions for the runaway electron flow are created. One more method is the injection of a huge number of radiating impurities, which allows to transform the stored in the pinch energy into radiation [4].

A possible way to suppress runaway electrons can be injection of high Z impurities in the form of tablets into the plasma confinement volume [5]. In this case the interaction with impurity is more localized but such an injection increases the runaway electron current. Also there are some experiments on the interaction of runaway electron flow with HF and microwave fields using the ECR heating or creation of constant current [6].

Despite of the different methods of the runaway electron flow suppression in the devices of controlled thermonuclear fusion the problem is still unsolved.

DESCRIPTION OF THE EXPERIMENTS

The experiments were carried out at torsatron U-2M. Inside the chamber of U-2M HF generator antennas for plasma creation are located. In this experiment one of these antennas is used as the control electrode for the runaway electrons. There was a constant voltage U_g supply on the antenna L_a. The feeder line from the HF generator and capacitor C_a were connected in parallel to the antenna. Resistor R acted as a limiting resistance for the protection of the voltage source. During the experiment the voltage U_g (from 0 to 100 V) and its polarity were changing. The magnetic field strength B_0=4 kOe. The working gas pressure was $1.6 \cdot 10^{-6}$ Torr (Fig. 3).

It is possible to reveal the runaway electrons because of X-ray. In the case of negative voltage supply to the antenna (-100, -50, -10 V) the controlled radiation hasn't been revealed. At the positive voltage supply (+20, +100 V) the X-ray, the microwave radiation and the Rogovski coil current were observed.

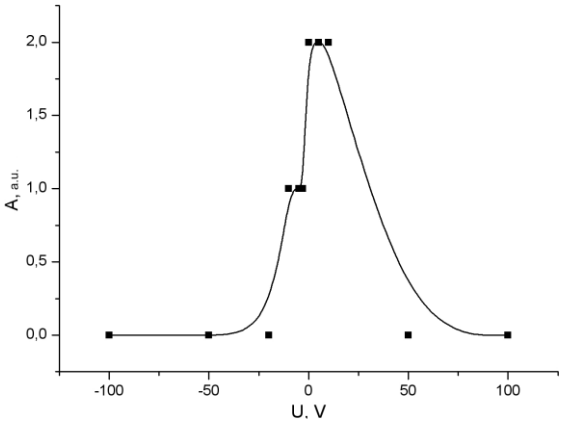

Fig. 3. Dependence of the level of hard X-ray in torsatron U-2M on the frame antenna potential

Suppression of the runaway electron flow was realized by supplying of negative or positive potential (0…100 V) to the peripheral probe (the frame antenna of the torsatron U-2M).

CONCLUSIONS

The runaway electron flows are forming in the torsatron U-2M confinement area at the magnetic field pulse edges due to the acceleration of background electrons by toroidal vortical electric field. The flow of

accelerated particles forms initial plasma by ionizing the working gas. Such initial plasma also serves as a source of free electrons which participate in the runaway electrons flow formation.

The runaway electron flow can be stimulated by means of additional SHF radiation injection into the confinement area of the torsatron U-2M at the magnetic field pulse edges.

The source of electrons is secondary ion-electron emission which appears during the injection of heavy-ion beam into the confinement area.

It has been experimentally found that the potential (both negative and positive) on the antenna-electrode influences the dynamic of runaway electrons as well as in case of U-3M [1].

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УПРАВЛЕНИЯ ПОТОКАМИ УБЕГАЮЩИХ ЭЛЕКТРОНОВ В ТОРСАТРОНЕ

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Исследованы возможности стимулирования и подавления потока убегающих электронов в рамках экспериментов на установке Ураган-2М. Стимулирование производилось за счет добавления заряженных частиц в момент начальной стадии образования вторичных убегающих электронов. Подавление потоков убегающих электронов осуществлялось подачей на периферийный электрод отрицательных или положительных потенциалов. Обсуждаются предполагаемые механизмы воздействия и возможное использование в установках УТС.

УПРАВЛІННЯ ПОТОКАМИ ВТІКАЮЧИХ ЕЛЕКТРОНІВ У ТОРСАТРОНІ

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Досліджені можливості стимулювання і пригнічення потоку втікаючих електронів у рамках експериментів на установці Ураган-2М. Стимулювання робилося за рахунок додавання заряджених частинок у момент початкової стадії утворення вторинних втікаючих електронів. Пригнічення потоків втікаючих електронів здійснювалося поданням на периферійний електрод негативних або позитивних потенціалів. Обговорюються передбачувані механізми дії і можливе використання в установках КТС.