FIRST RESULTS OF MULTICHORD SOFT X-RAY DETECTION ARRAY ON THE U-3M TORSATRON.

M.B. Dreval

Institute of Plasma Physics of the NSC “Kharkov Institute of Physics and Technology”, Kharkov, Ukraine

A miniature pinhole camera array for spatially and temporally resolved measurements of soft X-ray plasma emission has been recently installed on the U-3M. The diagnostics has been tested in different types of the U-3M discharge. In low density frame antenna discharges with so-called “H-like” transition a fast SXR emission profile modification is observed. A phase shift of the SXR perturbation induced by the transition as well as different shapes of the perturbation is observed in different channels. The transition can be associated with MHD instability. Different shapes of the SXR emission profile has been observed in different discharge conditions. The SXR array is en excelent tool for study different types of the MHD activity. Different types of the low frequency MHD activity have been observed in the U-3M torsatron. The recently installed SXR diagnostics opens opportunity of detailed studies of the MHD activity together with its driver – the plasma pressure gradient. In the paper we are presented recent experimental results obtained with the use of SXP, without deep analysis these experiments.

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INTRODUCTION

Soft X-ray (SXR) diagnostics is an important tool for study of various phenomena in tokamaks, stellarators, reverse field pinches, etc [1-3]. An advantage of the SXR diagnostics is a possibility of the multichannel plasma profile evolution measurements with excellent temporal and spatial resolutions. The SXR diagnostics is widely used as a perfect tool for the plasma fluctuation studies. Nonetheless, the SXR signal dependence from set of parameters as well as its integral character forms difficulties in the SXR data interpretation. For a 2 μm *Al* foil filter, installed in the U-3M SXR diagnostics case, the measured signal is proportional to the integral from $n_e^2 Z^2 T_e$ if T_e=0.25…1 keV in a case of bremsstrahlung radiation only [4]. An amount of diagnostics installed on the U-3M is limited. In such a situation a multiline SXR diagnostics is one of few available for plasma profile measurements diagnostics. It is a unique in U-3M diagnostics, which allows studying main plasma profile using single discharge data (also available H_α profile is not directly related to the plasma core). First time since a long U-3M operation, the SXR diagnostics provides plasma profile evolution data every plasma pulse with sufficient temporal resolution. In the present paper the SXR data are shown for different U-3M experiments. Despite the fact, that for a complete understanding of the described experiments a data from all available diagnostics are required, the presented SXR data provides substantial amount of new information. The plasma profile behavior during so-called H-like mode transition [5, 6] is one of the U-3M questions without an answer up to now. Expected plasma confinement improvement causes plasma temperature or density rise (or both of them), that is always causing substantial rise of the SXR emission. A transport barrier can be localized by the SXR emission profile gradient steepening. The SXR profile evolution during similar to the H-like transitions is studied in the present work. Another important problem, discussed since a beginning of the Alfven heating studies in Kharkov is localization of the resonances [7] and consequently the power deposition localizations. Local features of SXR emission profile can provide important information about a complex nature of the Alfven wave power deposition in U-3M. One more topic is low frequency plasma fluctuations. The fluctuations were observed in old U-3 experiments and were associated with high β [8]. SXR fluctuations are studied in the present work. These fluctuations are appearing in discharges with rather low plasma.

1. SXR DIAGNOSTICS SETUP

The 2 μm *Al* foil has been installed in the U-3M SXR pinhole diagnostics [4] to cut-off low energy radiation.

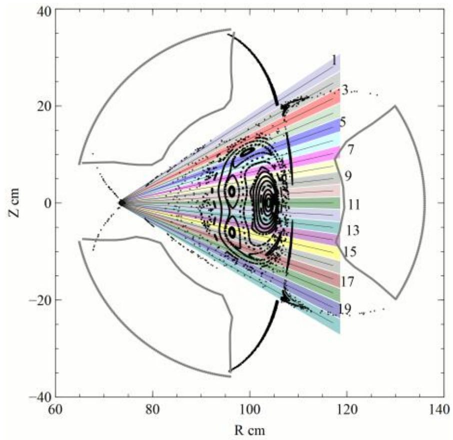

Fig. 1. Lines of sight and viewing angles of the SXR detector array across the U-3M cross section “A–A”

The SXR camera array consists of a 20 channel photodiode linear array IRD AXUV-20EL. The camera is viewing horizontally through a symmetric plasma cross section “A–A”, as it is shown in Fig. 1. The SXR photodiode photocurrent amplifiers gain is 2.5•10^7 V/A. The amplifiers bandwidth is 10 kHz. It allows to suppress successfully high level RF noise and to register SXR signals [4].

2. SXR PROFILE BEHAVIOR DURING THE TRANSITION

The transition is observed in the low density frame antenna U-3M discharges [5, 6]. Fig. 2,a shows SXR signals from channels with opposite impact parameters. Fig. 2,b shows clear 20 kHz MHD activity, which is always accompanied the transition [9].

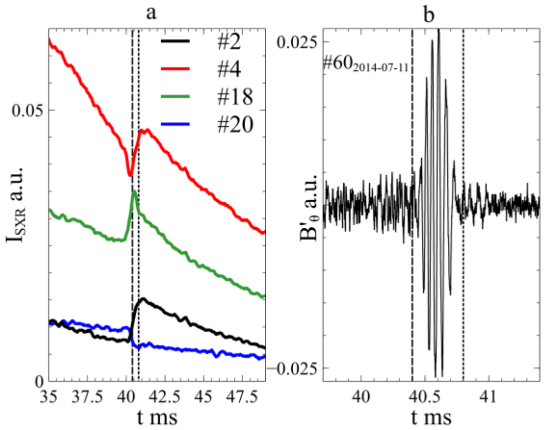

Fig. 2. Evolution of SXR signal in channels with opposite impact parameters (a); magnetic probe data (b)

As it is clear from the Fig. 2, the transition is related to the complex U-3M plasma column perturbation associated with MHD activity. The SXR profile shift from channel №20 to channel №2 is observed at the plasma periphery. Significant phase delay in the SXR emission perturbation is observed in deeper channels №4 and №18. This experimental effect can be explained by a rotation of some plasma region.

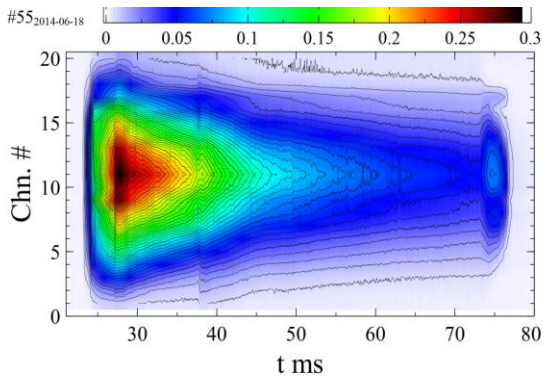

Fig. 3. SXR profile in a frame antenna discharge

Detailed SXR profile temporal behavior in a discharge with the transition is shown in Figs. 3, and 4. In addition to the complex plasma column movement, a transient decrease of the SXR emission temporal decay is also observed. Rather small SXR emission rise is not clear enough for the SXR emission gradient steepening localization. At present, it is impossible to separate the MHD event and possible confinement improvement influence on the SXR emission.

We should note, that due to the SXR electronics bandwidth limitation the 20 kHz mode is not observed in the SXR diagnostics.

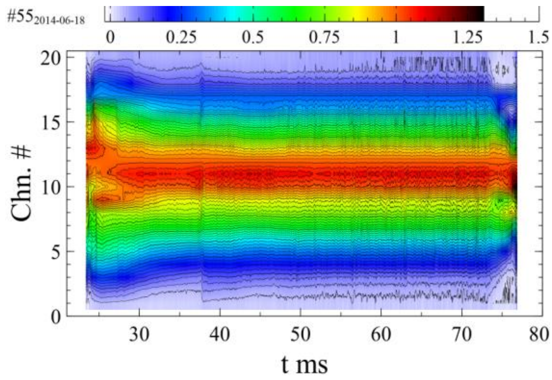

Fig. 4. SXR profile normalized to data of channel №12

3. SXR PROFILES IN DIFFERENT U-3M DISCHARGES

Substantial SXR emission rise after RF power switching off is always observed in the low density frame antenna discharges. An example of this increase is shown in Fig. 3 at 73…75 ms. The SXR signal increase is evidently associated with the density increase, which is always observed at the end of this type of the U-3M discharge [6]. An asymmetry of the SXR emission profile is clearly shown in a normalized SXR profile (see. Fig. 4) at the breakdown/buildup stage. This asymmetry can be associated with a transient modification of the RF power deposition location in the absence of equilibrium. A peaking of the normalized SXR emission profile after RF power turning off (73…75 ms) does evidently represent better plasma confinement in a central region as well as some influence of the edge RF power deposition. This deposition disappears after the switching off. The SXR emission from the periphery is dropping due to worst confinement in this region.

Substantial amount of the SXR data in the three half turn (THT) antenna discharges was also obtained recently in U-3M. An example of the SXR profile modification in the final degradation stage of the THT antenna discharge is shown in Fig. 5. A clear peaking of the SXR emission profile near the end of discharge indicates, that plasma cooling at the periphery occurs. Probably a degradation of the RF power absorption at the periphery appears at the end of the THT antenna discharge under consideration.

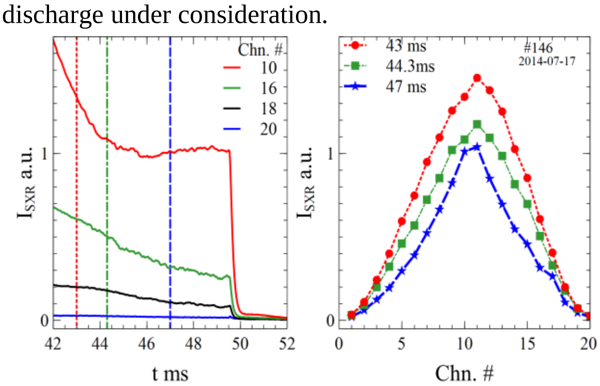

Fig. 5. SXR time evolution (left) and SXR profile in the end of a THT discharge (right)

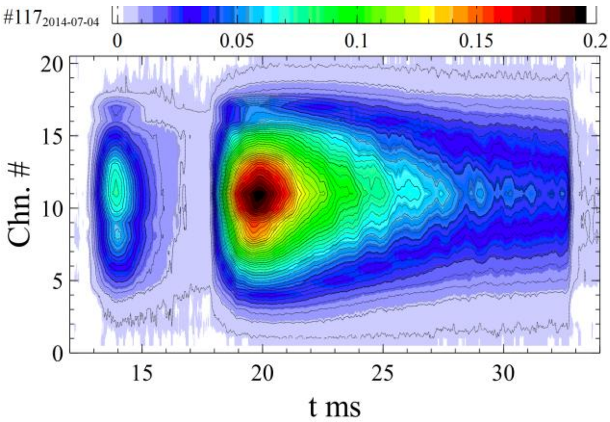

Fig. 6. SXR profile in a THT antenna discharge with frame antenna plasma build-up

Another example of the THT antenna discharge is shown in Fig. 6. The first peak (at 12…16 ms) corresponds to the low power frame antenna plasma creation stage. A second stage represents medium power THT antenna discharge.

4. 1 kHz SXR EMISSION FLUCTUATIONS

Substantial SXR emission fluctuations in a frequency about 1 kHz are observed in THT antenna medium power discharges.

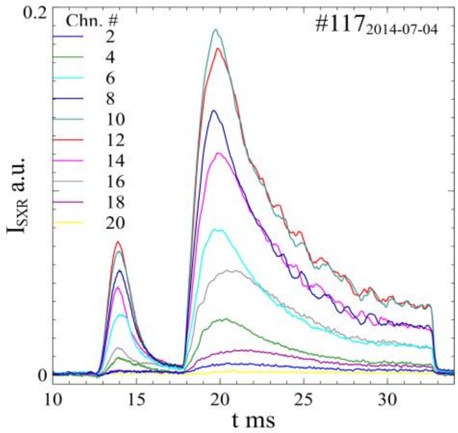

Fig. 7. Evolution of SXR signals. THT discharge with frame antenna plasma build-up

An opposite phase of the perturbation is observed in SXR channels with opposite impact parameters, as it is shown in Figs. 7, 8 shows only the fluctuating part of SXR signals without its DC component.

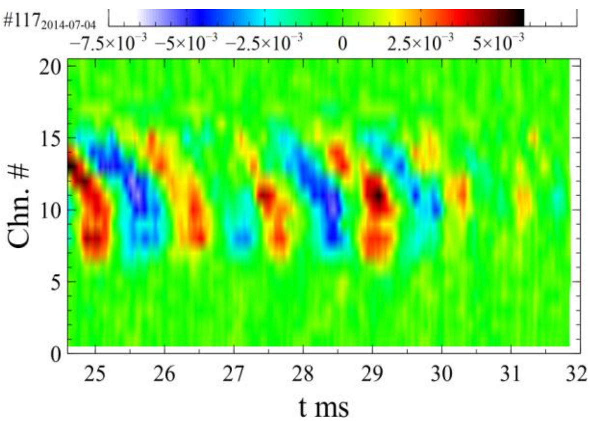

Fig. 8. Profile of the fluctuating part of the SXR data

The SXR perturbation maximum and minimum are simultaneously appear in the profile. Systematic radial movement of the SXR perturbation can be explained by a poloidal rotation of “hot” and “cold” plasma spots. Rather similar amplitude of the perturbation in central channel #11 and in other channels indicates that it is not a plasma profile vertical shifts. (In case of the shifts the perturbation amplitude in the central channel should be substantially higher than the perturbation in the outer channals). Similar SXR profile behavior can be caused by magnetic islands rotation in tokamaks [1, 2]. The fluctuations are localized between channels #6 and #15. This area is located in a central plasma region (ρ<0.5), deeper than the four islands chain [10]. An example of simultaneous appearing two cold spots is shown in Fig. 9.

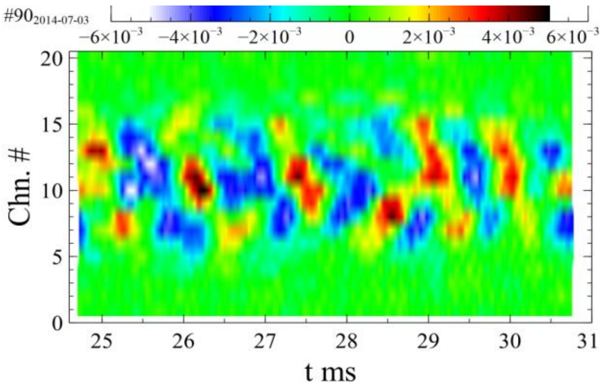

Fig. 9. Profile of a fluctuating part of the SXR data

It look like two perturbations are simultaneously rotating in approximately the same plasma region as in the previous discharge. Due to influence of the complex topology of the magnetic surfaces it can be a case of two hot/cold plasma spots as well as a case of the four rotating plasma spots [1, 2]. The fluctuations under consideration appear in the THT antenna discharges with low enough U-3M plasma heating power. In discharges with higher RF heating power the SXR fluctuations of different type are observed. The same frequency range, but same phase of the SXR perturbations in the whole SXR emission profile is characterizing this type of the fluctuations. We should note that in most of the U-3M THT antenna discharges with high enough plasma temperature and medium for U-3M plasma density $(3…5)\cdot10^{12}$cm^{-3} no SXR fluctuations are observed.

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ПЕРВЫЕ РЕЗУЛЬТАТЫ МНОГОКАНАЛЬНОГО ДЕТЕКТОРА МЯГКОГО РЕНТГЕНА НА ТОРСАТРОНЕ У-3М

М.Б. Древаль

Миниатюрный датчик для измерения временного поведения и пространственного распределения излучения мягкого рентгена был недавно установлен на торсатроне У-3М. Диагностика протестирована в различных видах разряда У-3М. В низкоплотных разрядах рамочной антенны с так называемым переходом в Н-подобную моду обнаружена быстрая модификация профиля излучения мягкого рентгена. Сдвижка фазы возмущения излучения мягкого рентгена, вызванная переходом, а также различные формы возмущения наблюдались на различных каналах. Переход может быть ассоциирован с МГД-неустойчивостью. Различные формы профиля излучения мягкого рентгена наблюдались в различных условиях разряда. Многоканальный датчик мягкого рентгена – это превосходный инструмент для изучения различных типов МГД-активности. Различные типы низкочастотной МГД-активности наблюдались на торсатроне У-3М. Недавно установленная рентгеновская диагностика открывает возможность детального изучения МГД-активности вместе с вызывающей её причиной – градиентом давления плазмы. Представлены последние экспериментальные результаты, полученные с использованием диагностики мягкого рентгена, без глубокого анализа этих экспериментов.

ПЕРШІ РЕЗУЛЬТАТИ БАГАТОКАНАЛЬНОГО ДЕТЕКТОРА М'ЯКОГО РЕНТГЕНУ НА ТОРСАТРОНІ У-3М

М.Б. Древаль

Мініатюрний датчик для вимірювання тимчасового поводження й просторового розподілу випромінювання м'якого рентгену був недавно встановлений на торсатроні У-3М. Діагностика протестована в різних видах розряду У-3М. У низькощільних розрядах рамкової антени з так званим переходом у Н-подібну моду виявлена швидка модифікація профілю випромінювання м'якого рентгену. Зрушення фази збурення випромінювання м'якого рентгену, що викликана переходом, а також різні форми збурення спостерігалися на різних каналах. Перехід може бути асоційований з МГД-нестійкістю. Різні форми профілю випромінювання м'якого рентгену спостерігалися в різних умовах розряду. Багатоканальний датчик м'якого рентгену – це чудовий інструмент для вивчення різних типів МГД-активності. Різні типи низькочастотної МГД-активності спостерігалися на торсатроні У-3М. Недавно встановлена рентгенівська діагностика відкриває можливість детального вивчення МГД-активності разом з причиною, яка її викликає – градієнтом тиску плазми. Представлені останні експериментальні результати, отримані з використанням діагностики м'якого рентгену, без глибокого аналізу цих експериментів.