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HXR measurement on GOLEM tokamak – dependence on pressure II

Date: 11.4.2013
Shots: 11799-11822

Goal: The goal of this measurement was to further investigate how HXR count depends on pressure.

Description

Similar measurement was already conducted, however its results were quite puzzling, because the HXR count was highly influenced by strange tokamak behaviour (see report for details). Our goal now was to try to avoid the strange phenomenon observed at the time, so that the results are more reliable. There was a glow discharge before shot 11802 (i.e. before the actual measurement commenced). A proposal was made that the discharge could prevent the issue from occuring, and it was also needed to check whether anything else changes. The settings of the tokamak parameters were not changed during the session (apart from pressure) and are noted below.

Preionisation ON C_{BT}=1000 V triggered at 5.0 ms C_{CD}=500 V triggered at 8.0 ms C_{BD} and C_{ST} were not charged.

The experimental setup was similar as it was it the previous measurement. An HXR scintillator detector was placed in proximity of the tokamak. The measured data were processed the same way as before, the same MATLAB script was used to count number of peaks in the signal.

Measured data

Shot #	p [mPa]	HXR [-]	Shot #	p [mPa]	HXR [-]
11801	10,08	631	11812	20,04	473
11802	10,12	903	11813	21,97	392
11803	8,58	930	11814	24	443
11804	6,46	895	11815	25,62	137
11805	4,68	839	11816	28,2	91
11806	3,2	26	11817	29,64	75
11807	7,33	804	11818	34,83	63
11808	11,35	778	11819	39,38	42
11809	14,13	592	11820	44,52	23
11810	15,98	620	11821	11,84	633
11811	18	637			

Figure 1:

Tab. 1 lists all relevant shots performed during the session. First shot (11801) was made just before the glow discharge. The HXR count dependence on pressure is plotted in Fig. 1.

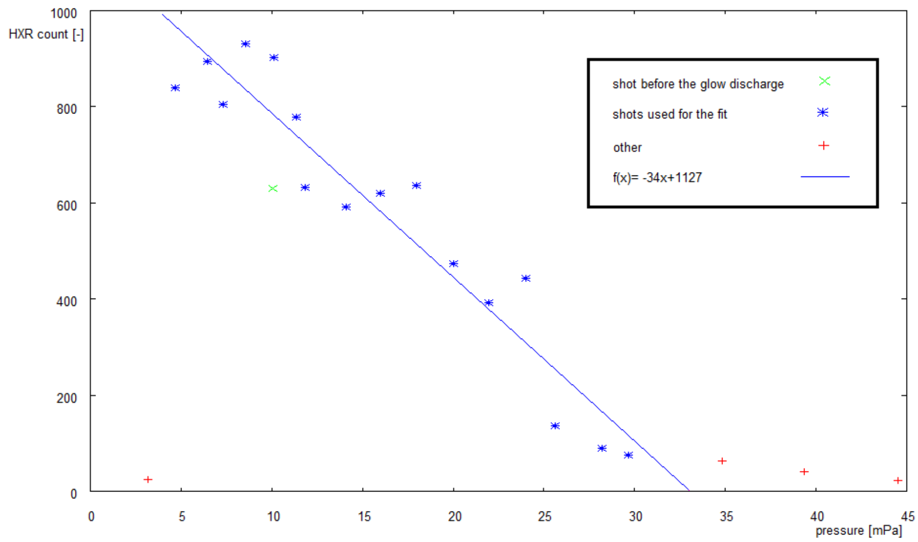

Figure 2: Fig. 1: HXR dependence on pressure

There are several things that should be noted. Firstly, the sudden drop in loop voltage that was troubling during the previous measurement was not observed. It is possible that the glow discharge performed before the measurement contributed to this. Secondly, plasma was achieved for much higher pressures than usually. The plasma was observed even for pressure above 40 mPa, which is something that does not happen very often. The glow discharge can again be the reason. The data now clearly show the trend, and there is no need to do any alternations to see it. Except for very low and very high pressures, the HXR count shows approximately linear decrease with pressure, which is exactly what was expected.

Conclusion

Due to the fact that the phenomenon observed during previous measurement was avoided, this measurement was more successful and the results more conclusive. The HXR count decreases linearly with pressure, as predicted by theory. The rate at which the runaway electrons are slowed is proportional to density, which is proportional to pressure. The linear behaviour apparently fades for high pressures, where the decrease is slower. However, it should be noted that pressures as high as observed in this session are not seen very often, usually plasma does not appear at all. The fact that it appeared this time may be attributed to the fact that there was a glow discharge prior to the measurement. Even at these pressures, some runaways are produced.

The presence of the glow discharge prior to the session clearly puts the tokamak in some sort of unusual state, although it is unclear what exactly happens (there is likely less impurities on the walls, but other effects may arise). This state appears to prevent the sudden drop in U_{loop} that was observed previously. It may also enable the plasma to exist for higher pressures than without the discharge. These statements however may not be true – more research would have to be done in order to test whether the glow discharge really has the above mentioned effects.

HXR measurement on the GOLEM tokamak – Spatial distribution of HXR radiation.

Date: 20.6.2013
Shots: 12611-12629

Goal: The mail goal of the measurement was to examine the spatial distribution of HXR emission, namely to scan the dependence of HXR emission on the vertical position of the detector.

Description

The measurement required that significant amount of HXR photons is present. With respect to this requirement, the machine parameters were set as follows (see shot 12611 to see the settings):
Preionisation ON
C_{BT}=600 V triggered at 5.0 ms
C_{CD}=500 V triggered at 5.5 ms

C_{BD} and C_{ST} were not charged.
Requested pressure p=12 mPa

These parameters were kept constant during the whole session, and the vertical position of the detector was changed. Glow discharge was performed in the tokamak after shot 12622.

Experimental setup

HXR radiation was directly measured by a NaI crystal scintillator detector mounted on the tokamak in a way that allowed shifting in the vertical direction. The analog signal was collected and digitized by the NIturbo data acquisition system. By plotting the raw signal in time, Fig. 1, stand-alone peaks can be observed, each corresponding to an incident photon. A simple MATLAB script was written to identify and therefore count the number of peaks in each shot. This script was used to post-process all shots within the session.

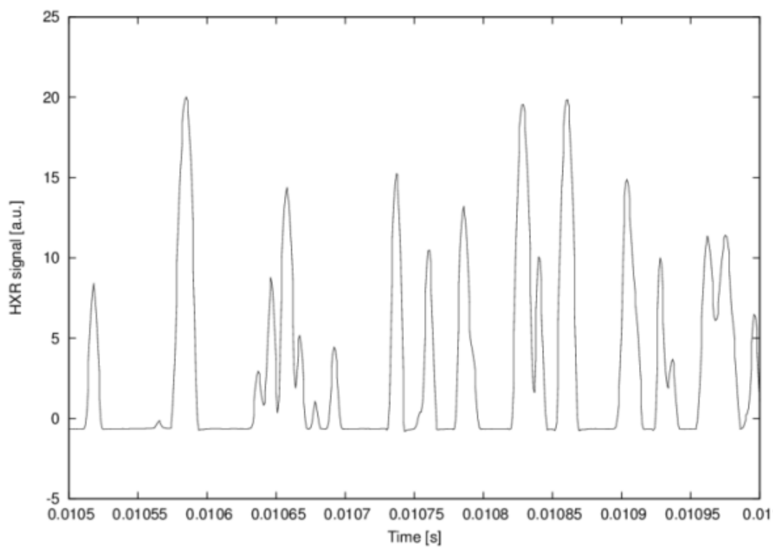

Figure 3: Fig. 1: An example of raw HXR signal from the detector plotted against time.

Measured data

Tab. 1 lists all shots performed during the session with available HXR data. HXR data from shots 12613 to 12616 were unavailable due to technical problems with the DAS.

#	d (cm)	HXR photons (-)	#	d (cm)	HXR photons (-)
12611	0	223	12623	98	59
12612	7	246	12624	0	69
12617	24	233	12625	40	90
12618	18	246	12626	75	53
12619	8	245	12627	0	40
12620	35	235	12628	98	54
12621	43	224	12629	98	61
12622	101	229			

Figure 4:

Tab. 2: All shots with available HXR data. The quantity d denotes the vertical distance of the detector from the horizontal plane defined by the torus.

It is very important to note that between shots 12622 and 12623, glow discharge was performed in the tokamak, decreasing the number of detected photons from several hundreds to several dozens. Pre and post glow discharge shots thus have to be treated as distinct batches.

It is qualitatively expected that the number of incident photons would fall with increasing vertical distance. Runaway electrons orbit the chamber and gain more energy until the centrifugal force increases their orbit enough to make them collide with the wall. They should therefore strike in the horizontal plane and their velocity should not have vertical component. The bremsstrahlung produced should have about the same direction as the electron that caused it.

In reality, the number of detected photons does not seem to change significantly with the vertical distance, at least not for the range that has been scanned (0-98 cm). Although the count shows small decrease, it is not significant considering the random variance of the points. One also has to realize that increasing the vertical distance also increases the total distance from the source, and even if the radiation is isotropic, the number of detected photons will slowly decrease due to geometry (the correction was not done).

The measured data from batches 1 (pre glow discharge) and 2 (post glow discharge) and their linear fits are visible in Fig. 2.

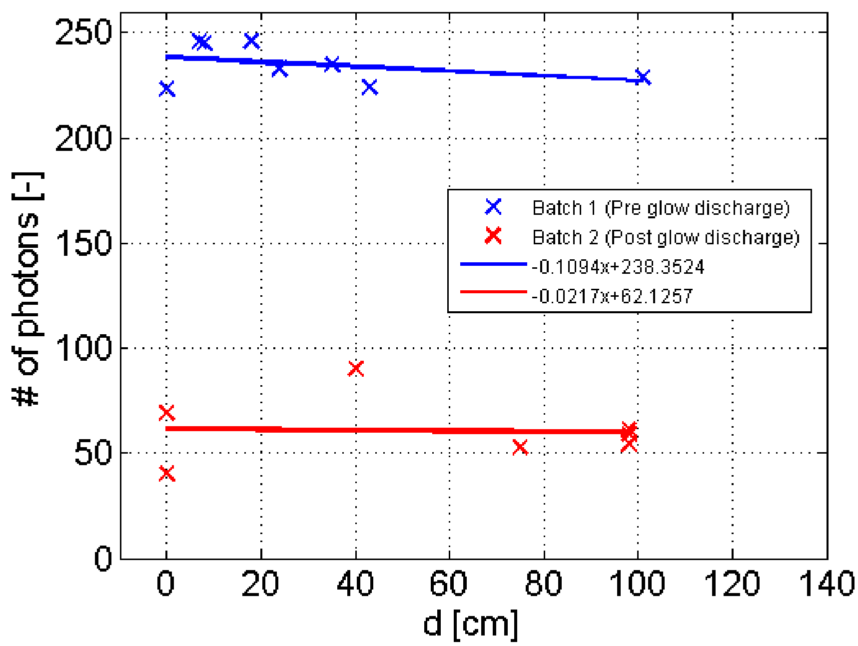

Figure 5: Fig. 2: Dependence of the number of detected photons on the vertical position of the detector.

Conclusion

HXR emission does not seem to depend (or the dependence is very hard to notice) on the vertical position of the detector. A few reasons for this behaviour can be suggested: - The HXR radiaton does not follow the direction of the runaways, but instead it is significantly scattered when passing through the chamber wall. The information about the direction of the runaways is therefore mostly lost after the radiation exits the tokamak.

- The runaways themselves are scattered and rapidly change direction while producing the radiation .

- The range on which the dependence was measured (0-98 cm) was too narrow. The scope was restricted by the hardware used to mount the detector on the tokamak. It was expected that the decrease will be much faster, hence the range had been considered sufficient when the measurement was prepared. Measuring further is possible, but it requires to carefully consider geometry of the situation.
- The number of shots was too low. If the dependence is light, it can be obscured by random variance of each shot. If more shots were performed, the dependence may become visible.

Apart from this inconclusive measurement of spacial distribution an interesting observation was made. By performing glow discharge in the tokamak, and thus lowering the level of impurities, HXR emission is significantly supressed. It could be illuminating to try measuring the dependence of HXR emission on Z_eff. Mitigation of damage to the first wall caused by runaway electrons is a principal issue for the ITER design.