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Large periodic fluctuations of plasma signals in EXTRAP T2R

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Large periodic fluctuations in the main global plasma parameters and in spectroscopic signals emitted from the whole plasma, both centre and edge, are studied in the EXTRAP T2R reversed field pinch (RFP) device.

Analysis of transient events in a plasma and relationships between different parameters is important for understanding plasma conditions, confinement, stability, zonal flow and turbulence (recently reviewed in [1]). Various oscillatory behaviours have been observed in recent studies of RFP plasmas [2-4] and have been ascribed to, for example, electrostatic fluctuations caused by turbulence intermittency and spatial structure in the Reynolds stress. Although generally these observations have shown oscillations with short periodicity, sawtooth oscillations with a period 2-5ms have been observed on MST [4]. Coherent oscillations of some parameters were observed in the previous EXTRAP T2 carbon walled machine with a periodicity of less than 1ms [5].

The periodic fluctuations described herein are for the first time studied in the all metal EXTRAP T2R device operating with a resistive wall mode (RWM) active feedback control system, which results in a prolongation of the plasma discharge, up to more than ten wall times [6].

Clearly visible large fluctuations with a periodic pattern are evident in many of the main plasma signals. These include the plasma current, average toroidal flux $\langle B_t \rangle$, theta ($\Theta = B_{pol}(a)/\langle B_{tor} \rangle$), loop voltage, resistance, multiple-chord soft x-ray emission (SXR), neutral molybdenum spectral line emission (MoI) and in the total radiated power in the VUV wavelength range (10 to 110 nm). The fluctuations are mostly seen in long discharges, i.e. with feedback control. The period of the fluctuations is fairly stable within a specific discharge and is typically between 2 and 5 ms. Fig. 1 shows the time evolution of several parameters during a typical discharge.

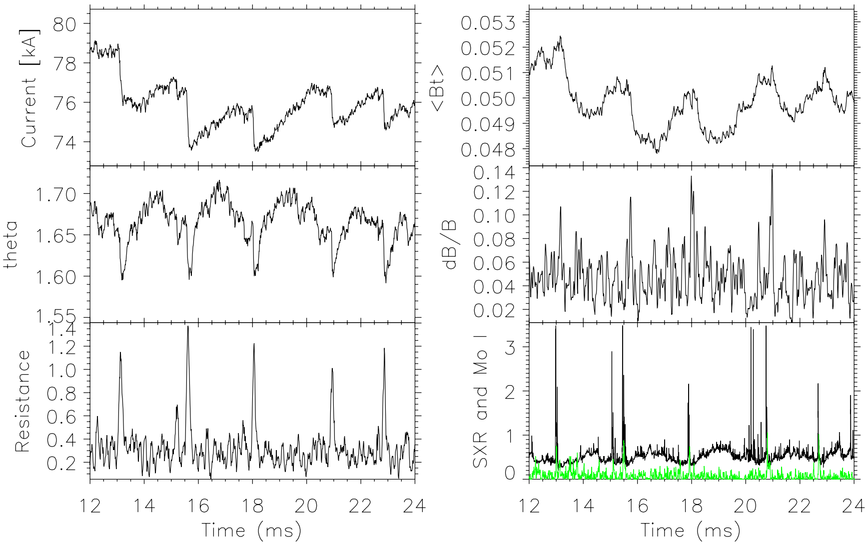

Fig. 1: Fluctuations in a typical discharge where <B_t> is the average toroidal flux, dB/B is the total magnetic fluctuation level and in the last panel the SXR is in black and the MoI in green.

A fluctuation cycle begins with a steady, linear increase in the plasma current and at the same time the average toroidal flux increases. After a few ms there is a very rapid event in the soft x-ray emission, an almost instant and strong increase in signal followed by an equally fast drop. Shortly afterwards, the emission from neutral molybdenum increases and slightly after this the resistance goes up and the current, theta and average toroidal flux drop rapidly. This is more clearly seen in Fig. 2 which shows an enlargement of the crash at 18ms.

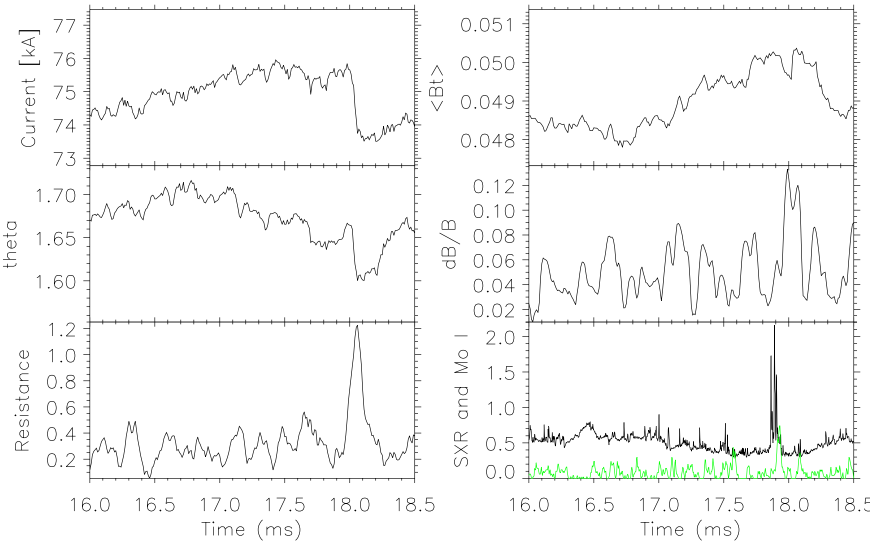

Fig. 2: A closer look at the crash at 18ms in Fig. 1 showing the same global parameters.

Strong line emission from higher ionization stages of molybdenum, emitted from more central parts of the plasma, appears in the VUV spectra during the time of the increase in plasma resistance (and drop in current). Fig. 3 shows four spectra between 10 and 60 nm measured between 17.7 and 18.4ms (each spectrum is recorded for 0.256ms). The green spectrum, recorded between 18.0 and 18.3ms, i.e. during the time of increased resistivity, shows a strong increase in spectral line emission at 34.1nm from MoXIII.

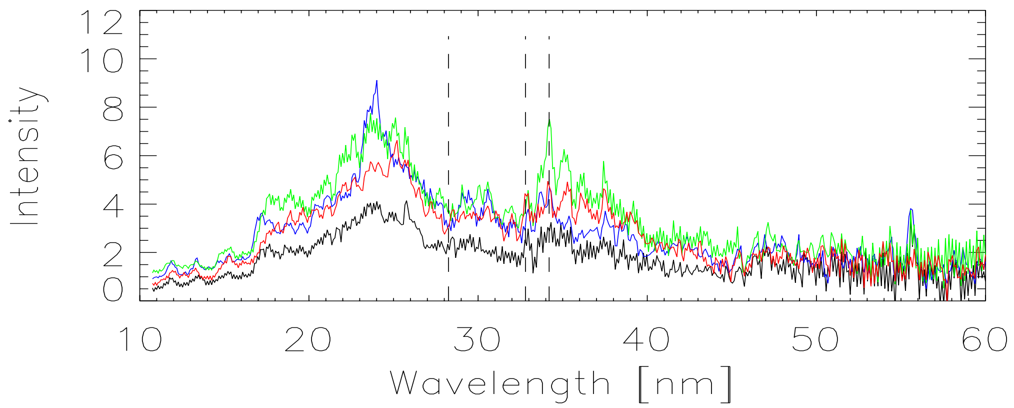

Fig 3: Time evolution of the VUV spectra from 10 to 60nm during the same crash event as in Fig. 2. The spectra are taken at 17.7ms (black), 17.9ms (blue), 18.2ms (green) and 18.4ms (red). Dashed lines show FeXV at 28.4nm, CrXIII at 32.8nm and MoXIII at 34.1nm.

The large fluctuations are also clearly seen in the total radiated power in the VUV which is very well correlated with the signal from neutral molybdenum.

The order of events suggests that after a period of improved conditions (increase in plasma current), there is some sort of crash (fast soft x-ray event) that causes increased influx from the wall which leads to increased resistivity and a drop in plasma current and the appearance of high ionisation stage impurities. The behaviour is almost reversed to that of a sawtooth crash or discrete dynamo event where there is a burst of average toroidal flux and slow decay until the next event [4,5].

Analysis of several discharges over a range of plasma operations have shown that: the step in loop voltage (ΔV_{loop}) at the crash increases with increasing pre- and post-crash Θ (Fig. 4a); there is a weak negative correlation between pre-and post-

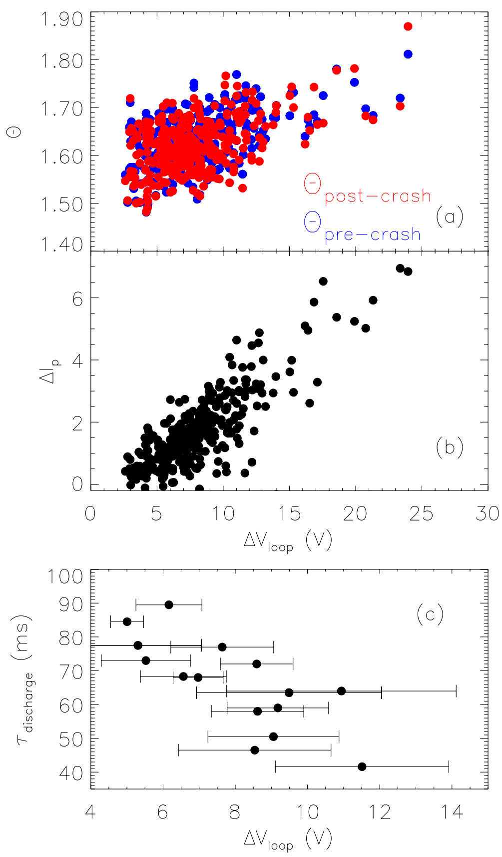

Fig. 4: Relationship between the step in loop voltage at the crash (ΔV_{loop}) and (a) pre- and post-crash Θ; (b) drop in I_p; and (c) length of discharge.

crash F and ΔV_{loop} at the crash; there is a larger drop in I_p at the crash for a large ΔV_{loop} (Fig. 4b); for longer plasma discharges ΔV_{loop} is smaller (Fig. 4c); and the crash in the soft x-ray signal is stronger with larger ΔV_{loop}. In many RFPs discrete events are more common at high theta [7] and these events are generally associated with larger MHD activity.

The ten-channel soft x-ray camera shows that the emission extends over the full radius but during the crash is concentrated towards the edges of the plasma with peaks at r/a ~0.5 symmetric around the centre (Fig. 5).

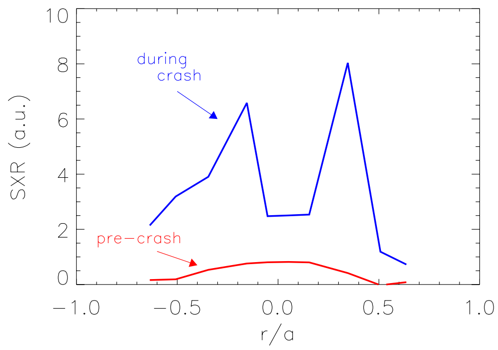

Fig. 5: Change in the radial profile of the SXR emission during a crash.

It is interesting to note that in some cycles there is a delay in the initial increase in the average toroidal flux when the plasma current first increases. In these cases there is, at the same time, a steady significant increase in the soft x-ray emission.

In conclusion, we have clear and periodic fluctuations in many of the main signals. It appears that prior to the crash (or afterwards) the plasma enters a phase of improved confinement which is ended by a fast, transient event in the soft x-ray, followed by increased impurity influx.

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