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Overview of global MHD behaviour in the RFX-mod Reversed Field Pinch

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Introduction The RFX Reversed Field Pinch device has recently undergone important modifications of its magnetic boundary [1], the more relevant for the present work being the substitution of the thick shell surrounding the vacuum chamber (450 ms Bv penetration time, to be compared to a 100-150 ms typical duration of a plasma discharge) with a thinner and more resistive one (50 ms Bv penetration time). As in other toroidal confinement devices, the behaviour of global MHD instabilities is deeply influenced by magnetic boundary characteristics and by the related mean equilibrium current and field profiles. The main purpose of this paper is to give an overview of the global MHD instabilities found during the first months of operation of RFX-mod, highlighting differences and similarities with respect to the machine in the previous configuration.

Experimental setup In order to evaluate the impact of the changes on MHD instabilities, the magnetic diagnostic system for the study of the static and fluctuating spectrum of magnetic fields was greatly improved [2]: 4 toroidal arrays of 48 coils measuring the 3 components of **B** are placed between the vessel and the new shell giving a detailed description of low frequency (0-5 kHz, up to 10 kHz sampling frequency) fluctuations for modes with toroidal and poloidal mode numbers n=0-24 and m=0-2 respectively. Toroidal and poloidal components of the magnetic field are measured by local pick-up coils, while the radial field is measured by saddle coils that extend 7.5° in toroidal direction and 90° in the poloidal one covering in this way the whole RFX-mod external surface. A further new set of magnetic pick up coils was installed inside the vacuum vessel as part of the Integrated System of Internal Sensors (ISIS, [3]). It is mainly composed by 2 toroidal arrays of 48 Bt coils equally spaced in the toroidal direction and allows for the first time in RFX the characterisation of the fast behaviour (>5 kHz) of global MHD instabilities as well as the study of local turbulent structures [4]. The acquisition of these magnetic measurements is not at present in its final configuration. Up to now approximately 30 channels have been acquired at a sampling rate of 2 MHz measuring fluctuations with a typical bandwidth of 200-400 kHz.

Slow fluctuations (0<f<5 kHz) The slow part of the magnetic fluctuation spectrum is dominated, as in the past, by the locking in phase and to the wall of the tearing modes, responsible, through the dynamo mechanism, for the sustainment of the RFP configuration. The amplitude of these fluctuations is comparable to what found in the past and can be as large as few % of the main equilibrium field and cause a local increase in the plasma-wall interaction. Operations with induced rotation of these modes using a technique tested in the past (see [5]) have already been successfully performed. No indications of spontaneous rotations of the whole mode structure have been found so far, but discharge optimisation is still in progress together with the commissioning of the new set of active coils [1] that will be in operation in the second half of 2005.

The dynamo modes are mainly m=1, with toroidal mode number n ranging from -7 to -15÷-20. Interestingly, shots with a wide spectrum made by many modes of similar amplitude (multiple helicity, or MH), and shots with a narrower spectrum where only few modes are evident (Quasi Single Helicity, or QSH) where both found during the first operations of RFX-mod. In Fig. 1 a MH and a QSH spectrum are shown from two 600 kA discharges. More information on QSH spectra and on their relations to the confinement properties in RFX-mod can be found in [6].

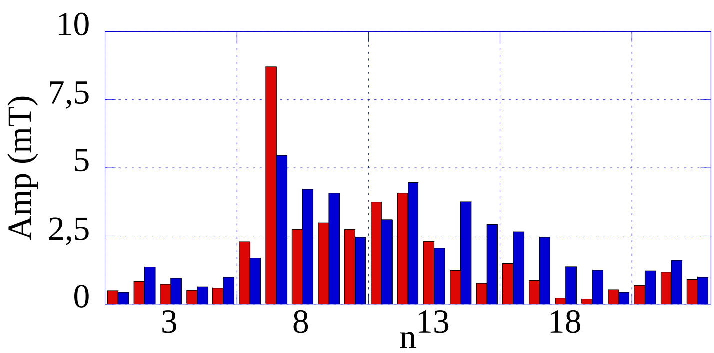

Fig. 1: Odd modes toroidal field spectra for two 600 kA RFX-mod discharges at 60 ms (#16170, red, QSH and #16637, blu, MH).

Of great interest is the presence of other instabilities related to a penetration time of the new shell shorter than the discharge duration (Resistive Wall Modes, RWM). These modes are indeed seen in the longest pulses (more than 130 ms duration reached up to now) as exponentially growing after 1.5-2 shell penetration times. Depending on the equilibrium configuration of the discharge, normally parameterised by the F parameter for RFPs, where F=Bt(a)/<Bt>, modes with different toroidal mode number *n* can appear as RWM, in good qualitative agreement with numerical simulations [7]. An example is shown in Fig. 2. A detailed description of the whole eigenfunction of these MHD instabilities can be obtained by using the measurement of toroidal and radial field components and solving the stability Newcomb equation with appropriate boundary conditions as shown in [8].

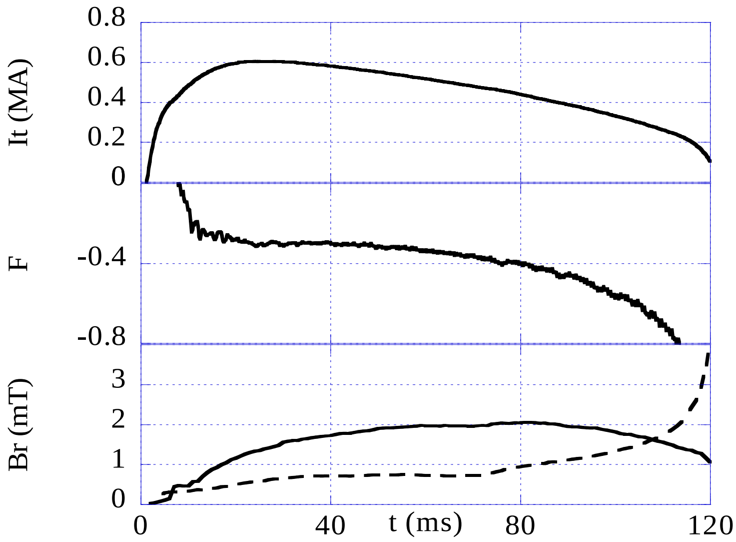

Fig. 2: n=-8 (continuous line), and n=+4 (broken line) time evolution for a deep F discharge as seen by external Br measurements (#16165).

Fast fluctuations (f>5 kHz): Fast fluctuations can be extensively studied for the first time in RFX-mod by the magnetic coils part of ISIS, [4]. Of course only a part of the measured fluctuation spectrum can be related to global MHD modes, i.e. mainly to the tearing dynamo modes. A more comprehensive study of fast magnetic fluctuations in RFX-mod can be found in [9].

Regarding fast fluctuations related to global MHD events, it is interesting to note that even in the presence of a global mode structure locked to the wall, as described previously, fluctuations rotating with velocities typical of the fluid velocities of the bulk plasma and with the same *m* and *n* numbers of the main tearing modes can be clearly seen. In fig. 3 such a case is shown. The two plots on the first row show a S(k,f) analysis of even and odd modes respectively; of particular interest for this work are the two peaks at frequencies below 50 kHz. A low-pass filtering of the signals (fig. 3,

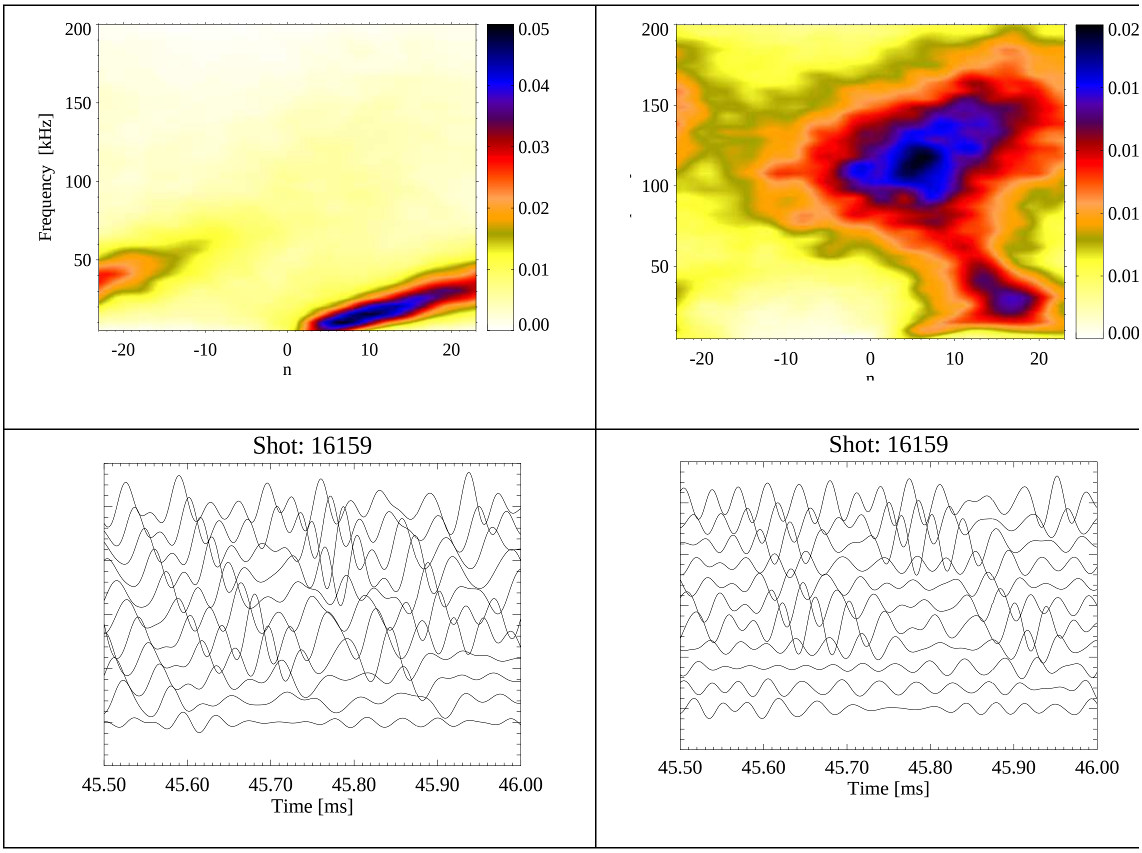

Fig. 3: S(n,f) for even and odd m modes (from left, top row) and low-passed signals for frequencies lower than 50 kHz (the toroidal distance between two consecutive lines is 7.5°).

bottom row) reveals the propagation of both even and odd structures at frequencies of approximately 20-30 kHz.

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