*32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-2.003 (2005)*

Impurity behaviour and radiation pattern in the RFX- mod reversed field pinch

L. Carraro, E. Gazza, L. Marrelli, P. Martin, M.E. Puiatti, P. Scarin, M. Valisa, P.Zaccaria,B. Zaniol and the RFX team
Consorzio RFX, Associazione Euratom-ENEA sulla fusione
Corso Stati Uniti 4, 35127 Padova, Italy

Introduction

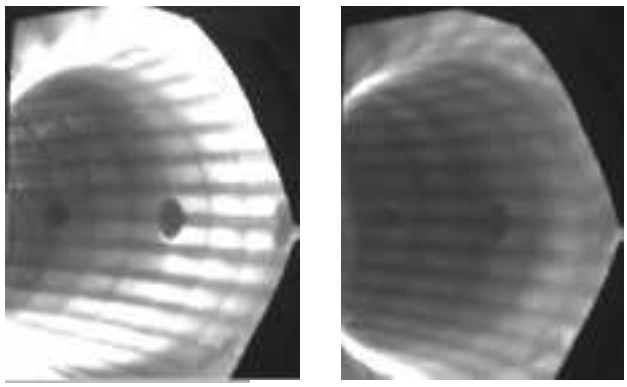
RFX-mod is the largest reversed field pinch operating nowadays, with 2 m in major radius, 0.459 m in minor radius and an installed power dimensioned to drive up to 2 MA of plasma current. In the long shutdown period completed at the end of 2004, several new features have been introduced. Above all, a closer resistive shell with external saddle coils has been installed to harness the rich spectrum of MHD modes. This paper describes the behaviour of the impurities in discharges with plasma current of about 600 kA, in terms of influxes from the wall, radiated power and effective charge; first results on the impurity toroidal velocity are also presented.

In the former machine configuration, impurities did not represent a major problem. Despite the strong plasma wall interactions the effective charge was kept at reasonable levels (i.e. below 2), especially at high density. In this respect first observations on the restarted machine confirm the trend. In fact, the measured effective charge towards the plasma density is comparable or slightly lower than what found in the former machine.

The effect on the influxes and on the emitted radiation of the strong poloidal and toroidal asymmetries associated with the plasma horizontal shift and with the wall-mode locking have been investigated.

Results and discussion

The TV camera pictures of the inner wall in 600kA discharges show strong plasma wall interactions (PWI) in the region where the phase locked MHD modes form a local deformation in the plasma column (see Fig.1a). Instead, far from the mode-locking position, the PWI is relatively smooth, without sparkling points, and with a wetted area smaller than in the past, due to the new tiles shape (Fig.1b). The emission spectra are very similar to the past ones, C and O remain the main impurities, He lines can be very bright after the glow discharge cleaning.



a) b)

Fig.1 a) TV camera pictures of the inner wall in 600kA in the region of locking .b)TV camera pictures far from the locking position.

Influx of C, H and O are measured routinely on a poloidal section along different chords [1]. The results of measurements towards the plasma density

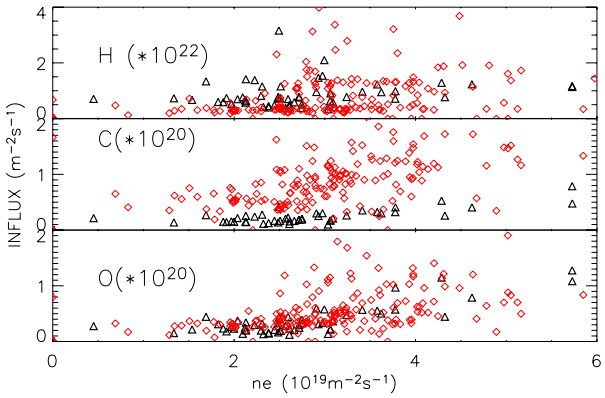


Fig.2 From the top: hydrogen, carbon and oxygen influxes towards plasma density in 600 KA discharges for RFX-mod (black triangles) and for RFX (red rhombs). Influxes are measured on an external chord.

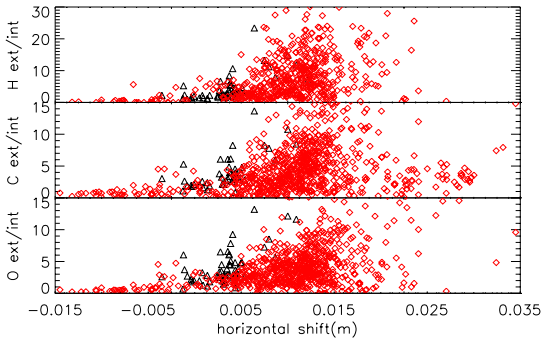


Fig.3 Influx poloidal asymmetry versus plasma horizontal shift, for RFX-mod (black triangles) and for RFX (red rhombs).

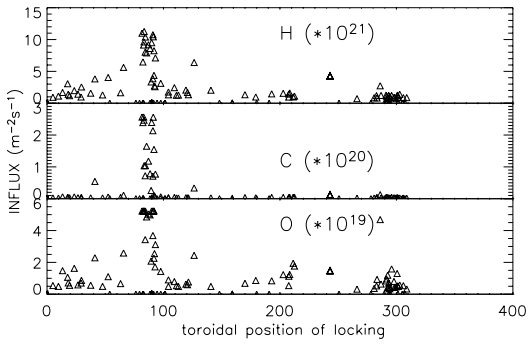


Fig. 4 Hydrogen , carbon and oxygen influxes on a vertical chord, close to the diameter , towards the toroidal position of the locking. For carbon the averaged influx far form the locking is about 3.e18 m^{-2} s^{-1}

are shown in Fig.2. The hydrogen influx seems to be independent on density at low and medium density, while for higher densities an increasing behavior is found. A slightly increasing behavior with density is found for C and O influxes; also for them a steeper increasing behavior is observed at higher densities. At given densities and current the hydrogen and oxygen influxes are comparable with those measured on the former machine, while carbon influxes are now smaller than in the past. Due to the ameliorated plasma equilibrium that can now be feedback controlled, the plasma horizontal shift is typically maintained around 0.5 cm throughout the pulse avoiding the most pronounced in-out influx asymmetry found for the highest shifts (Fig 3). Such improvement as well as the new shape of the carbon tiles may explain the decreased carbon influx.

Carbon and oxygen influxes are linearly dependent, confirming what found for the former machine [2]; obviously the linear coefficient is different from the past one, due to the decreased carbon influx.

The MHD modes, lock at the wall preferentially near the 2 poloidal gaps [3] on the RFX-mod mechanical structure; the influx diagnostic station is close to one of the 2 gaps and the measured influxes increase by one or more than one order of magnitude when the mode locking is in front of the diagnostic (Fig 4).

The total radiated power typically is less than 10% of the Ohmic power, and its behaviour towards I/N is very similar to that derived in the old RFX (Fig.5). This is consistent with the presented influx behaviour, taking into account that the more

efficient radiating impurity (which in our case is O) does not vary with respect to the past and that the electron temperature is a little bit lower [4]. Also the measured effective charge towards the plasma density (see Fig.6) is comparable or slightly lower than what found for the former machine.

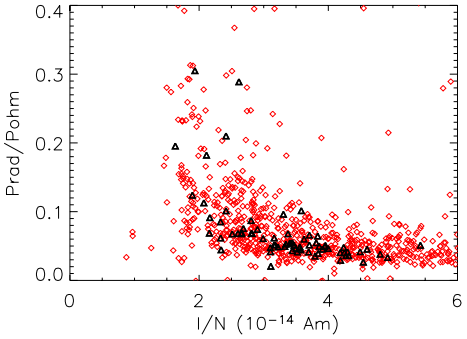


Fig.5 Total radiated power fraction versus I/N for 600KA RFX-mod (black triangles) and RFX discharges (red rhombs).

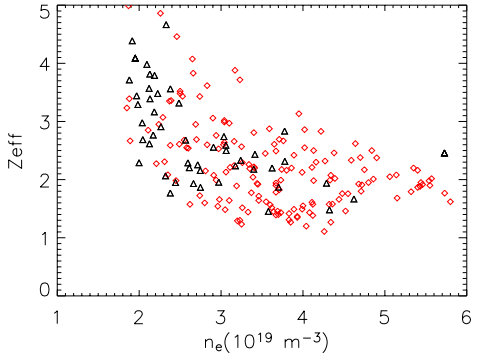


Fig.6 Effective charge measured from visible bremsstrahlung versus electron density for 600KA RFX-mod (black triangles) and RFX (red rhombs) discharges.

The emitted power radial profile shows asymmetries due to the local horizontal shift, qualitatively very similar to the RFX situation before the shell changes [5]. Fig. 7 shows the emitted power radial profile and the behaviour of the emitted power integrated over the external and the internal area of a poloidal section, towards the measured global horizontal shift. Unfortunately it is not possible to investigate quantitatively the toroidal emission asymmetry; when the locking is in front of the bolometer diagnostic the signals saturate.

The toroidal velocity of CV and CIII are non zero also when the modes are fully locked at the wall. To toroidally rotate the modes frozen on the wall an externally induced magnetic torque is applied [6]; the perturbation itself affects the measured velocity, about independently on the behaviour of the mode locking. When the perturbation is in front of the measurement station, the CIII velocity changes its sign (see Fig.8); in the past experiment the changes in the edge flow velocity had been consistently related to a change of the radial electric field, independently measured also by the Langmuir probes [7,8].

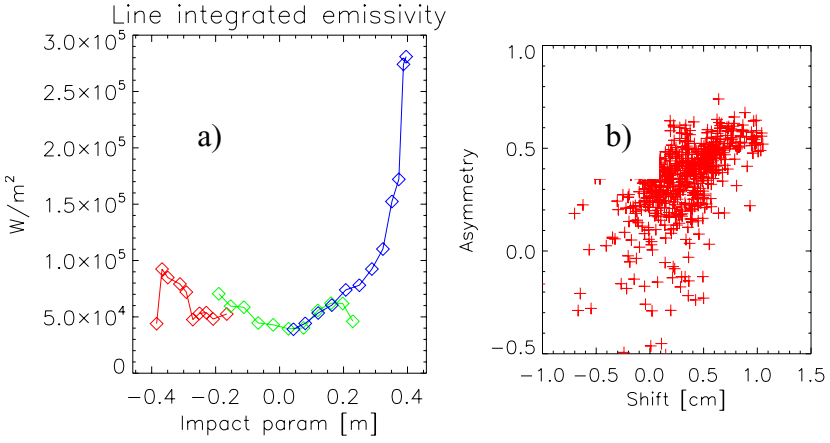


Fig.7 a) Emitted power radial profile. b) Emitted power integrated on external and internal region towards the plasma horizontal shift.

The effect of the induced magnetic perturbation on the CIII flow velocity measured at the edge of the plasma is also confirmed by the Gas Puffing Imaging diagnostic [9], which measures the toroidal propagation of density fluctuations [10].

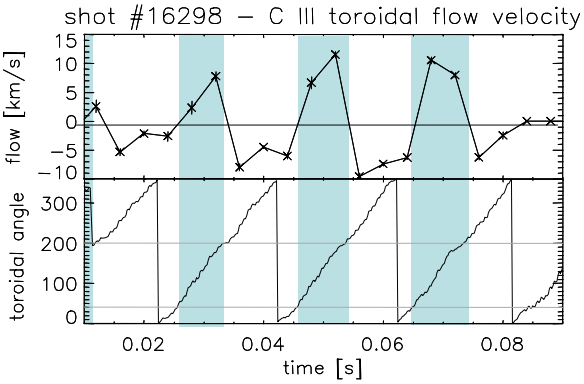


Fig.8 Measured CIII toroidal velocity and toroidal position of the maximum of the external m=0 applied perturbation as functions of time. The green rectangles represent the time intervals during which the maximum of the perturbation is 'seen' by the diagnostic.

Conclusions

The first results on the impurity influxes and emitted radiation in RFX-mod at 600 kA have been presented. The new shape of the carbon tiles and the improved axial equilibrium control limit the carbon influx with respect to the past, while the same hydrogen and oxygen influxes have been found. Concerning oxygen it has to be noted that now the wall cleaning baking procedure is at lower temperature (180 °C) than in the past (300 °C).

The behaviours of the emitted power towards I/N and of the plasma effective charge towards the density are in line with the past. The presence of wall locked modes implies strong asymmetry on the influxes and on the emitted power. The use in RFX-mod of the available active coil system to contrast the plasma MHD activity [3] will hopefully mitigate the toroidal asymmetries of particle influxes and radiation. The poloidal asymmetry of the influxes is smaller that in the past, consistently with the ameliorated equilibrium control, the radial profile of the emitted power in-out asymmetry does not show strong difference with the past, anyway a tomographic reconstruction (at the moment not yet available) has to be looked for to clarify the situation. The impurity toroidal velocity at the edge changes its sign when an external perturbation is active, in the former RFX this was related with a change of the radial electric field, measured with the Langmuir probes.

Acknowledgements

This work was supported by the European Communities under the contract of Association between EURATOM/ENEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] L.Carraro et al. Rev. Sci. Instrum. 66(1995) 610
[2] L.Carraro et al Journal of Nuclear Material 220-222 (1995) p.646
[3]S.Martini et al. This conference P5.054
[4]L.Marrelli et al This conference P5.053
[5]L.Marrelli et a.l 24th EPS Conference Berchtesgaden 1997 Vol 1 p.333
[6] R.Bartiromo et al. Phys. Rev. Letters 83 (1999) 1779
[7]L.Carraro et al. Plasma Phys. Controll. Fusion 40 (1998) p.102
[8]L.Carraro et al. Journal of Nucl.Mat.313-316 (2003) p.97
[9]R.Cavazzana et al. Rev.Sci.Instrum. 75(2004) 4152
[10]R.Cavazzana et al.P. This conference P1.073