CHARACTERIZATION OF THE RFX EDGE PLASMA

V.Antoni, M.Bagatin[b], H.Bergsåker[a], D.Desideri[b], E.Martines[b], G.Serianni[c], L.Tramontin[b]

Istituto Gas Ionizzati del CNR, EURATOM-ENEA-CNR Association, Italy
[a]Manne Siegbahn Institute of Physics, Sweden
[b]Dipartimento di Ingegneria Elettrica, Università di Padova, Italy
[c]Dipartimento di Fisica, Università di Padova, Italy

Introduction The edge region of the Reversed Field Pinch (RFP) experiment RFX ($R = 2$ m, $a = 0.457$ m at the inner wall) /1/ has been investigated by an array of 6 Langmuir probes and 6 heat sensors mounted on a graphite limiter. The limiter is mushroom shaped and the probes are flush with the limiter surface. Each probe consists of a 3 mm diameter cylindrical graphite tip insulated by a machinable ceramic mount /2/. In this campaign two Langmuir probes, 4 mm beyond the tip of the limiter, have been operated in single probe configuration ($50 \div 200$ Hz, ± 150 V sinusoidal voltage sweep) and the other 4 were floating. The limiter has been protruded into the plasma up to 4 mm without any significant change in main plasma parameters. At the deepest insertion the surface temperature of the graphite rose up to 2000 degrees, with an incident energy flux of the order of 100 MW/m^2 as derived by the energy sensors 1 mm beyond the tip of the limiter. Taking into account the surface exposed to the plasma, the power collected by the limiter results <<1% of the input ohmic power during the current flat-top. Typical waveforms of the plasma current and line averaged density compared with the limiter floating potential are shown in fig.1.

Measurements The data refer to a range of toroidal current I and line averaged electron density n_e of $500 < I < 700$ kA and $2.5 < n_e < 5 \cdot 10^{19}$ m^{-3} respectively. As previously found in other RFP experiments /3/ the energy flux in the outer region of the plasma is strongly directional and exhibits a maximum when the collecting surface is exposed with the normal parallel to the magnetic field and oriented towards the electron drift side. In fig.2-a the asymmetry between energy sensors exposed to opposite directions is reported as a function of the angle α. The maximum is at $\alpha = -10°$, where the probes are aligned with the local magnetic field in the outer region, as derived by magnetic measurements. In fig.2-b the energy flux asymmetry is plotted as a function of X (where X is the difference between the inner wall radius and the location of the tip of the limiter) for a fixed $\alpha = -10°$. During the limiter insertion the temperature and ion saturation current have been monitored. The asymmetry shows an increase when the limiter enters into the plasma and its floating potential changes sign, as shown in fig.3-a.

The electron temperature on the ion drift side is $T_e \sim 10$ eV almost uniform, with a slight tendency to decrease at deeper insertions (fig.3-b). On the other hand the ion saturation current, which with uniform temperature is proportional to the electron density, exhibits an exponential decay with two different decay lengths inside the port hole pipe and into the plasma $\lambda = 15$ mm and $\lambda = 3$ mm respectively (fig.3-c). To derive the particle flux the collection surface has been assumed to be the geometrical surface of the probe, since the ion Larmor radius in the outer region is comparable to the radius of the tip. The parallel flux at $X \sim 0$ mm results $\Gamma_{//} \sim 10^{22}$ m^{-2} s^{-1}. Applying a particle balance equation in the Scrape Off Layer originated right inside the pipe, with the decay length inside the port hole pipe $\lambda \sim 15$ mm the perpendicular flux results comparable to $\Gamma_{//}$, in agreement with spectroscopic measurements of hydrogen influx /4/.

The ion saturation current has been measured at different angles and the results are shown in fig.4, where the ratio between the current collected by two probes in opposite directions and located at $X = -4$ mm is reported. An angular dependence is observed with a maximum at $\alpha \sim -60°$.

At fixed insertion $X = 0$ the electron density $n_e(a)$ and temperature $T_e(a)$ at the edge have different behaviour with the line averaged density n_e. Indeed $n_e(a)$ tends to increase more than linearly whereas $T_e(a)$ is almost constant, as shown in fig.5.

<u>Discussion</u> The angular dependence of the energy flux at the edge confirms that the energy transport in RFP is anisotropic and according to

the Kinetic Dynamo Theory (KDT) /5/ the asymmetry can be related to the presence of fast electrons at the edge. The power lost by these fast electrons is ~2/3 of the total power lost by transport, confirming that they are the main loss channel in RFP, as found in smaller experiment such as ETA BETA II /6/. These fast electrons can also account for the difference observed on the parameters between the ion and the electron drift side. Indeed on the electron drift side the current vs. voltage characteristic of the Langmuir probes changes sharply when the limiter enters the plasma. This behaviour can be explained as a distortion due to the current carried by fast electrons which in turn is affected by electron secondary emission processes. On the other hand the asymmetry between the ion saturation currents can be fitted by a simple model by which $I_s = 0.5 A n_e (c_s + v_{/\!/} \cos\alpha + v_{\perp} \sin\alpha)$ where A is the collection surface and c_s the ion sound velocity. The perpendicular drift velocity $v_{\perp}$ results ~25% of c_s and the parallel drift velocity $v_{/\!/}$ ~10% in the electron drift direction. In particular the perpendicular velocity is consistent with **E**x**B** drift due to an outward electrical field, inside the pipe, of the order of 1 kV/m.

Conclusions Energy and particle fluxes at the edge of the RFX experiment reveal anisotropic behaviour due to the presence of fast electrons and ion drift related to radial electrical field. In the range of plasma current and density explored so far, the electron temperature at the edge is almost constant at a value ~10 eV, whereas the electron density tends to increase more than linearly with the plasma density.

References

/1/ G. Malesani and G. Rostagni, *Proc. of 14th Symp. on Fusion Technology*, Avignon (1986) Vol. I, 173.

/2/ V. Antoni, M. Bagatin, D. Desideri, N. Pomaro, G. Gadani, P. Gaggini, M. Monari and A. Parini, *Rev. Sci. Instrum.* **63**, 4711 (1992).

/3/ S.Ortolani, *Plasma Phys. and Contr. Fusion* **34**, 1903 (1992).

/4/ V. Antoni, M. Bagatin, L. Carraro et al., Hydrogen recycling and impurity production in RFX, *Proceedings of this Conference.*

/5/ A.R. Jacobson and R.W. Moses, *Phys. Rev. A* **29**, 3335 (1984).

/6/ V. Antoni, M. Bagatin, D. Desideri and N. Pomaro, *Plasma Phys. and Contr. Fusion* **34**, 699 (1992).

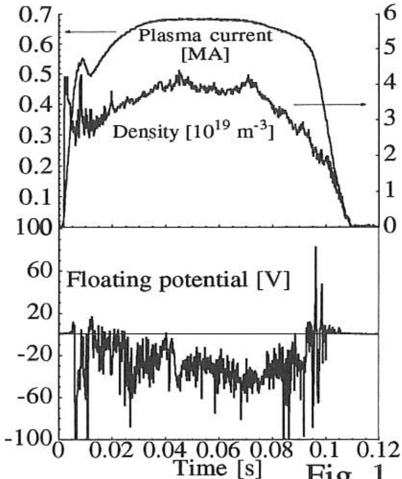

Fig. 1

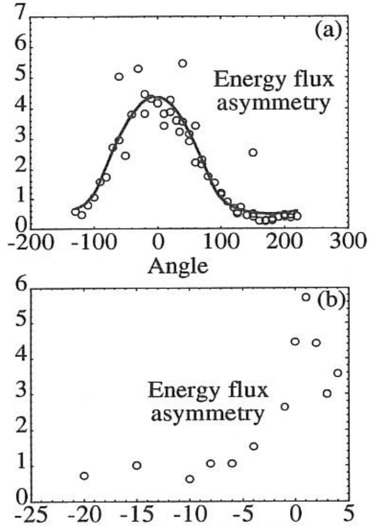

Fig. 2

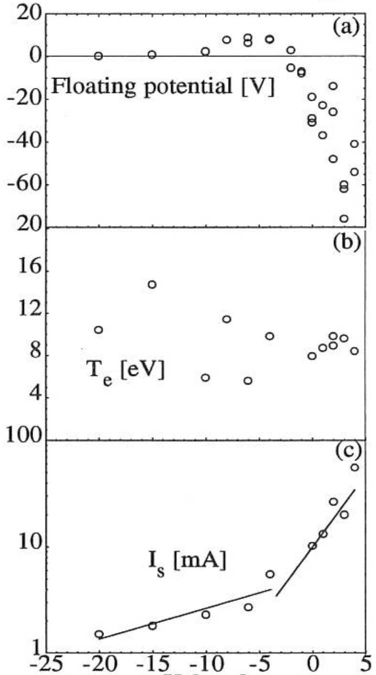

Fig. 3

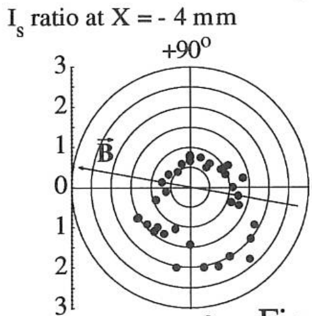

Fig. 4

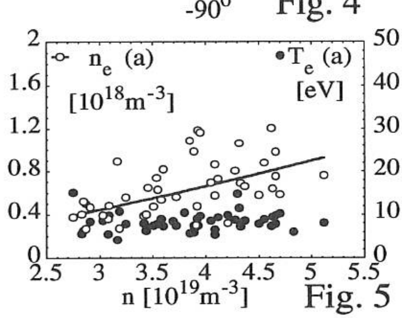

Fig. 5