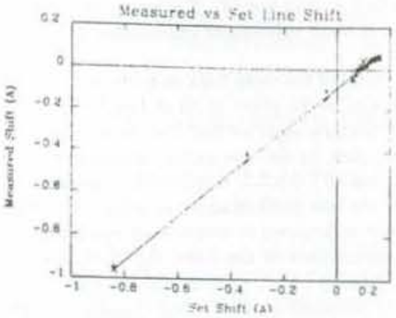

Fig. 1: Check of accuracy in line shift measurements using a Cd-lamp. The grating was turned in steps of 0.01 Å. Data evaluation by double-Gaussian fits.

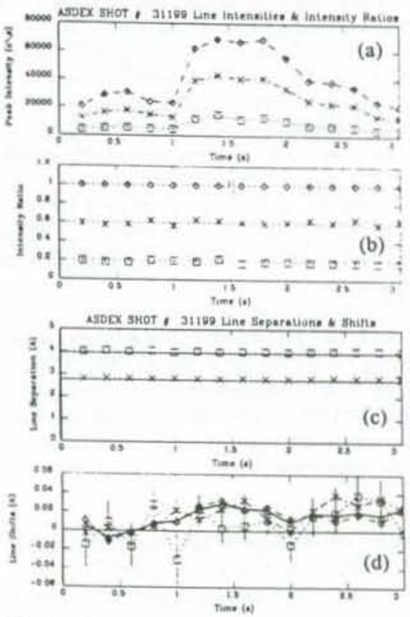

Fig. 3: C III triplet line intensities (a), ratios (b), separations (c) and shifts (d). NI from 1.0-2.6s. H-phase from 1.2-1.8s.

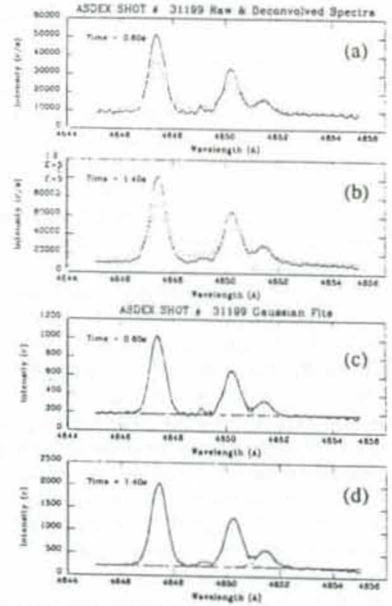

Fig. 2: C III triplet. Above: raw (dashed) and deconvolved data (solid line) for OH (a) and NI phase (b). Below: deconvolved data and triple-Gaussian fit (c,d).

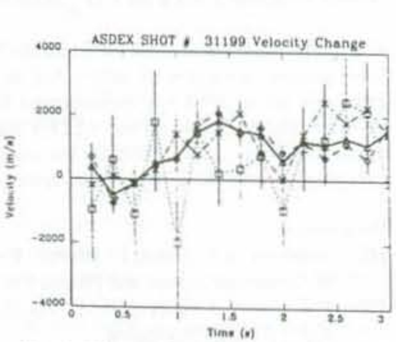

Fig. 4: Measured poloidal velocity: solid line: weighted mean of whole multiplet, dashed lines: single spectral lines (symbols as in Fig. 3).

LOCALIZED DENSITY MEASUREMENTS ON ASDEX USING MICROWAVE REFLECTOMETRY

M. Manso, F. Serra, A. Silva, J. Matias, F. Nunes, J. Leitao, J. Mata, P. Varela, S. Vergamota
Instituto Superior Tecnico, Lisboa, Portugal

J. Neves, J. Pereira, L. Cupido
Universidade de Aveiro, Aveiro, Portugal

F. X.- Söldner, G. Siller
Max-Planck-Institut fur Plasmaphysik, Garching, FRG

1. Introduction

Reflectometry is based on the propagation and reflection of probing waves in the inhomogeneous fusion plasma. For O-mode propagation the density of a reflecting plasma layer ne(Xc) is determined by the microwave frequency (F) which equals the local plasma frequency; the position Xc is evaluated from the phase delay $\Phi(F)$ between the incident and reflected waves. If the frequency is swept, a density profile can be obtained from the phase shift $d\Phi/df$ the wave undergoes in the plasma, integrated from f=0 to f = F:

$$X_c(F) = \frac{c}{2\pi^2}\int_0^F \frac{d\Phi}{df}\,(F^2 - f^2)^{-1/2}\,df$$

In fixed-frequency, global plasma movements and local plasma density fluctuations can be studied from the phase shift $d\Phi/dt$ resulting from the movements of the reflecting layer.

Broadband swept systems have been recently developed for TORE SUPRA /1/, ASDEX /2/ and DIII-D /3/, and a multichannel narrowband system for JET /4/. The ASDEX reflectometric system consists of three reflectometers (O-mode) in the frequency bands 18-26.5 (K-band), 26.5-40 (Ka-band) and 40-60 GHz (U-band), as described in /2,5/; electron densities measurements can be performed in the region starting from the plasma radius close to the magnetic separatrix on to the gradient region, (from 0.4 to $4.45 \cdot 10^{13}$ cm^{-3}). Broad band experiments were made with simultaneous swept operation of three reflectometers (2ms). Plasma density profiles and density perturbations have been measured for several plasma scenarios. Results are presented and the scope and the limitations of the evaluating techniques are discussed.

2 - Experimental results

As an example of typical broadband reflectometric measurements, we show in Fig.1 a K-band signal obtained (a) during shot 27328 (ohmic, $\bar{n}e$ = $3.9 \cdot 10^{13}$ cm^{-3}) and (b) before the plasma discharge. Clear fringes due to the plasma can be observed; the frequency minima are automatically detected (as indicated below the horizontal axis of the figure). The phase shift $\Delta\Phi/\Delta f$ is evaluated from the minima for each frequency band and fitted to a unique curve as shown in Fig.2(a); the curve exhibits oscillations that result from the plasma density fluctuations. The corresponding density profile is shown in Fig. 2(b); the data from both HCN (- - -) and YAG (o) lasers is also presented.

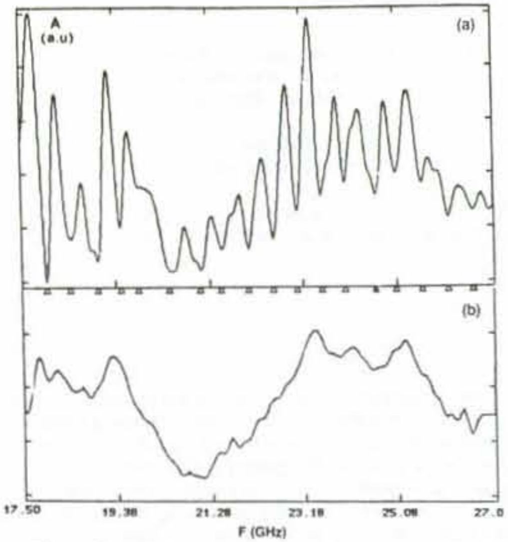

Fig. 1: Output signal of the K band reflectometer obtained (a) during ASDEX shot 27328 (1100 ms - 1102 ms), and (b) before the plasma discharge.

Several numerical analysis techniques were developed in order to smoothing and/or filtering the perturbations /6/. These techniques aim at obtaining the nondisturbed density profile. Figure 3 shows the profile of shot 27328 after smoothing (a); it can be seen that the shape (Fig.2b) has not been changed. In Fig.3 it is also plotted (b) the profile concerning shot 27294 (LHCD, $\bar{n}e=1.3*10^{13}$ cm^{-3}), in order to illustrate the wide range of densities measured with the reflectometric system.

The influence of the non-measured part of the phase shift curve (below F_1 =18 GHz) on the evaluation of the profiles was studied, by assuming different profile shapes between X0(ne=0) and the first reflecting layer $X1(F_1)$. The study showed that the shape of the nonmeasured part of the pedestal affects mainly: (i) the outer part ($\Delta X \leq 1$ cm) of the evaluated density profiles, (10-20%); (ii) profiles concerning high density plasmas ($\bar{n}e > 3x10^{13}$ cm^{-3}).

Two similar shots, 27327 and 27328, (with the plasma radially displaced by 1.7 cm), were analyzed; a linear shape for the pedestal was considered. The measured density profiles for ne < $2*10^{13}$ cm^{-3}, are presented in Fig. 4. The radial shift of ~ 1.7 cm between the two profiles is recovered, showing both the validity of the assumed linear shape for this case, (from the point of view of profile evaluation), and the accuracy of the reflectometric system in measuring radial movements of the plasma.

In some situations significant modifications of the plasma reflected waves are observed. An example is presented in Fig. 5, for shot 29285 when a m=2 tearing mode is present. The output signal of the Ka band reflectometer shows both amplitude and phase modulations due to the rotating (f_{rot}) mode (Fig.5). The period of the modulations can be determined, namely from the time interval Δt = 700 μs between two beat frequency maxima, as indicated in Fig.5; the mode frequency can be

estimated: $f_{rot} \sim \Delta t^{-1} \sim 1.4$ kHz, this beeing in agreement with the magnetic data . Broadband reflectometry can therefore give the time scale of localized modifications of the profile occuring during the 2 ms measuring time; amplitude information can also be obtained. A detailed study of this example is done in an accompanying paper /7/

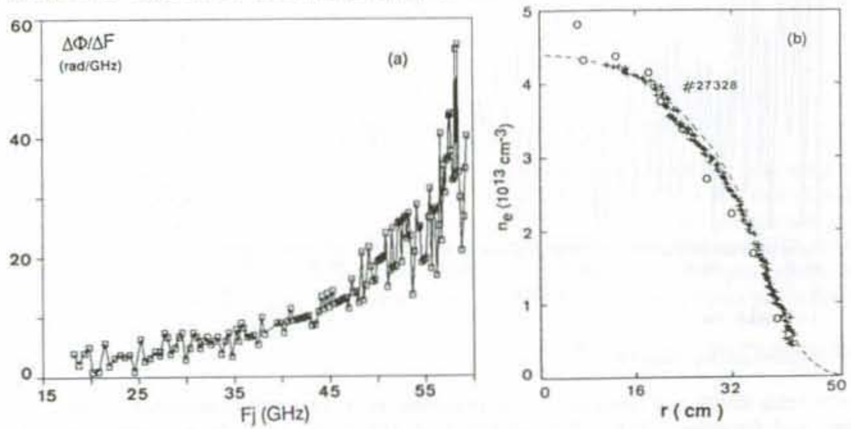

Fig. 2: (a) Phase shift curve including the phase information from the three reflectometers, with the minima obtained from raw data, for shot 27328; (b) density profile evaluated from phase shift curve (a).

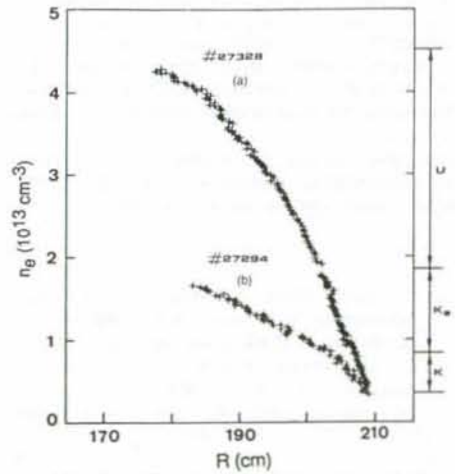

Fig.3: Density profiles for shots (a) 27328 (t=1100 ms), after smoothing of the phase characteristic, and (b) 27294 (t=1100 ms), direct from raw-data

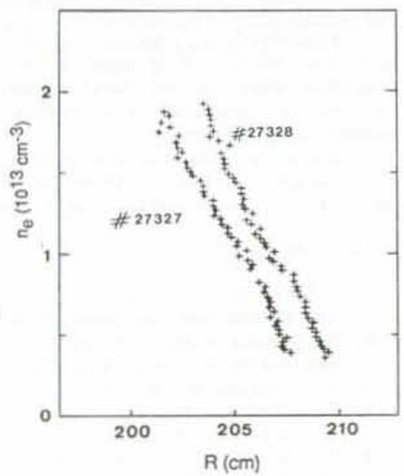

Fig. 4: Density profiles (K and Ka bands), for shots 27327 (Ro = 164.9 cm) and 27328 (Ro = 166.6 cm), at t = 1300 ms.

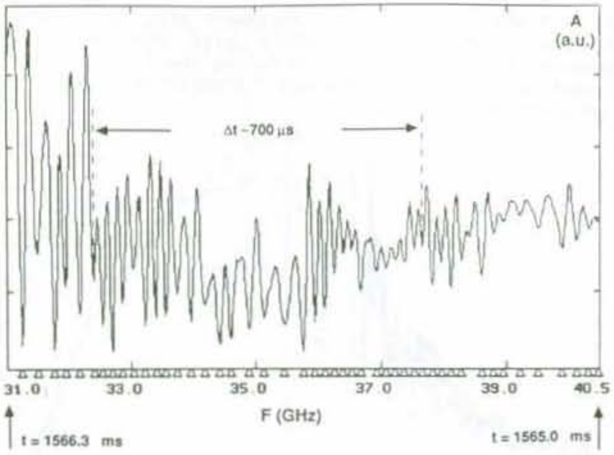

Fig.5: Output signal of Ka band reflectometer, from t=1565 ms to 1566.3 ms, for shot 29285, when a rotating magnetic island (f_{rot}~1.4 KHz) is present.

3 - Concluding remarks

The ASDEX reflectometric system had started swept-frequency operation by mid-December 1988. The analysis of the broad band data reveal that the difficulty of profile evaluation comes from the errors in the phase shift resulting from the plasma density fluctuations. Nonlinear stochastic numerical filters have been develloped (now being tested) that may provide a useful tool for routine evaluation of the data, for situations where the reflectometric signals are strongly disturbed by the plasma fluctuations.

Fixed frequency measurements (homodynic detection) were carried out and the study of plasma density fluctuations, based both on fixed and broadband experimental results, was initiated. A new heterodynic detection is beeing developed that will allow more sensitive measurement of plasma density fluctuations.

The reflectometric system was upgraded during the summer 1989 shutdown of ASDEX by installing three new reflectometers, aiming at fixed-frequency correlation reflectometric measurements; experiments have started recently.

References

/1/ P. Millot, F. Simonet, Proc. 14th Eur. Conf. on Controlled Fusion and Plasma Heating, Madrid, Vol. 11D, Part III, p. 1303 (1987)
/2/ M. Manso, F.Serra et al., Proc. 15th Eur. Conf. on Cont. Fusion and Plasma Heating, Dubrovnik, Vol. 12B, Part III, p. 1127 (1988)
/3/ T. Lehecka et al., Rev. Sci. Instrum. 59, 1620 (1988)
/4/ R. Prentice et al., 15th Eur. Conf. on Controlled Fusion and Plasma Heating, Dubrovnik, Vol. 12B, Part III, p. 1115 (1988)
/5/ M. Manso, F. Serra et al., Proc. 16th Eur. Conf. on Controlled Fusion and Plasma Heating, Venice, Vol. 13B, Part IV, p. 1517 (1989)
/6/ F. Nunes, Internal Report CAPS/IST (1989)
/7/ M. E. Manso, A. Silva et al. This conference.

Tangential Soft X-Ray/VUV Tomography on COMPASS-C

R.D. Durst, P.G. Carolan, B. Parham, the COMPASS Group

AEA Fusion/Euratom Association
Culham Laboratory, England

The COMPASS Tangential Soft X-Ray Camera (TAN SOX)

This diagnostic exploits toroidal symmetry to tomographically reconstruct soft x-ray or VUV emissivity contours from a tangential view of the plasma [1,2,3]. A 0.4 mm pinhole images the plasma onto a P-11 (ZnS:Ag) scintillator screen [3]. Between the pinhole and this screen is a filter wheel with two soft x-ray edge filters (1 keV and 2 keV) and two VUV filters (10 eV and a 140 nm, 10 nm FWHM interference filter). The efficiency of the system peaks at 3-4 keV and decreases monotonically thereafter so that the effective energy range lies between a selected filter edge to about 15 keV.

The phosphor screen is fiber optically coupled to a Microchannel Plate (MCP) intensified photodiode camera. The camera has a resolution of 128x128 pixels and a maximum framing rate of 330 Hz. The MCP gain is externally controllable from $10^3 - 10^6$ and can be gated down to 5 nsec.

The camera control and data acquisition are managed by an IBM AT compatible PC which is linked to the camera via fiber optics. An add-in board containing an Intel 8253 programmable timer provides the camera with the frame timing (synchronized to the plasma t_0) and the MCP gate commands. This board also controls the MCP gain.

The video data is sent to the PC via a 50 MHz analog optical link and is digitized by a frame grabber board (Data Translation 2861). The frame grabber has sufficient on-board memory to acquire up to 256 frames per shot and is coupled to a fast (8 MFLOPS) array processor (DT7020) which is used to tomographically invert some of the raw data.

Because of the very large amounts of data that this diagnostic can generate (up to 4 MB per shot, though the typical data load is presently < 1 MB) on-line data compression is used before the data is stored in the main COMPASS data archive. Differential run length compression [4] is used which results in a compression factor of about 4 with no loss of information content. The raw data is compressed by the PC processor at 30 sec/MB and then sent to the data archive on the main COMPASS VAX via Ethernet. The PC-VAX link is controlled by Digital's PCSA software which allows the PC to directly access VMS files.

The techniques used for the tomographic reconstructions are Maximum Entropy [5] and Bayesian Regularized Least Squares Optimization [6]. The two techniques produce similar results though the latter is preferred for on-line processing because of its greater speed. Using this algorithm a 32x32 pixel inversion typically takes 10-15 seconds to converge. Thus, several images may be reconstructed between shots.

Further details on the system and the inversion techniques used will be presented in [7].

Results from Ohmic Discharges

Figure 1 shows reconstructions of two typical COMPASS discharges. Parameters for these shots were, respectively, 100 kA, 1.0 T, $1.7 \times 10^{19} m^{-3}$ and 100 kA, 1.2 T, $1.7 \times 10^{19} m^{-3}$. The frame times were, respectively, 13 and 14 msec while the filters were