ADVANCES IN MICROWAVE REFLECTOMETRY ON ASDEX UPGRADE

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1 – Introduction

The FM-CW microwave diagnostic on ASDEX Upgrade has been primarily designed to perform density profile measurements [1][2][3], both at the High and Low Field Sides (HFS and LFS). For this purpose the diagnostic has been equipped with nine O-mode reflectometry channels (five at LFS/four at HFS) and two X-mode channels (to measure the outer edge of the plasma). All channels are swept in frequency simultaneously to probe the density profile (up to $n_e \sim 6.44 \times 10^{19}$ m^{-3}), in 20 µs. They can also operate in fixed frequency to study plasma fluctuations at selected density layers. Two additional fixed frequency reflectometers probe continuously density layers located close to, and inside the plasma separatrix, during the complete discharge. They are dedicated to fluctuation studies and specifically monitor the L-H mode transition. In view of the great interest to measure the core plasma density in regimes with improved core confinement, much effort has been dedicated to upgrade the channels probing higher densities. Here we analyse the new performance of the diagnostic to measure inner plasma regions. We present density profiles obtained entirely from O-mode reflectometry, from the edge to the bulk plasma, in regimes with improved core confinement. The results demonstrate that the profile can be measured in discharges with central peaked density profiles, with both high spatial and temporal resolutions. In fixed frequency experiments, we show that the diagnostic is very sensitive to the abrupt drop of plasma fluctuations, both when transient (L-mode edge) and steady state barriers (H-mode edge) are formed, in agreement with the improving of the swept reflectometry signals.

2 – Newly upgrades to the system

The memory deepness of the data acquisition system has been increased from 720K to 3000K. As a consequence of this the number of available electron density profiles as increased to 3000, allowing a better temporal resolution or the use of burst averaging kipping at same time a reasonable number of profiles per discharge. A new programmable pulse generator is now used permitting a more flexible choice of the acquisition windows.

A new V band antenna using a hog-horn configuration replaced the existing one of the X mode Low Filed Side (LFS) channel, which was a standard horn. This antenna produces a focused beam which is more suitable for probing extended plasma regions, contributing for an improved performance of this channel. The gain is 25 dB and the focal distance is 1 m.

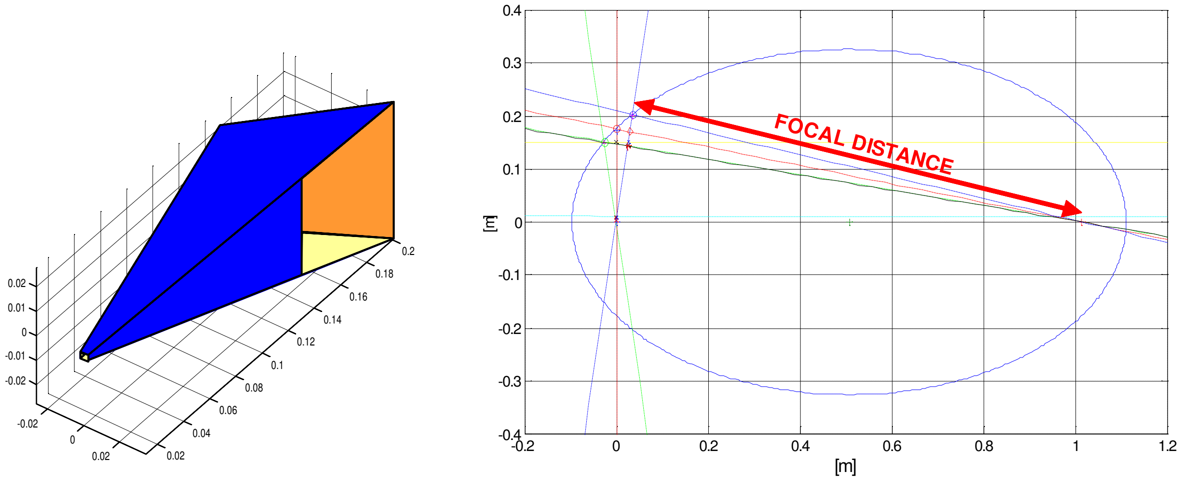

Figure 1 – *Schematic representation of the V band X mode antenna*

A new heterodyne detection with quadrature detection was implemented for the V band channel of the fluctuation monitor. All the sources are phase locked frequency synthesizers contributing for a very low overall phase noise of the system, essential for this type of detection. With this system the phase and intensity of the electron density plasma fluctuations can be clearly characterized.

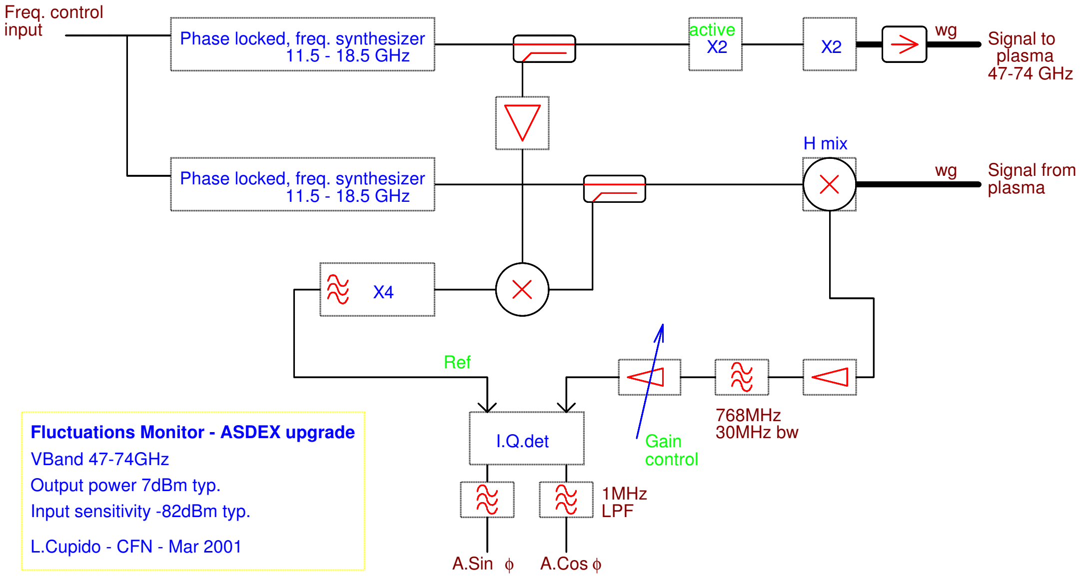

Figure 2 – *Schematic of the V band heterodyne system with quadrature detection*

Some electronic instrumentation with aging problems has been replaced and more sensitive heterodyne detections have been implemented on the V and W bands. The LFS in-vessel setup was completely rebuild, and a new enhanced heat shield using graphite tiles was added for a better protection of the antennas and waveguides.

2 – Experimental results

The importance of having the higher frequency bands fully operational could be jugged from the graphic of figure 3. As an example on high density plasmas the density shoulder (a relevant information for evaluating the plasma confinement) can only be seen on these higher bands. The modifications made on the V and W bands limited the sweep time to be larger then 50 µs. We expect to overcome this limitation in a near future. With these sweep times and a low level of plasma turbulence the reconstruction of the electron density profile from a single sweep is a simple question, as it could be inferred from the spectrograms from figure 4, that results from the merging of the signals of four frequency bands.

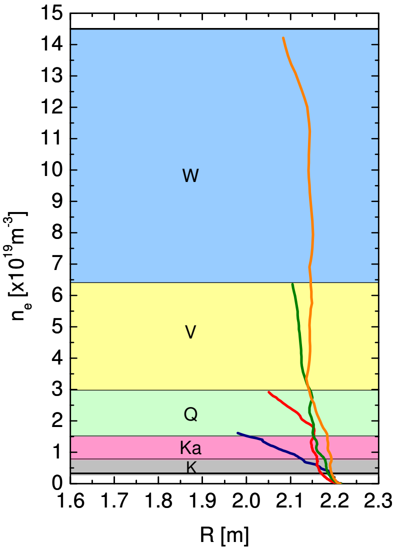

Figure 3 – *Plasma regions covered by the different frequency bands*

During an ELMy H mode and in particular close to an ELM the signals exhibit strong modulations, mainly on the LFS of the plasma. The ELM precursor can be seen at t = 2.20063 s where large fluctuations can be seen (figure 5). And again at the maximum of the Ha around t = 2.20098 s the signals are strongly perturbed.

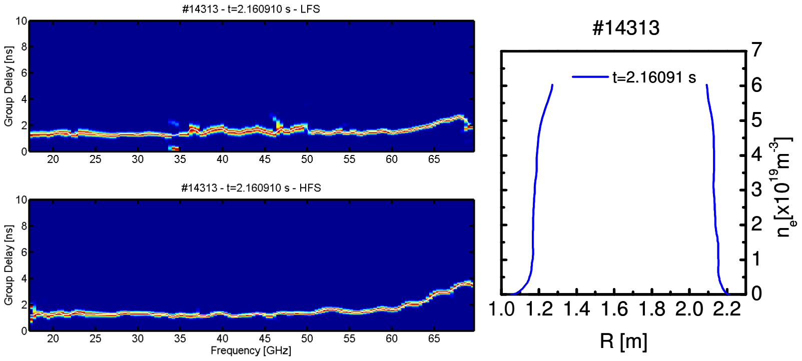

Figure 4 – *Spectrograms and electron density profiles.*

Reflectometry can perform automatic density profile measurements during pellet injection, when the plasma exhibits strong movements, as it could be seen on figure 6.

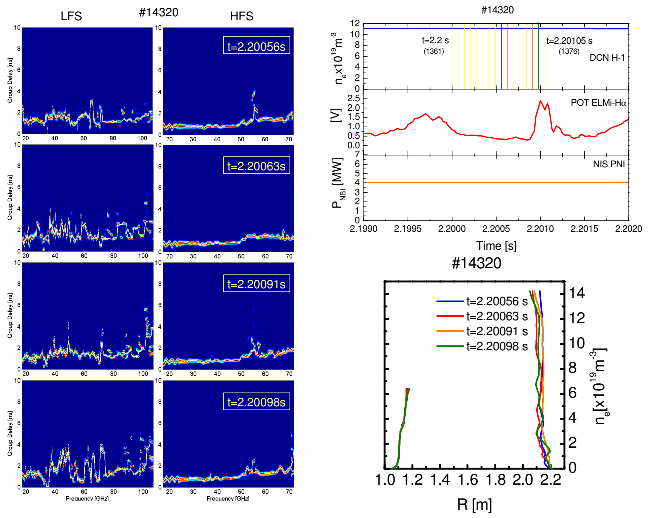

Figure 5 – *Electron Density profiles during an ELMy H mode*

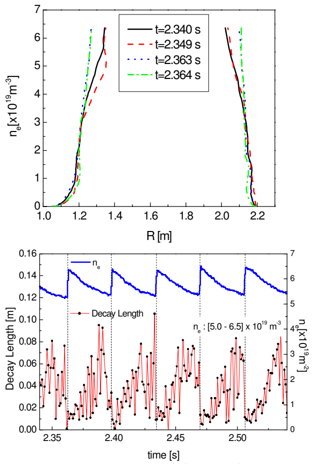

Figure 6 – *Density profiles during HFS pellet injection. The variation of the decay length of the resulting profiles is perfectly synchronized with observed profile peaking due to the pellet injection.*

It is possible to combine the fixed frequency measurements with the profiles. In this way it is feasible to spatially pinpoint the probed layers by the fixed frequency reflectometers and localize the fluctuations.

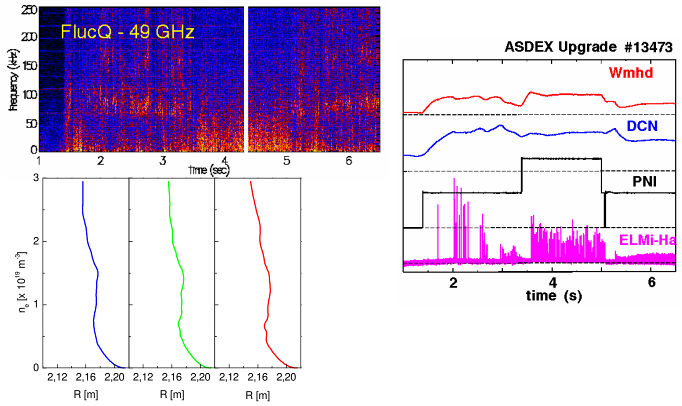

Figure 7 – Combined fixed frequency and broadband measurements

2 – Conclusions

The recent upgrades to the system improved the overall performance of the diagnostic, although some adjustments are still needed. The density profile can be measured in discharges with central peaked density profiles, with both high spatial and temporal resolutions. The ability to give simultaneous profile and fluctuation measurements can deliver detailed information about the localization of the density fluctuations.

[1] A. Silva et al., Fusion Technology, edited by C. Ferro, M. Gasparotto, and H. Knoepfel (North-Holland, Amsterdam,1992), Vol. 1, p. 747.

[2] A. Silva et al, Rev. Sci. Instrum. 67, 4138, (1996).

[3] A. Silva et al, Fusion Engineering and Design 46, 389, (1999).

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