36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-1.182 (2009)

Turbulence properties of the edge plasma at TEXTOR measured by Beam Emission Spectroscopy

D. Dunai[1], S. Zoletnik[1], G. Anda[1], G. Petravich[1], S. Kálvin[1], J. Sárközi[1], A. Krämer-Flecken[2], B. Schweer[2], S. Soldatov[3] and the TEXTOR team

[1] *KFKI RMKI, Association EURATOM, Budapest, Hungary*
[2] *Institut für Energieforschung - Plasmaphysik, Forschungszentrum Jülich GmbH, Association EURATOM, Trilateral Euregio Cluster, Jülich, Germany*
[3] *Department of Applied Physics, Ghent University, Rozier 44, 9000 Gent Belgium*

Introduction

A Beam Emission Spectroscopy diagnostics system optimized for density turbulence measurements has been recently installed at TEXTOR tokamak[1]. The combination of a bright Lithium atomic beam, high throughput optics and specially developed low noise high frequency detectors makes this diagnostics optimal for turbulence measurements. A 16 channel avalanche photodiode (APD) camera unit utilizing low-noise amplifiers measures the beam emission in 500 kHz analogue bandwidth with 2.5 MHz sampling. The 16 cm radial coverage extends from the Scrape Off Layer (SOL) into the edge plasma to r/a=0.85. The photon flux at the maximum of the emission profile is up to ~$3*10^{10}$ photons/sec/channel causing 2% photon statistical noise in the signal including the excess noise of the APD amplification process. At this signal level the photonic noise exceeds other noise sources of the amplifier and measurement of plasma density fluctuations become possible over the whole radial range. This is even true at r/a<0.9 where the fluctuation level drops below 1%, as correlation techniques are sensitive down to the 0.1% level in light fluctuations. In the SOL the amplitudes are much higher (in the 1 % range) but measurement is complicated by a relatively large background light level originating from the limiter in the background. A fast beam chopper system has been developed[2] for this situation where the beam can be switched on and off with up to 250 kHz frequency. This is higher than the background light fluctuation caused by SOL turbulence therefore the beam light can be corrected for the background. These measurements complement the results of the correlation reflectometry which are available only for 0.6<r/a<0.95.

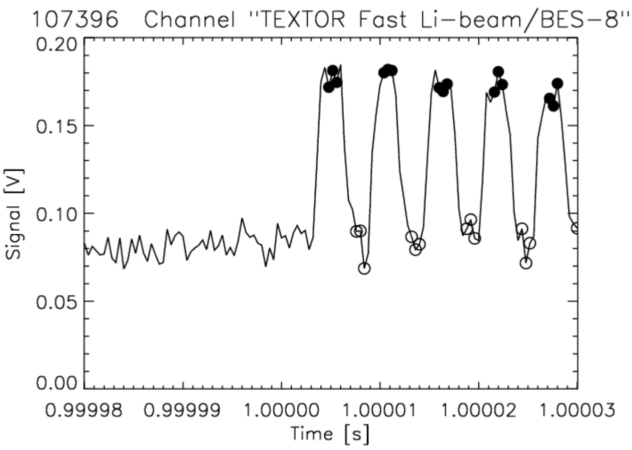

Fig. 1. Fast beam chopping experiment. The beam is chopped (cut) until 1 s, from that on it is switched on/off for periodically with 5.6 μs period time. (r=42 cm)

Fast background correction

The fast beam chopping can be used for measuring the background light level with extremely good temporal resolution. An example is shown in *Fig. 1.* where the beam is deflected (chopped) until 1 s. From this time the beam is switched on for 2.8μs and switched off for the same amount of time periodically. From the plot it is clear that after the beam-on time period the beam is removed as the signal returns to the background level. The open and closed circles indicate samples which are used for determination of the beam-on and beam-off light, respectively. These 3 samples are averaged to form samples of virtual beam-on and beam-off signals, which can be handled in the same way as ordinary measurement data. The only problem is that in the given case the time resolution is 5.6μs and the background signal is half sample time shifted from the beam-on signal. A common timescale can be established by adding an additional sample between two consecutive ones using linear interpolation. After this step the background can be subtracted from the beam-on signal and the background corrected Li-beam signal becomes available. *Fig. 2.* shows an example of the resulting signals around the Last Closed Flux Surface (LCFS) of TEXTOR. In this particular channel the Li-beam signal is comparable in amplitude to the background. One can even see with the naked eye that the background signal has lower frequency components, which is well confirmed by the difference in the autocorrelation function of the two signals.

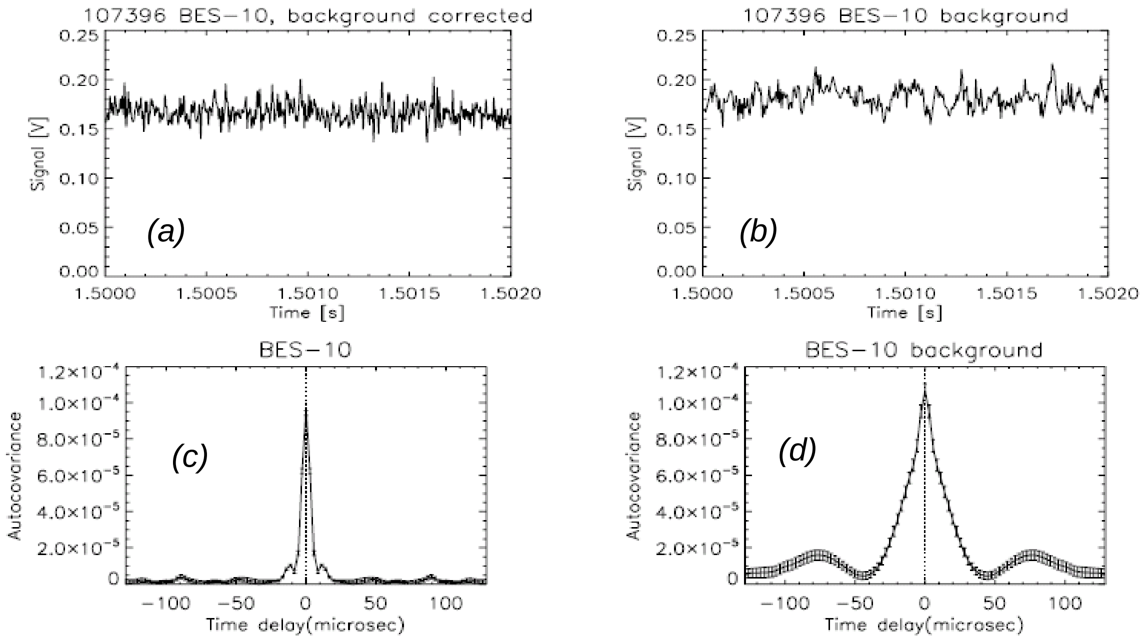

Fig. 2. Background corrected Li-beam signal (a) and the background signal (b). Plots (c) and (d) show the autocorrelation function of the two signals (r=44 cm).

This type of background correction is perfect if the signal has components much slower than the chopper period time (5.6 µs) in the above example. Such cases include edge density profile changes during and before ELMs, disruptions and other transients. However, close to the chopper frequency background subtraction is not perfect.

High time resolution density profile evolution during L-H transition

In a certain configuration with sufficient heating TEXTOR exhibits a limiter H-mode characterized by a modest increase in confinement time and ELMs. In very recent experiments the Li-beam diagnostic was used for measuring density profiles, the edge turbulence amplitude and poloidal propagation velocity at the L-H transition. Details of the density profile changes at the L-H transition are not known yet. The above described high frequency beam chopping makes the Li BES an ideal tool to resolve this. Fig 3. shows three selected background corrected signals and their background during an L-H transition and the first ELM. Although the local Li beam light intensity is not strictly proportional to the density, this relation holds approximately at the plasma edge, where the beam attenuation is small. This way we consider the intensity signal in *Fig 3 (a)* as density. The L-H transition is triggered by an ELM like phenomenon at time 1. A steep pedestal develops within 2 ms and even during this time an MHD modes appears at the steep part of the profile (2). At time (3) an ELM is triggered indicated by a sudden flattening of the profile. Multiple filaments can be

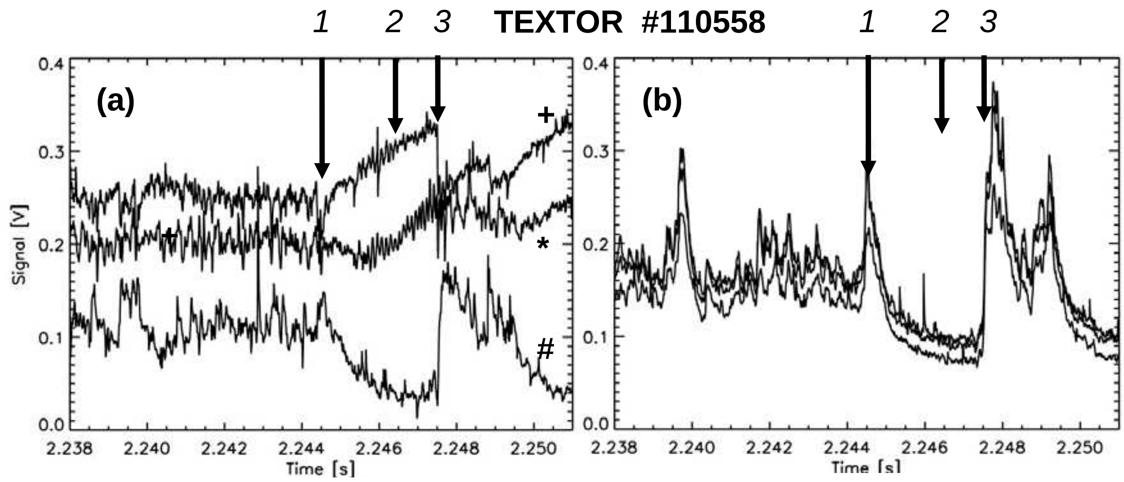

Fig. 3. (a) Background corrected Li beam and (b) background signals at the plasma edge (+: r=38cm, *: r=39cm, #: r=42.4cm) around the L-H transition. The marked instances are: 1: start of L-H transition, 2 : edge MHD mode (ELM precursor) 3: first ELM

observed in the SOL during the next 2 ms while the pedestal recovers. The background signal in *Fig. 3 (b)* is believed to originate from region close to the vessel wall. Therefore all background signals are similar: at each ELM like event a spike is observed. The pronounced bursting activity in the L mode disappears immediately in the H mode and reappears only during the ELM. Detailed studies of these phenomena are underway.

Characteristics of Quasi Coherent mode

Quasi coherent mode is a broadband wave like structure typically in the range of 30-100 kHz[3]. It appears inside the LCFS and is never seen outer in the SOL. Li BES is capable to study the behaviour of these modes in different plasma parameters. As an example spectra

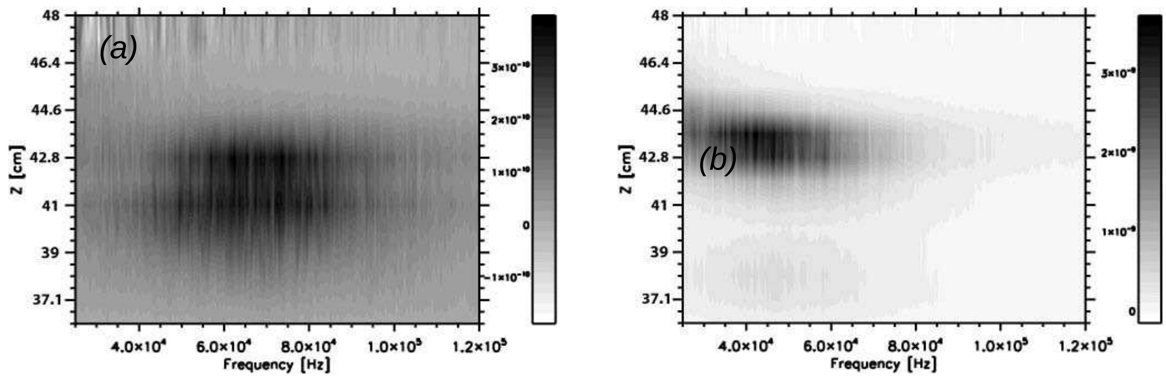

Fig. 4. Autopower spectra of Li BES signals in different densities otherwise with same plasma parameters at (a) $1.5*10^{19}$ and (b) $3.5*10^{19}$ line averaged density.

measured in a density scan is presented in *Fig 4*, where the line averaged density was increased in steps from $1*10^{19}$ m^{-3} to $3.5*10^{19}$ m^{-3}. There is a well observable change in the spectra as the mean frequency of the peak moves from 70 kHz to 40 kHz. No correlation was observed with reflectometry measurement, which is located 180 degrees poloidally and 90 degrees from the Li beam. The QC structures are therefore poloidally and/or toroidally localised. The poloidal wavelength of the mode can be determined from fast poloidally deflected Li beam measurements, where 2 virtual beams are present in the plasma and cross-correlation is calculated between them[4]. Such correlation function is shown in Fig. 5c., where 90 degrees phase shift is observed for 1.5 cm beam deflection indicating 6 cm poloidal wavelength. The radial correlation length appears to be typically 2 cm.

Turbulence and flow velocity change at the limiter H-mode discharge

The beam was also operated with fast deflection mode at 400 kHz in limiter H-mode measurements. At this high frequency the poloidal propagation delay of turbulence can be measured by calculating the shift of the maximum cross-correlation between the two poloidally deflected beam signals as shown in Fig. 5(c)[4]. From the -6 μs shift and the approximately 1.5 cm deflection the poloidal flow velocity at the plasma edge is about 3 km/s. (Outside the LCFS the flow velocity is reversed.) Calculating this time delay from 2 ms long signals one can construct the time evolution of the propagation delay and the fluctuation power (from the amplitude of the cross-covariance). These quantities are shown in Fig.5 (a) and (b) for 3 radial locations at the plasma edge but inside the LCFS. At the start of the NBI heating the amplitude of the turbulence, dominated by the QC mode, drops sharply within 4 ms to a very low level. Fig.5(b) shows that the poloidal propagation time stays constant within about 10% up to the point when the QC mode disappears and the time delay calculation becomes unreliable. The dashed lines in (a) and (b) show the same time when the fluctuation amplitude has already dropped considerably but clearly the time delay is still constant. Changes of the poloidal flow velocity can still be detected with lower time resolution later in the discharge. This method enables measurement of the flow velocity profile during H-mode transition and will be studied in detail.

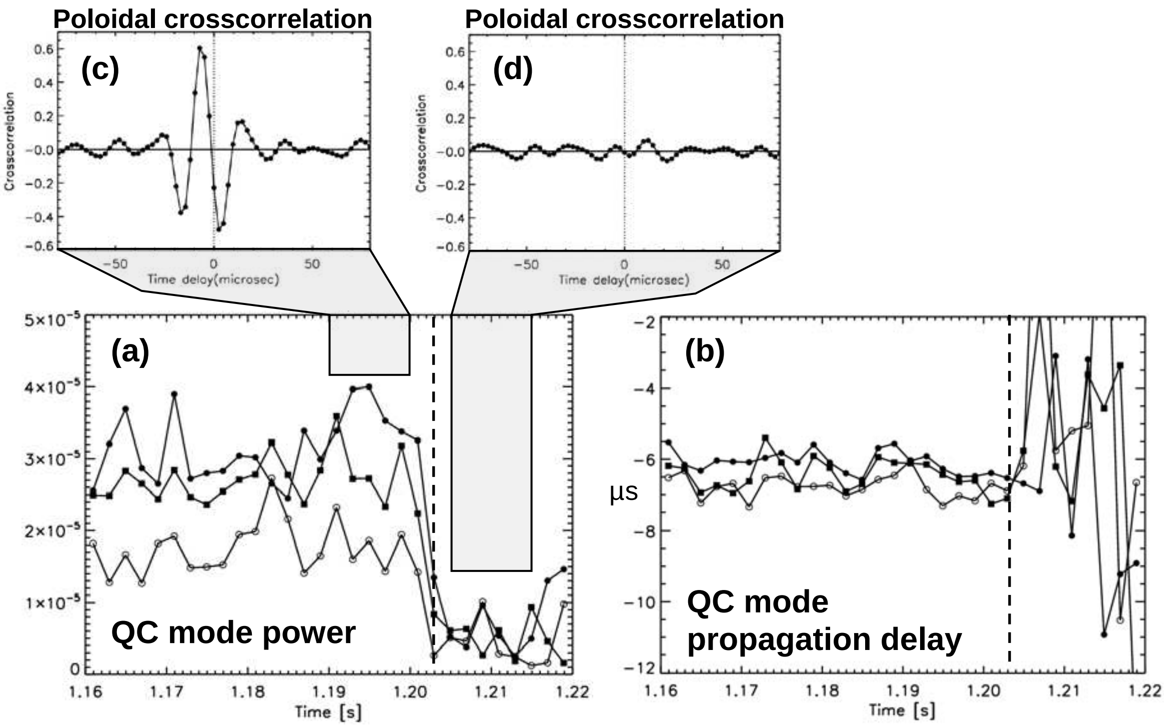

Fig. 5. (a) The fluctuation power in the 25-80 kHz frequency range as a function of time when the QC mode is suppressed. (r=36.9 cm: open circle, 38 cm: square, 39 cm: full circle). (b) The poloidal propagation delay of turbulence as a function of time in the same time window as in (a). The time resolution is 2 ms. The small figures at the top show the cross-correlation between poloidally offset channels at r=38 cm before and after the change.

References

[1] G. Anda et al., *35th EPS Conference 2008 ECA Vol.**32D**, P-5.076 (2008)*
[2] S. Zoletnik et al., *Rev. Sci. Instrum.* **76** 073504 (2005)
[3] A. Kraemer-Flecken et al., *Nucl Fusion* **44** 1143 (2004)
[4] S. Zoletnik et al., same conference *P1. 192*