23P038-P

Study of filament features of edge plasma fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I)

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In order to extract the fluctuation component from the raw data of fast camera, a pre-processing technique, Sliding Time Window Averaging Subtraction (STWAS) has been developed to remove the background of slowly varying bulk plasma emission. Processed image shows clear filament structures. Preliminary quantitative features of the filaments are discussed. Automatic procedure for evaluating mode number and width of the filament is planned.

1. Introduction

Blob is known as an intermittent turbulence structure in the plasma edge. It is stretched along the magnetic field line and forms $k_{//}/k_{\perp} << 1$ filament structure with much higher density than the background plasma [1]. Although Langmuir probes are routinely applied to measure the poloidal and radial structures, a fast camera can provide 2D images of such fluctuation structures by measuring mainly the visible light emission from edge plasma. It features non-invasive observation, wide view region and high spatial resolution.

It is difficult to recognize filaments in a raw image. Phase analysis clearly shows some narrow belts with the same phase shift, which implies the existence of filaments [2]. However, more filament information such as mode number and width is needed to further understand edge turbulence. Until now, a pre-processing method has been developed to extract the fluctuation component from the raw data before further analysis.

2. Diagnostics setup

In 2010, two fast cameras were installed on Heliotron J to simultaneously measure fluctuations in the tangential (#10.5), top and horizontal views (#11.5, Fig.1). Supersonic Molecular Beam Injection (SMBI) is employed at #11.5 port to enhance local emission by increasing the neutral particle density. A Langmuir probe array was installed below this port, which can be used to locate the field of view. Using the frame frequency of 30 kHz and shutter speed of 100 kHz, filaments were tracked in toroidal and poloidal directions from the top and horizontal views.

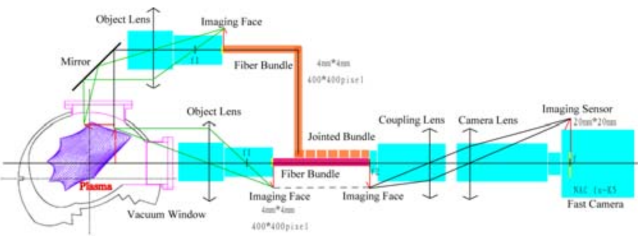

Fig.1. #11.5 Fast Camera System on Heliotron J

3. Data Analysis

3.1 *Pre-processing*

The raw signal of fast camera data contains both long time scale component from the slowly varying bulk plasma "background" and short time scale fluctuation from probably edge turbulence [3]. Fluctuation component is rather weak compared to the "background". In this section we will focus on a typical shot in SMBI experiment with co-NBI heating for pre-processing.

Using time average in a specified time window around a time point as "background" value and sliding the window point by point, we can get a background curve I_{bg}. Then applying the following equation:

$$I_f = I_{raw} - I_{bg}$$

where I_f is the fluctuation intensity, and I_{raw} is the raw signal, the fluctuation component is calculated. The result with a 0.5ms sliding time window is shown in Fig.2. The extracted fluctuation is very similar to that from a 2kHz high pass FFT filter, and we do not need to modify the distorted edge amplitude for STWAS method. Effect of the STWAS pre-processing is illustrated in Fig.3. Filament structures along magnetic field line are clearly shown.

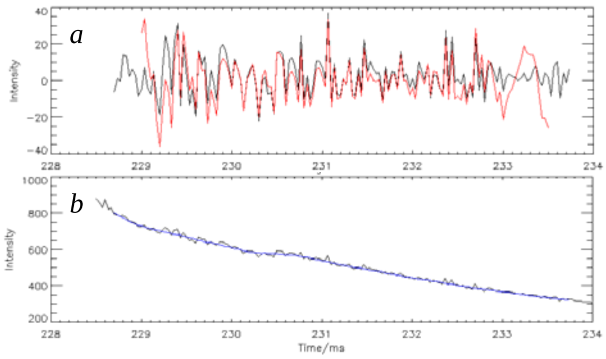

Fig.2. 0.5ms STWAS result: *a.* extracted fluctuation with 2kHz high pass FFT filter (red) and STWAS (black); *b.* raw signal (black) and "background" by STWAS (blue)

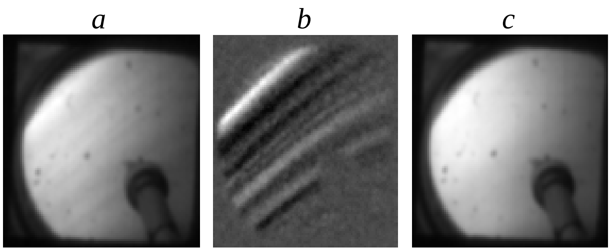

Fig.3. *a.* a raw image; *b.* an extracted fluctuation image; *c.* a background image

3.2 *Filament tracking*

After pre-processing, raw images are filtered with respect to an amplitude and size threshold to extract "official" filaments [4], which is defined by a critical size and amplitude conditions of the fluctuation data. Amplitude condition for each point is set to 1σ, where σ(x, y) is the standard deviation(STD) of time series fluctuation at point (x, y) during pre-processed regime. Size condition is set to 4 pixel at the poloidal direction, which is about 6mm actually. However, both the two conditions still need optimization based on more analysis results. Figure 4 shows an example of the fluctuation signal along a poloidal direction line at specified time point. There are three filaments and the full width half maximum (FWHM) is about 5, 8, 12 pixel, responding to actual poloidal width of 7.5mm, 12mm and 18mm, respectively. Further work is still needed to automatically calculate the averaged filament number/poloidal length and FWHM in the future.

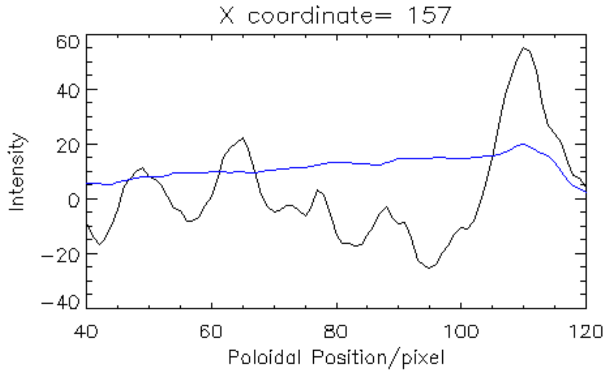

Fig.4. Fluctuation signal along a poloidal direction line at specified time point (black) and standard deviation during studied period (blue)

Acknowledgments

The authors are grateful to the Heliotron J technical staff for conducting the experiments. This work was performed with the support and under the auspices of the NIFS Collaborative Research Program.

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