Dust visualisation in TJ-II with intensified visible Fast Cameras

E. de la Cal, J.L. de Pablos, D. Carralero and C. Hidalgo

Laboratorio Nacional de Fusión
Asociación Euratom-Ciemat

Abstract

A visible fast camera equipped with an image Intensifier and atomic line filters is used in TJ-II for spectroscopic dust observation. First results show characteristic features depending on filter and clearly differing from those without the filters as is usually done in existing experiments. Preliminary discussions of the observed results are presented.

Keywords: Fusion plasmas, dust, fast cameras.

Visualización de Partículas de Polvo en TJ-II con Cámaras Rápidas Intensificadas

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Resumen

Se ha instalado en TJ-II una cámara rápida visible CMOS equipada con intensificador de imagen y filtros de interferencia para la visualización espectroscópica de partículas de polvo. Primeros resultados muestran imágenes características según el filtro utilizado (según línea atómica filtrada), siendo además claramente diferentes de las imágenes tomadas sin filtros. En este informe se presentan los primeros resultados.

Palabras clave: Plasmas de fusión, polvo, cámaras rápidas.

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Introduction

High speed or fast cameras are widely used in present day fusion experiments for dust observation. The studies mainly are focused on dust trajectories, number of events as a function of the wall state, the main sources within the reactor, etc [see e.g. 1-4]. In TJ-II an intensified visible Fast Camera equipped with an image intensifier and atomic line filters of Lithium and H_α was used during the 2009 campaign. The goal was to make spectroscopic studies of the dust emission. The filtered dust fast movies could be used in principle to:

- understand the light radiation from dust (Blackbody versus atomic emission)
- learn about the dust composition and the hydrogen content
- track the dust inside the plasma and measure its lifetime or residence time
- see the contribution to impurity influx (relative value with respect to sputtering) and to fuelling.

First results are here reported and discussed and future experiments are foreseen for 2010.

Experimental set-up

Fast or high speed cameras capable of operating in the 10^5 frames per second speed range are today commercially available and offer the opportunity to plasma fusion researchers of two-dimensional (2D) imaging of fast phenomena such as turbulence, ELMs, disruptions, dust, etc. When using interference filters to monitor, e.g. impurity line emission (spectroscopic imaging), the photon flux is strongly reduced and the emission cannot be imaged at high speed. Therefore, the TJ-II fast camera was equipped with an image intensifier that amplifies the light intensity onto sensor. An effective amplification of up to two orders of magnitude of the light intensity is feasible with the used image intensifier without any significant distortion of the image for our applications. The camera looks tangentially to a poloidal limiter (Figure 1).

Results

The image intensifier allowed to make very fast filtered movies: 15 μs with Lithium filter (TJ-II is a lithium coated reactor) and down to 1 μs with H-alpha filter. First observations indicate that without filtering the dust light is very punctual (localised as spots) and its intensity is much higher than plasma emission. This is a strong indication that the main contribution is Blackbody radiation (as in so called "hot spots"). The lifetime is up to several tens of milliseconds and the main source is the limiter (when inserted). The trajectories can be as long as the whole field of view of the camera. With interference filters the light intensity level is comparable to that of the plasma emission. Figure 2 shows a caption with Li I filter, 30000 frames per second camera speed and 15 μs exposure time. The emission cloud above the whole limiter surface is due to the lithium atoms sputtered by the plasma that are excited before being ionised. The calculated penetration depth of a few centimetres of sputtered lithium is in good agreement with this emission pattern. The localised stronger emission clouds is attributed to mobile dust particles, not hot spots, since they change their position. It should be remembered that since with filters the continuum Blackbody radiation is strongly cut by at least 2 orders of magnitude, the emission should be mainly atomic line emission. In fact the emission structure with filters is not "spot-localised" but more like a cloud. This is attributed to the atomic neutral expulsion (due to ablation or sputtering) from the dust particle towards the surrounding plasma. Moreover, with filters the lifetime (and trajectories) of dust is much shorter, generally smaller than 100 μs. If the emission is due to atomic excitation of the plasma and not due to heating, this lifetime should be an indication of the time the dust particle is inside the plasma and not travelling in the vacuum chamber outside the denser and hotter plasma regions. This would mean that the long dust trajectories seen without filtering would mainly be trajectories outside the Separatrix. Perhaps electric fields produce repelling forces that screen the plasma from most dust particles. Those dust particles that enter the plasma (seen with the filters) are rapidly ablated (burned) due to the strong heat fluxes and have therefore a short lifetime. Movies with H_α filter show even a shorter lifetime of the emission clouds. The H_α-filtered hydrogen emission that is detected is attributed to the hydrogen atoms, which are contained in the dust particle and are desorbed thermally when the dust is heated (by the plasma). The importance of studying these hydrogen dust emission is linked to the fact, that dust is a big concern for future fusion reactors operating with tritium, since first it can be the main tritium inventory within the reactor and second, it is mobile in case of accident.

Conclusions and General perspectives

More experiments are foreseen for the next campaign: a special system for simultaneously observing the same plasma with and without filtering has been installed. A carbon CIII line (465 nm) filter and a Long-Wave pass filter with cut at 700 nm for Blackbody radiation discriminating atomic lines where acquired for future experiments.

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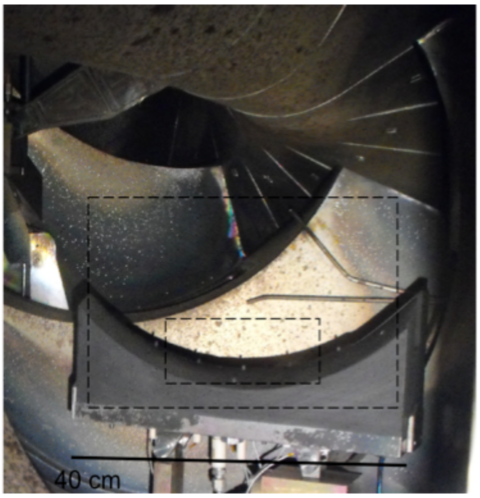

Figure 1: Tangential camera view with the poloidal limiter at the lower part.

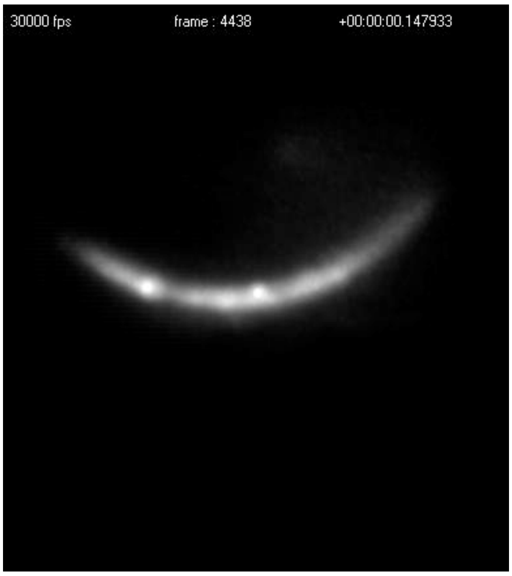

Figure 2: Dust observation in TJ-II with Li I filter, 30000 frames per second camera speed and 15 μs exposure time.