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ScienceDirect
Journal of Nuclear Materials 363–365 (2007) 1446–1449
journal of nuclear materials
www.elsevier.com/locate/jnucmat

An electrostatic detector for dust measurement on HT-7 tokamak

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Abstract

An electrostatic dust detector has been successfully developed to measure dust event in situ and in real time on the HT-7 tokamak. For measuring dust near the edge plasmas and preventing interference of electrons and ions, the shielding plates were designed and installed around the dust detector. The electric signal of dust has been successfully measured during LHCD discharges on HT-7 tokamak. The measured dust signal was in good agreement with bursts appeared on multi-channel H_α radiation and on multi-channel ECE diagnostics. Diagnostics of the spectrum and the measurement of impurity emission during dust bursts were studied in detail. It is interesting that there is a delay between dust bursts and CIII line emission. It is observed that the delay time between dust signal and measured CIII line emission is about 0.3 ms in the HT-7 tokamak.

PACS: 52.70.Nc; 52.55.Fa

Keywords: HT-7 tokamak; Dust

1. Introduction

The existence of dust in plasma devices has been known for a long time [1,2]. Particulates are often found in the bottom areas of fusion devices after operational campaign. Abundant particulates have been also observed in the HT-7 device. The presence of dust in fusion plasmas and its role in the performance of magnetic fusion devices have been discussed in many papers [1–4]. It is crucial to know what impact dust has on core and/or edge plasma parameters, contamination, and core plasma confinement, which has been investigated in many devices, for example, flakes falling into DITE and PDX tokamak plasmas caused plasma disruptions [2]. And deliberate dust spreading experiment has been performed on the JIPPT-IIU tokamak [3]. The usual way of studying dust in fusion devices is to collect dust particles in the opening of devices and then analyze them, but the machine needs flushing for some time. During this process very small particles may have already been removed in the airstream [4]. Another way to observe dust has been developed, which used fast cameras [2,5] to record dust images during discharges. These images demonstrate that dust particles move in toroidal directions with a speed of ~10–100 m/s. The high

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doi:10.1016/j.jnucmat.2007.01.204

mobility of dust poses additional threat in burning plasma experiments, where it will be radioactive and contain tritium. Also dynamics and transport of dust particles in tokamak edge plasmas has been studied. The interactions of a dust particle with a corrugated surface or plasma turbulence can cause it to exit the recycling region and fly through the scrap-off layer plasma towards the tokamak core. Dust formation in and transport from the divertor region can play an important role in core plasma contamination. The dust particle density around the separatrix has been estimated to be $\sim 10^{-2}\,\text{cm}^{-3}$ [6]. It is necessary to measure the dust in situ and in real time, to investigate the impact of dust in vacuum chamber of fusion devices. New diagnostic has been developed to observe the dust [7]. Recently, an electrostatic dust detector with shielding plates has been successfully developed to measure particulate at the edge plasma in the HT-7 tokamak.

The Hefei Tokamak-7 (HT-7) is a superconducting tokamak, and it was reconstructed from the original Russian T-7 tokamak in 1994. It has a major radius of $R = 1.22$ m, minor radius of $a = 0.27$ m in the circular cross section. The plasma is limited with two toroidal limiters (located at top and bottom) and one belt limiter (located at the mid-plane at the high field side). The total graphite plasma facing area of the HT-7 limiters is about $2.35\,\text{m}^2$. The rest of the plasma facing surface is formed by the stainless liner within a metallic torus with $r = 0.33$ m. The diagnostic systems relevant to dust measurement are as below (1) the vertical five-channel far-infrared (FIR) (2) 9-channel CIII line emission (3) two multi-channel H_α radiation arrays (4) multi-channel electron cyclotron emission (ECE) as shown Fig. 1.

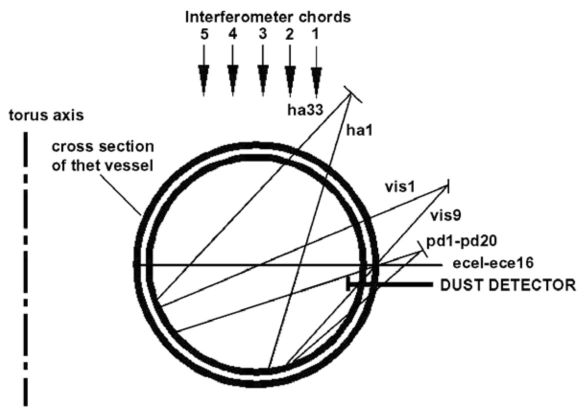

Fig. 1. The diagnostic systems relevant to dust measurement.

2. Experimental setup

The electrostatic dust detector has been developed to measure dust near the edge on HT-7 tokamak. Standard circuit board technology was used to deposit a grid of interlocking traces on a circuit board as shown in Fig. 2. The traces width and space distance were 150 μm, respectively. It covered an area of $2.0 \times 2.0\,\text{cm}^2$. In the absence of dust, the detector could stand off a voltage of more than 500 V. To simulate the effect of dust the grid was tested with particles scraped from HT-7 tokamak tile. Miniature sparks appeared when particles landed on the metal grid and created a short circuit, hence the dust event could be recorded as shown in Fig. 3.

The shielding plates were designed and added around the detector in order to prevent the interference of electrons and ions. The length of the shield-

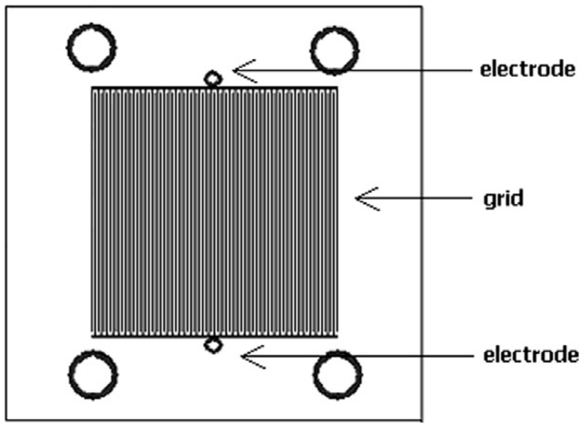

Fig. 2. Schematic drawing of the detector circuit: trace width and spacing distance 150 μm, respectively, overall area $2.0 \times 2.0\,\text{cm}^2$.

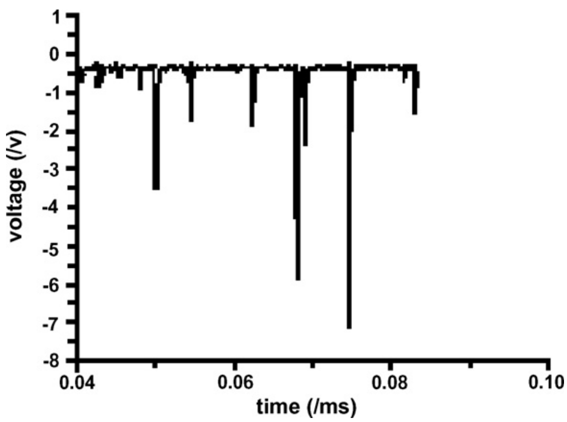

Fig. 3. Record of dust event.

ing plate was design to be as long as 43 mm in order to avoid receiving ions and electrons thoroughly. The whole detector unit was mounted on a manual removable stick attached to a gate valve 7.2 cm below the midplane. The ISOBE3000 isolate amplifier was adopted to transfer the dust signal to the HT-7 central data acquisition system.

3. Measurement result

The experiment performed under these conditions: minor radius $a = 0.27$ m, plasma current $I_p = 60$ kA, toroidal field $B_t = 1.8$ T, and LHCD pulse duration is about 10 s. The graphite limiters were water-cooled actively. The radius of the stainless steel liner is 0.33 m. The detector was positioned at $r = 0.31$ m as shown in Fig. 4.

The measured dust signal is shown in the bottom of Fig. 5. The plasma current (I_p) and center line-average electron density (n_{e0}) are kept at about 60 kA, and $0.6 \times 10^{19}/\mathrm{m}^3$. Dust was observed in the plasma discharge. The bursts also appeared on multi-channel ECE diagnostics, multi-channel H_α signals and multi-channel CIII line intensity as shown in Fig. 5. The horizontal displacement of plasma (PLHB in Fig. 5) implied that there were strong interactions between plasma and the wall during dust bursts. The correlations amongst dust, ECE signal (ece03), H_α signal (Ha10) and CIII line intensity (Vis9) existed clearly in Fig. 5. When the signal was observed on dust detector, the burst appeared on H_α signal and ECE signal almost simultaneously as shown in Fig. 5. However, the time delay between dust signal and CIII line emission is about 0.3 ms in Fig. 5. It is observed that the dust event occurred normally at $t > 8$ s after plasma startup in the HT-7 tokamak.

It is confirmed that shielding plates are necessary for the detector to avoid receiving electrons and ions. The relation between amplitude of dust and H_α intensity is shown in Fig. 6. The linear relationship exists between the amplitude of the dust signal and intensity of H_α. It implied that the amplitude of the dust signal represents the numbers of particulates simultaneously received by the detector or larger size particulate. Fig. 7 shows dust effect in plasma, deduced from the 9-channel visible spectroscopy for CIII intensity (vis1–9 in Fig. 7). It is clearly observed that the delay time between dust

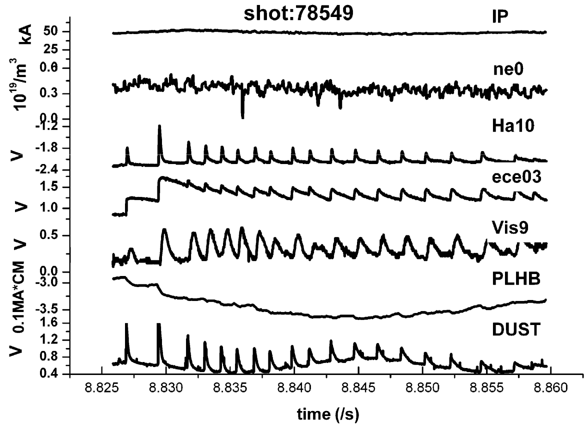

Fig. 5. Dust signal measured near the edge of HT-7 tokamak plasmas. From top to bottom are plasma current, center line-average electron density, H_a, ECE radiation, visible spectroscopy for CIII intensity, horizontal displacement of plasma and dust.

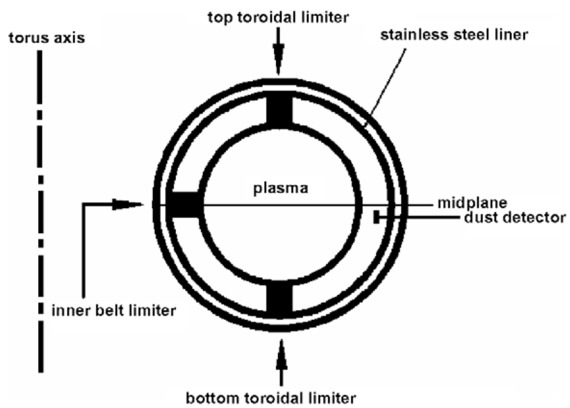

Fig. 4. The position of the detector.

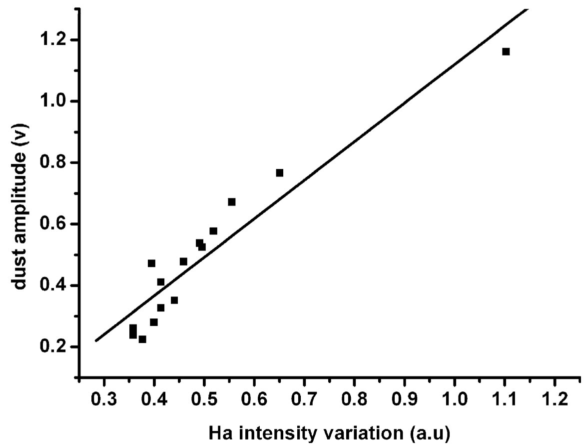

Fig. 6. The correlation between amplitude of dust and the H_a intensity.

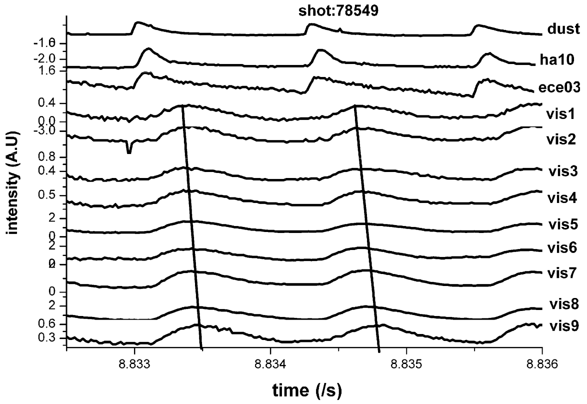

Fig. 7. Dust effect in plasma, deduced from 9-channel visible spectroscopy for CIII intensity.

signal and measured central CIII line emission (vis1 in Figs. 1 and 7) is generally about 0.3 ms in the HT-7 tokamak. The different responses between different channel visible spectroscopy signals imply a poloidal plasma rotation of asymmetric poloidal radiation in Fig. 7.

4. Summary

In summary, an electrostatic dust detector with shielding plates has been successfully developed to measure dust event in situ and in real time on the HT-7 tokamak. It is confirmed that shielding plates are necessary for the detector to avoid receiving electrons and ions. The electric signal of dust has been successfully measured during LHCD discharges on HT-7 tokamak. The measured dust signal was in good agreement with bursts appeared on multi-channel H_α radiation and on multi-channel ECE diagnostics. It is interesting that there is a delay between dust bursts and CIII line emission. It is observed that the delay time between dust signal and measured CIII line emission is about 0.3 ms in the HT-7 tokamak. It is also observed that the different responses between different channel visible spectroscopy signals may be a poloidal plasma rotation of asymmetric poloidal radiation.

Acknowledgements

We thank our colleagues at Institute of Plasma Physics, the Chinese Academy of Sciences for the experiment preparation and performing. The authors would like to thank Dr Yu Yang and Jianshen Hu for valuable discussions. This work was supported partly by JSPS-CAS Core-University Program on Plasma and Nuclear Fusion.

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