Statistical analysis of temporal and spatial evolution of in-vessel dust particles in fusion devices by using CCD images

Suk-Ho Hong1,2,3,4, Kyoungh-Rae Kim1,2, Yong-Un Nam2, Jin-Il Jung2, Christian Grisolia5, Volker Rohde6, KSTAR team1, Tore Supra team5, and ASDEX Upgrade team6

1National Fusion Research Institute, 113 Gwahangno, Yuseong-Gu, Daejeon, 305-333, Korea
2Center for Edge Plasma Science (CEps), Hanyang University, Seoul 133-791, Korea
3Department of Electrical Engineering, Hanyang University, Seoul 133-791, Korea
4Department of Nuclear Fusion and Plasma Science, University of Science and Technology, 113 Gwahangno, Yuseong-Gu, Daejeon, 305-333, Korea
5Association EURATOM-CEA-Cadarache, DSM/IRFM, St. Paul les Durance, 13108, France
6Max-Planck-Institut für Plasmaphysik, Association EURATOM-Association, 85748 Garching, Germany

Motivation

- Flaking of radioactive tritiated co-deposits of nano- to micrometer size.
  - Tritium (10% of 35g) was trapped in deposited a-CH layers during the JET DTE1 campaign.
- A strong chemical reactivity with air (hot dusts, ITER accidental scenario).
- Damage to first wall & diagnostics due to high velocity impact.
- To control the amount of dusts in vacuum vessel, it is important to monitor the dust creation events of dust particles in Fusion devices.

CCD image processing

CCD image processing technique [1]

Pattern recognition
- Background: Plasma emission intensity
- Temporal change in the plasma emission intensity has to be slower than the acquisition speed of CCD cameras
- Target pattern: Well-defined straight line-like trajectories of dust

Procedures
1. Conversion to the grayscale images
2. Filters for noises
3. Subtraction between the target frame and the background frame
4. Conversion to the 1bit black and white (BW) images
5. Counting dust particles, integrating frames
(The frequency of the events / The creation zone of the dust particles)

KSTAR 2010, 2011 campaign

KSTARTV2011 program [2]
- Identify the plasma position.
- Measure the well-defined straight line-like trajectories of dust along the toroidal direction.
- Measure Θ both ends of dust trajectory.
- Trajectories at inboard side.

Dust particles cannot get through the core plasma.

Dust velocity distribution

- Measure 1237 trajectories.
  - Velocity range 7 - 385 m/s.
  - Peak at 30 m/s.
  - Exposure time: 2 ms.

DCEs in AUG

AUG 2007 campaign

DCEs decrease as the plasma operation time increases.
DCEs are dominant at divertor.

DCEs in KSTAR

KSTAR 2010, 2011 campaign

DCEs increases during D-shaping experiment, then stays low and almost constant during the campaign.
DCEs are dominant at divertor as in the case of AUG.

Dust Velocity distribution

- Measure 1821 trajectories.
  - Velocity range 0 - 412 m/s.
  - Peak at 50 m/s.
  - Exposure time: 1.5 - 4.8 ms.

DCEs in Tore Supra

CIMES Campaign

DITS Campaign

- Large amount of DCEs during the restart of the machine, but soon decreased.
- DCEs are strongly dependent on plasma operation scenarios (input power) and machine history.
- Frequent disruptions were occurred during the DITS campaign with repetitive long pulse. DCEs in DITS campaign show that dusts can limit the plasma operation.
- The origins of DCEs were identified.