Observation of Island-Like Structures in Synchrotron Imaging emitted by Runaway Electrons on EAST

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Runaway electrons (REs), generated during tokamak disruptions, might pose significant threats to the integrity of the device. The 3D magnetic perturbation field, induced by MHD instabilities or resonant magnetic perturbations (RMPs), is of widespread interest due to its potential for RE mitigation. With 3D magnetic perturbations, island-like structures in synchrotron imaging have been observed on JET[1] and DIII-D[2], yet the underlying mechanisms remain not fully understood.

Here we report an experimental observation of rotating island-like structures in synchrotron imaging emitted by REs on EAST. The experiments are done in low-density ohmic plasmas and the imaging from synchrotron emitted from high-energy REs are observed by the infrared camera. The rotating n=1 RMPs with 1 Hz are applied during the current flattop. A central bright spot accompanied by two rotating islands is observed in the infrared camera imaging. The two islands are situated at the periphery of the bright spot and appeared to rotate around it with 1 Hz. The central spot is circular with a missing segment in the lower right corner, and the islands are also invisible in that area, due to the geometric effect in imaging of the infrared camera (Figure 1(a)).

A simulation code incorporating SOFT[3] (a test particle code including the relativistic guiding center motion model) and an imaging calculation tool based on a cone radiation model has been developed. Firstly, the RE orbits in the presence of the perturbed magnetic field are calculated. Then using the cone radiation model, the synchrotron imaging of REs with the given orbits is simulated, which is found to be qualitatively consistent with the experimental observations. Comparing the experimental results and simulations, it is found that the island-like structures in the images are mainly caused by the overlapping of drift islands of REs. When the resonant condition is suitable and these drift islands are overlapped, the stochasticity significantly altered the topology of RE orbits in the poloidal plane, leading to an island-like distribution. This distribution then resulted in island-like structures in the image when the pitch angle met the appropriate conditions (~0.1 on EAST).

This work provides a clear understanding of the cause of the island-like structures in synchrotron images of REs, offering physics insights that may help explain other similar phenomena. It also serves as evidence for the existence of a sticky region within stochastic fields, suggesting that REs could be partly confined within the perturbation field.

1. Sommariva, C. *et al.* Dynamics of JET runaway electron beams in D_2 -rich shattered pellet injection mitigation experiments. *Nucl. Fusion* **64**, 106050 (2024).
2. Marini, C. *et al.* Runaway electron plateau current profile reconstruction from synchrotron imaging and Ar-II line polarization angle measurements in DIII-D. *Nucl. Fusion* **64**, 076039 (2024).
3. He, K. *et al.* Full-orbit simulation of fast ion loss under resonant magnetic perturbations in the EAST tokamak. *Nucl. Fusion* **61**, 016009 (2021).

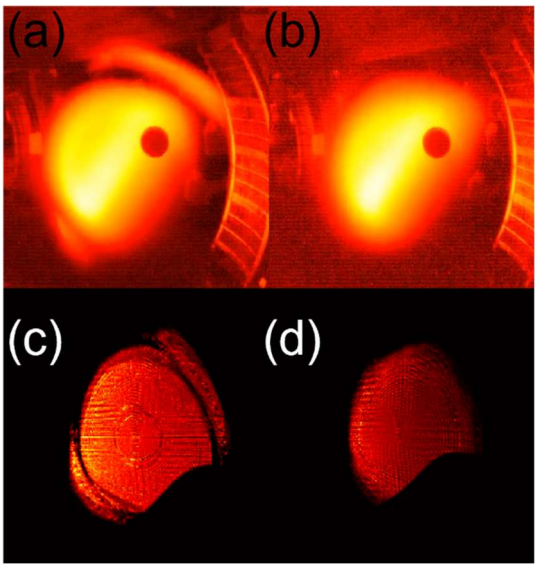

Figure 1 (a) imaging with island-like structure and (b) imaging without island-like structure measured by infrared camera; (c) simulation result with island-like structure and (d) simulation result without island-like structure