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Investigation of Hard X-Ray emission in Lower Hybrid Wave Experiments on the TST-2 Spherical Tokamak

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We have studied the hard X-ray (HXR) emissions and underlying mechanisms[1] induced by Lower Hybrid Wave (LHW) experiments on the TST-2 spherical tokamak[2]. By examining the HXR energy under different plasma current conditions, we can gain insights into the generation, transport, and loss mechanisms of fast electrons, as well as their impact on overall plasma stability and confinement. Hard X-ray production is often tied to high-energy electron beams striking the tokamak walls or detectors. HXR bursts indicate transient high-energy deposition, which may damage device components. Studying burst characteristics helps develop protective measures and reduce potential harm to the device.

The TST-2 spherical tokamak is a compact experimental device that utilizes LHW to drive plasma currents of up to 27 kA. Through HXR radiation analysis, various physical phenomena related to high-energy electron dynamics are explored, including high-energy electron formation and interactions with vessel components.To address potential errors in the pulse height analysis, such as signal pile-up, techniques like gating and template fitting are applied to separate and correct overlapping signals in high-count-rate situations.

We often observed HXR bursts as shown in Fig.1, which typically occur during rapid changes in plasma current, correlating strongly with loop voltage fluctuations. Furthermore, the relationship between plasma current during the flat-top phase and maximum HXR energy is examined. These bursts correlate with loop voltage spikes and magnetic field fluctuations, pointing to possible magnetohydrodynamic (MHD) instabilities. Numerous high-energy X-rays appear within about 10 microseconds. Intriguingly, the total X-ray energy released in each burst can reach nearly half of the total X-ray energy emitted throughout the discharge, which may impact the current drive process. These bursts occur more frequently when the upper antenna is used and when the plasma position is closer to the antenna, suggesting that localized coupling or high-power density regions might trigger such MHD events. Investigating the temporal profiles, spatial distributions, and underlying physics of these bursts is critical for improving overall efficiency and safety in fusion reactors. Further analysis may involve advanced diagnostics and modeling tools to clarify the role of electron acceleration and wave-particle interactions. By correlating burst occurrence with detailed plasma measurements, researchers can develop improved control techniques and potentially mitigate the adverse effects of MHD instabilities.

References

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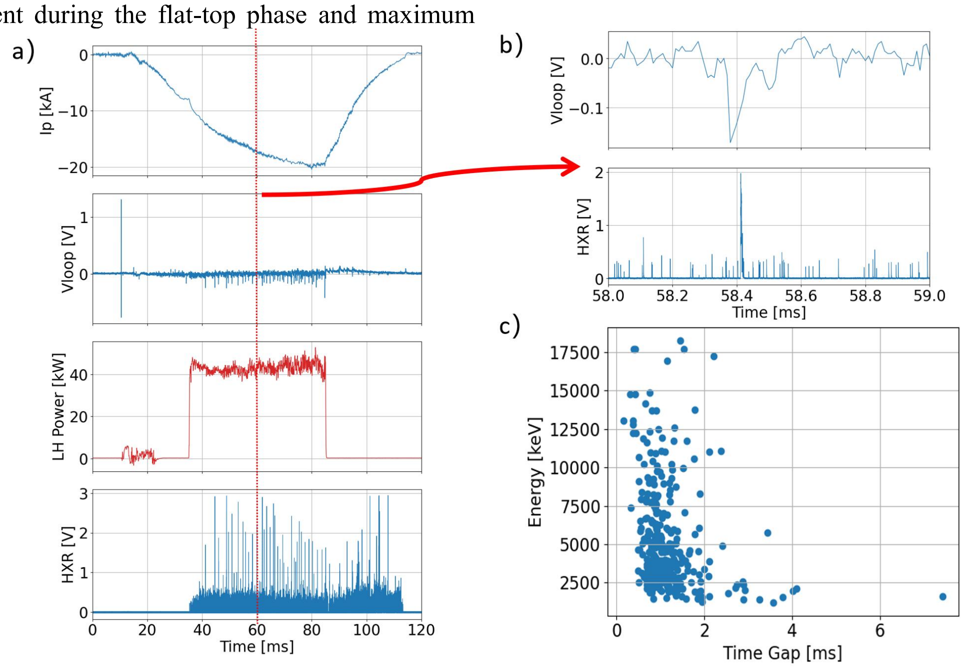

Figure 1. a) Plasma current, loop voltage, LH power, and raw HXR data. b) Expanded view of loop voltage and HXR.

c) Energy of burst events and their corresponding time differences. The periodicity is approximately 0.8 ms.