Effects of LHCD and LBO on Runaway Electron Dynamics during Disruptions in the HL-2A Tokamak

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ABSTRACT

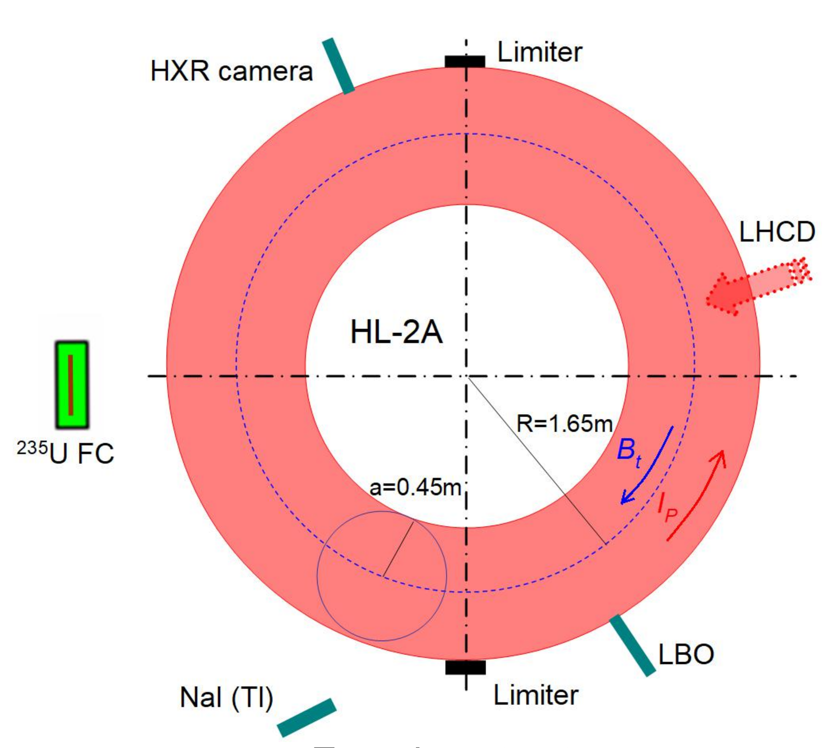
Runaway electrons (REs) during disruptions are a crucial issue for future large tokamaks due to the local impact of RE beam and large thermal loads they can place on the plasma facing components. Utilizing the newly developed key systems in the HL-2A tokamak for the study of RE dynamics during disruptions, such as: hard X-ray (HXR) camera, laser blow-off (LBO) system, and massive gas injection (MGI) system, the effects of lower hybrid current drive (LHCD) and laser blow-off (LBO) on RE dynamics during disruptions have been systematically investigated. RE generation during disruptions has been successfully avoided for the first time by the LBO-seeded impurity. However, the enhancement of RE generation during disruption with LHCD has been found. With the aid of a hard X-ray (HXR) camera, the physical mechanism of the RE dynamics during disruptions has been observed and these allow a detailed analysis of the generation and evolution of the REs.

Motivation

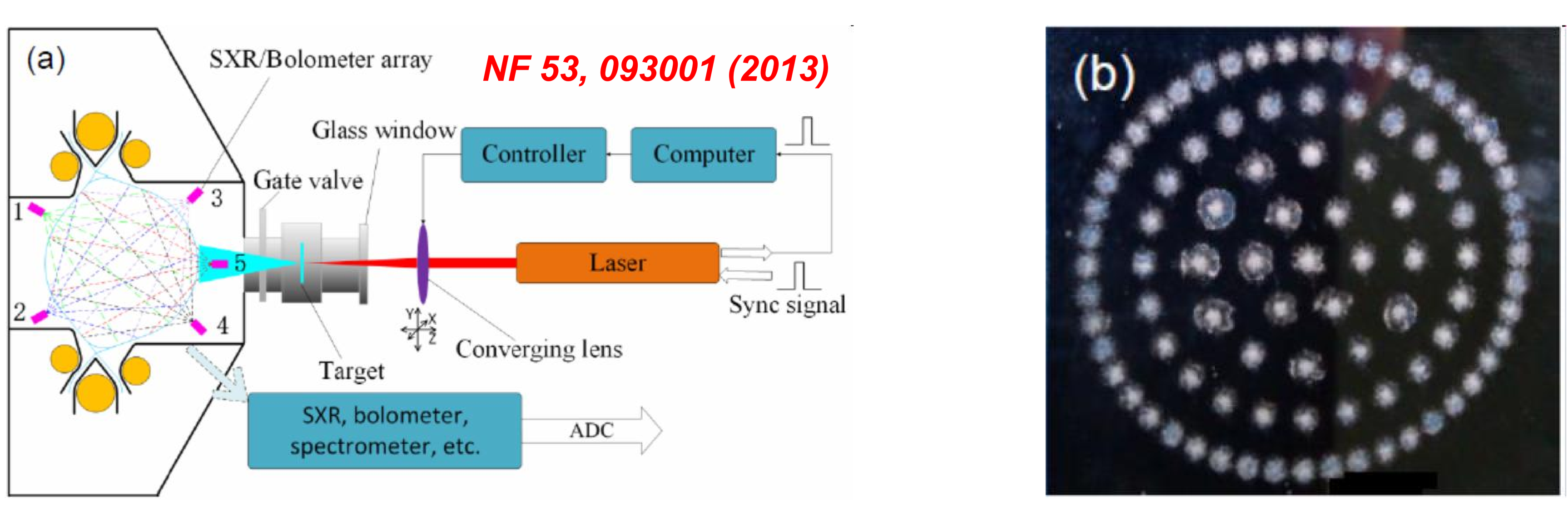
- One of the outstanding problems of tokamak fusion reactor is the possible damage caused by REs.
- REs are nearly collisionless, they continue to gain energy (up to tens of MeV) from the toroidal electric field.
- During disruptions, a large quantity of particles and energy are lost from the plasma. ~180 MJ of RE beam stored energy will be released during a major disruption in ITER.
- The localized heat load on the first wall (FW) due to the RE beams can damage drastically the wall materials and pollute the plasma.

Exiperimental conditions

- The HL-2A device (R=1.65 m, a=0.4 m, B_t=2.8 T, I_p=0.5 MA) is a tokamak with closed divertor chambers. At present it is operated with a lower single null configuration.
- A LBO system is installed on the equatorial-plane port and the impurities are vertically injected into plasma.
- A LHCD system with a power of 2.0 MW has been developed recently for the HL-2A tokamak.



Experiment setup



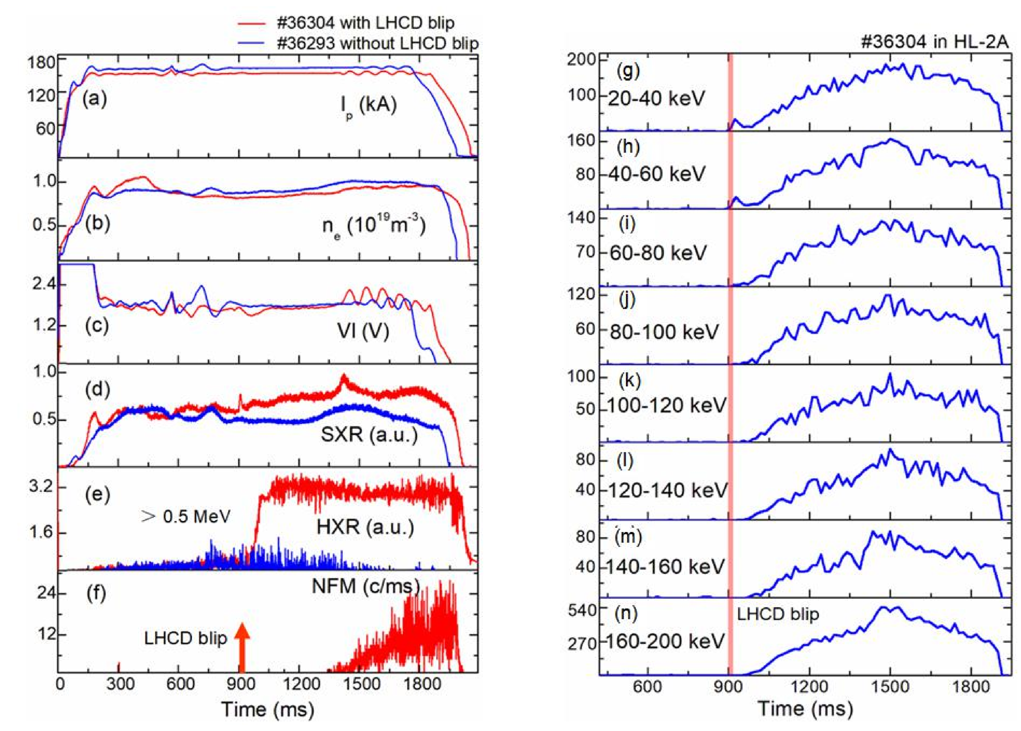
(a) Schematic diagram of the LBO system in HL-2A; (b) LBO target with footprints of laser ablation.

TABLE I. Main parameters in the RE experiment in HL-2A

Plasma current, I_p	150-200 kA
Central line-averaged electron density, n_e	(0.7-2) $\times 10^{19}$m^{-3}
Central electron temperature, T_e	1-2 keV
Toroidal magnetic field, B_t	1.2-1.8 T
Plasma edge safety factor, q_{95}	4.0-6.0
Effective ionic charge, Z_{eff}	2.0-3.0
LBO injection impurity	W
LHCD power and pulse width	0.3-1.0 MW, 500 ms

Exiperimental results

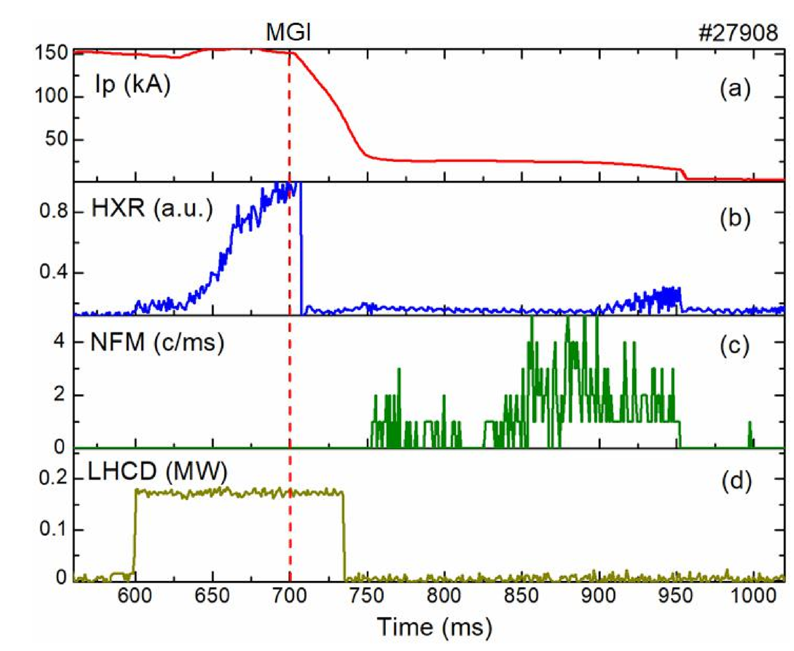
Enhancement of RE generation with LHCD



Typical RE generation enhancement discharge induced by a LHCD blip.

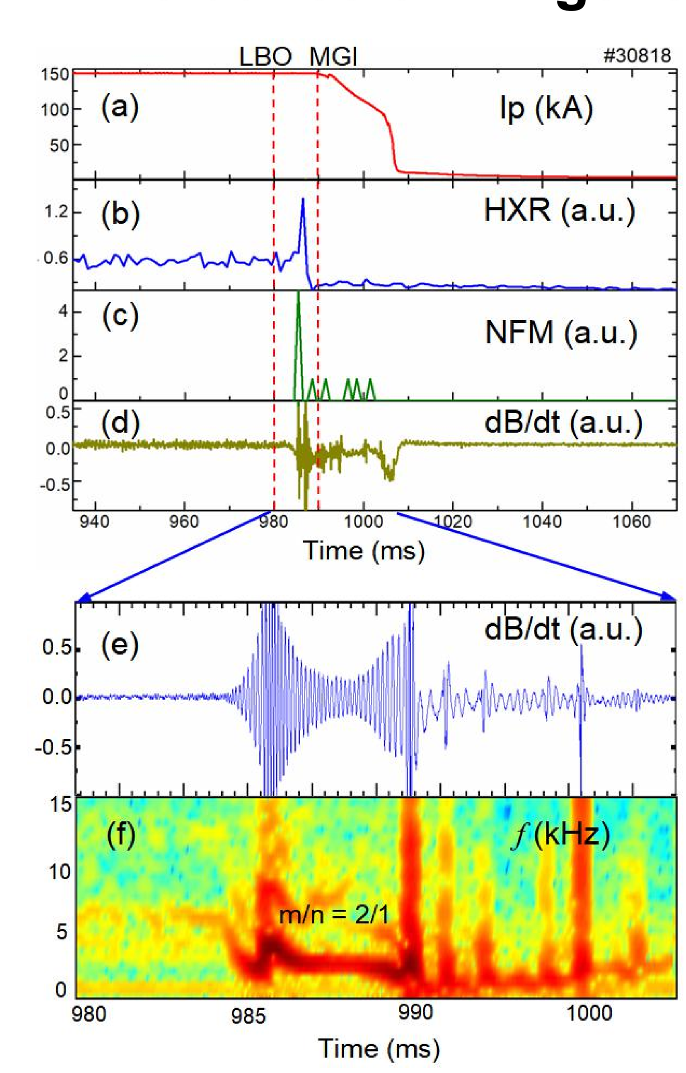
- ✓ Signals of the HXR radiation and neutron flux rapidly increases, implying that RE generation is enhanced.
- ✓ The fast electrons produced by LHCD extend to 60 keV, which exceeds the critical energy for runaway.
- ✓ RE generation enhancement comes from the synergetic effects of Dreicer and avalanche RE generation.

- ✓ A runaway current plateau was formed during the current quench phase.
- ✓ Compared with the disruptions without LHCD, that with LHCD is very easy to generate the runaway current plateau.
- ✓ Enhancement of disruption-produced RE generation is attributed to the conversion of the energetic electrons created by LHWs directly into REs through the hot tail mechanism.

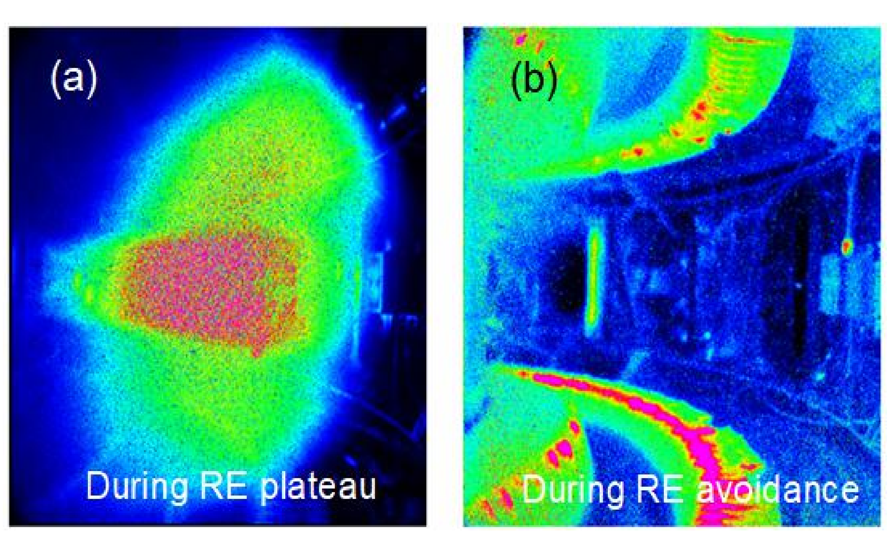


Enhancement of RE generation during disruptions with LHCD.

Avoidance of RE generation during disruptions with LBO



Avoidance of RE generation during disruptions with LBO.



Comparison of RE beam images during disruptions without (a) and with (b) LBO

- ✓ Strong magnetic fluctuation was excited about 5 ms after LBO.
- ✓ The poloidal and toroidal mode numbers are m/n=2/1.
- ✓ The "seed" electrons that form the RE beam are "killed" by LBO.

Conclusions

- Effects of LHCD and LBO on RE dynamics during disruptions have been systematically investigated.
- A runaway current plateau is easy to be formed during a disruption with LHCD, which is attributed to the conversion of the energetic electrons created by LHWs into REs through the hot tail mechanism.
- RE generation during disruptions has been successfully avoided for the first time by the LBO-seeded impurity. Strong magnetic fluctuation (m/n=2/1) was excited about 5 ms after LBO, which causes almost all energetic electrons are lost.

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