Measurement of Disruptive Runaway Electrons by Synchrotron Radiation

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Runaways and Disruptions

Disruption is a sudden loss of the energy confine in the plasma. It is a major concern for future tokamak operation because of their effects on wall compenents.

The generation and loss of runaway electrons (REs) following disruptions have potentially serious consequences in large tokamaks if the electrons are dumped into the plasma facing surface[1].

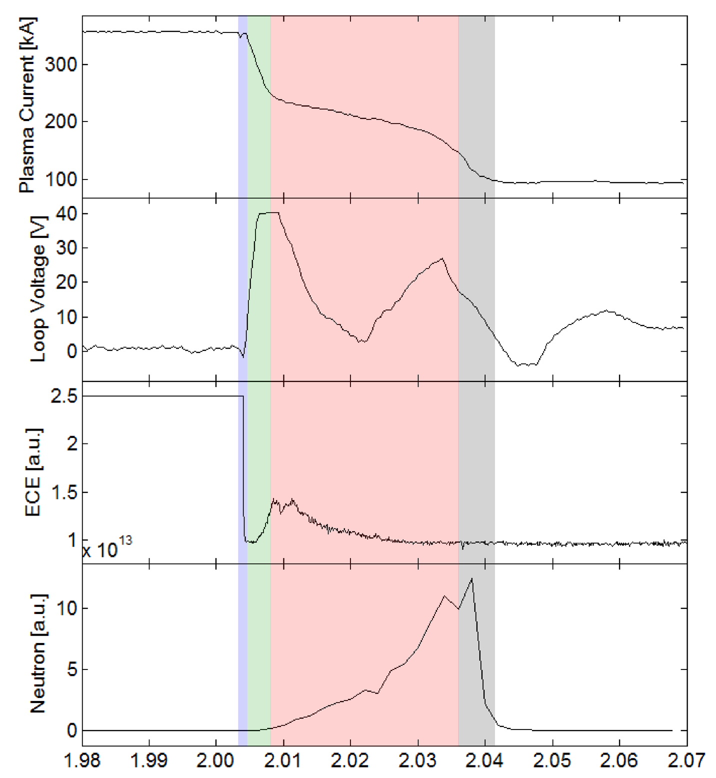


Figure 1. Temporal evolution of (top to bottom) plasma current, loop voltage, ECE and neutron signal during an induced disruption.

- Negative V_{loop} spike
- T_e drops
- High plasma resistance
- Vloop increases
- RE seed formation
- REs build up
- REs acquire MeV energies
- Confinent loss
- REs are dumped onto PFC

Diagnostic Method

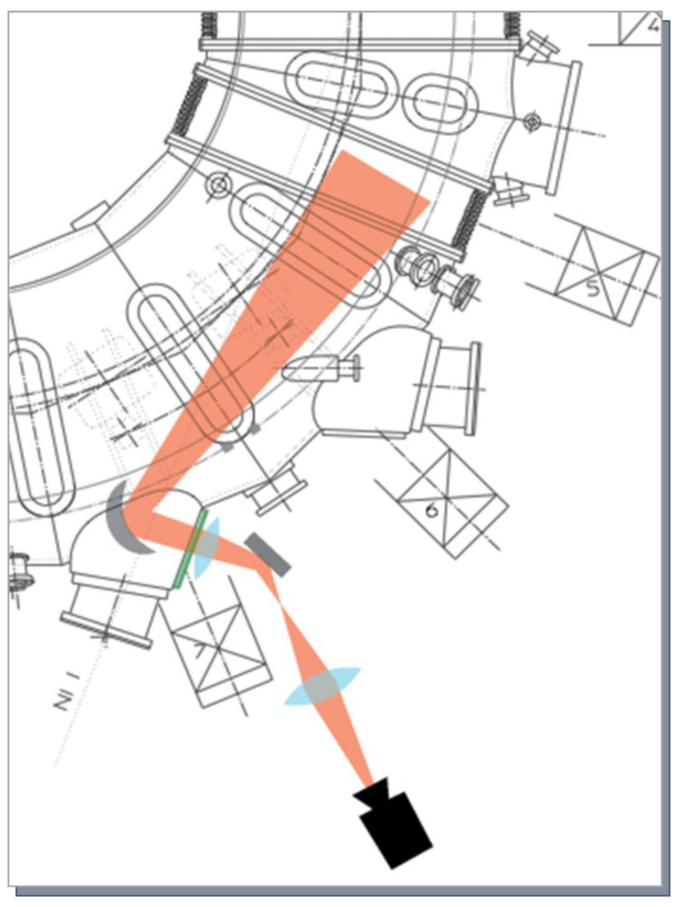


Figure 2. Schematic top view of TEXTOR with experimental setup for synchrotron measurement

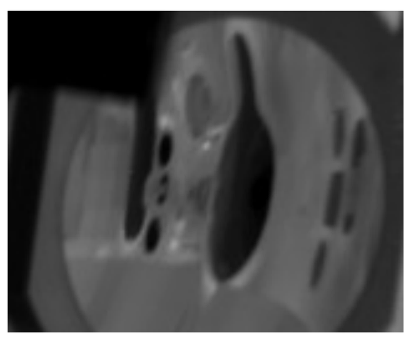


Figure 3. IR-Camera viewe area

IR-camera is located in the equatorial plane and observes plasma tangentially in the electron approach direction. This enables the observation of the confined REs.

In the current study, disruptions were induced by argon injection at 2 s after the startup[2]. This procudure garantees the generation of a substantial number of REs.

Runaway Electron Current

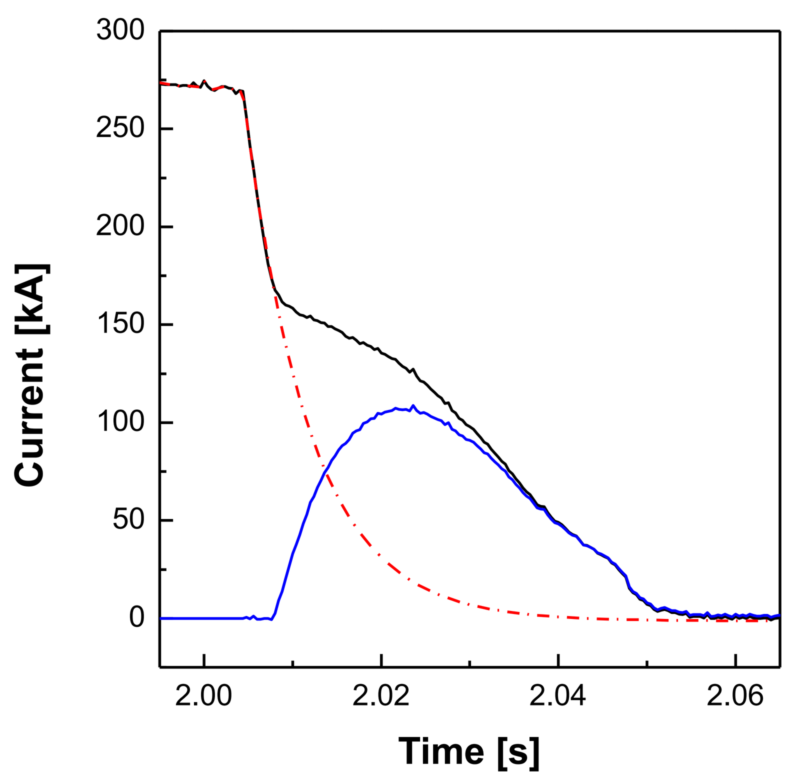


Figure 5. Temporal evolution of the plasma current

I_p : total plasma current

I_{th} : current carried by thermal plasma

I_{re} : runaway current $= I_p - I_{th}$

References

[1] R.D. Gill, Nucl. Fusion **33**, 1613 (1993)

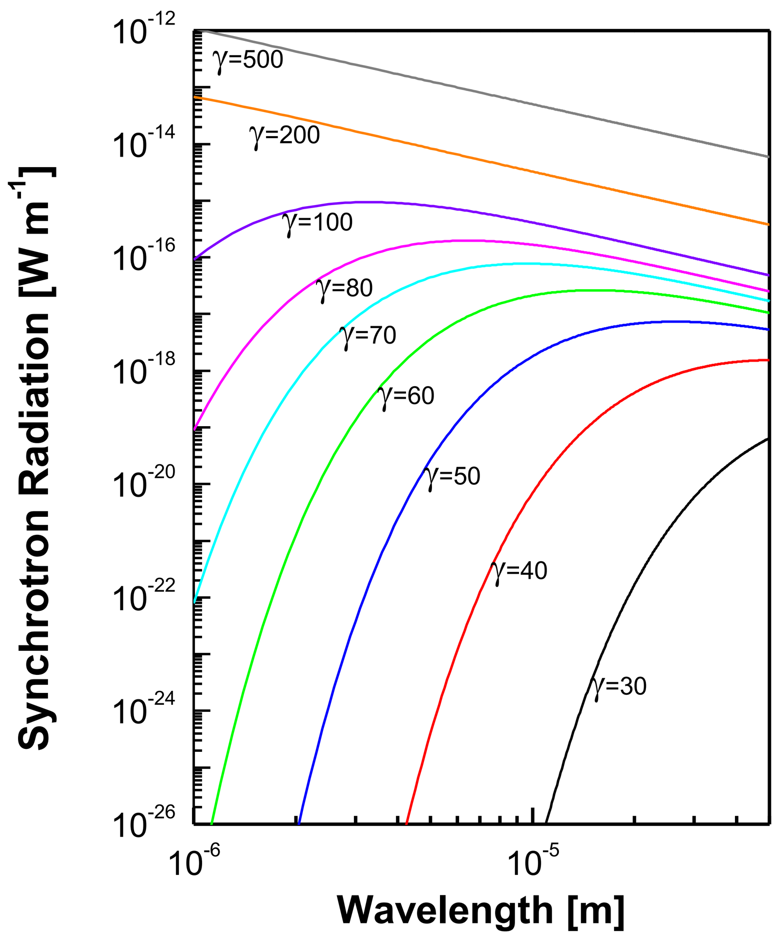
[2] M. Forster, et al., Phys. Plasmas **19**, 092513 (2012)

[3] R. Jaspers, N.J. Lopes Cardozo, F.C. Schueller, et al, Nucl. Fusion **36**, 367 (1996)

[4] J. SCHWINGER, Phys. Rev. **75**,1912(1949)

[5] K.H. Finken, J.G. Watkins, D. Rusbuldt, et al, Nucl. Fusion **30**, 859 (1990)

Spectrum of monoenergetic electrons



As follows from Maxwell theory, REs with energy greater than 25 MeV emit synchrotron as a result of their helical orbit. The power emitted by one electron per wavelength interval is[4,5]

$$P_\lambda = \frac{4\pi\, m_0 c^3}{\sqrt{3}\,\gamma^2 \lambda^3}\int_w^\infty K_{5/3}(x)dx$$

$$w = \frac{4\pi R}{3\lambda\gamma^3}$$

Figure 3. Spectrum of the synchrotron raditation for monoenergetic electrons

Synchrotron Radiation

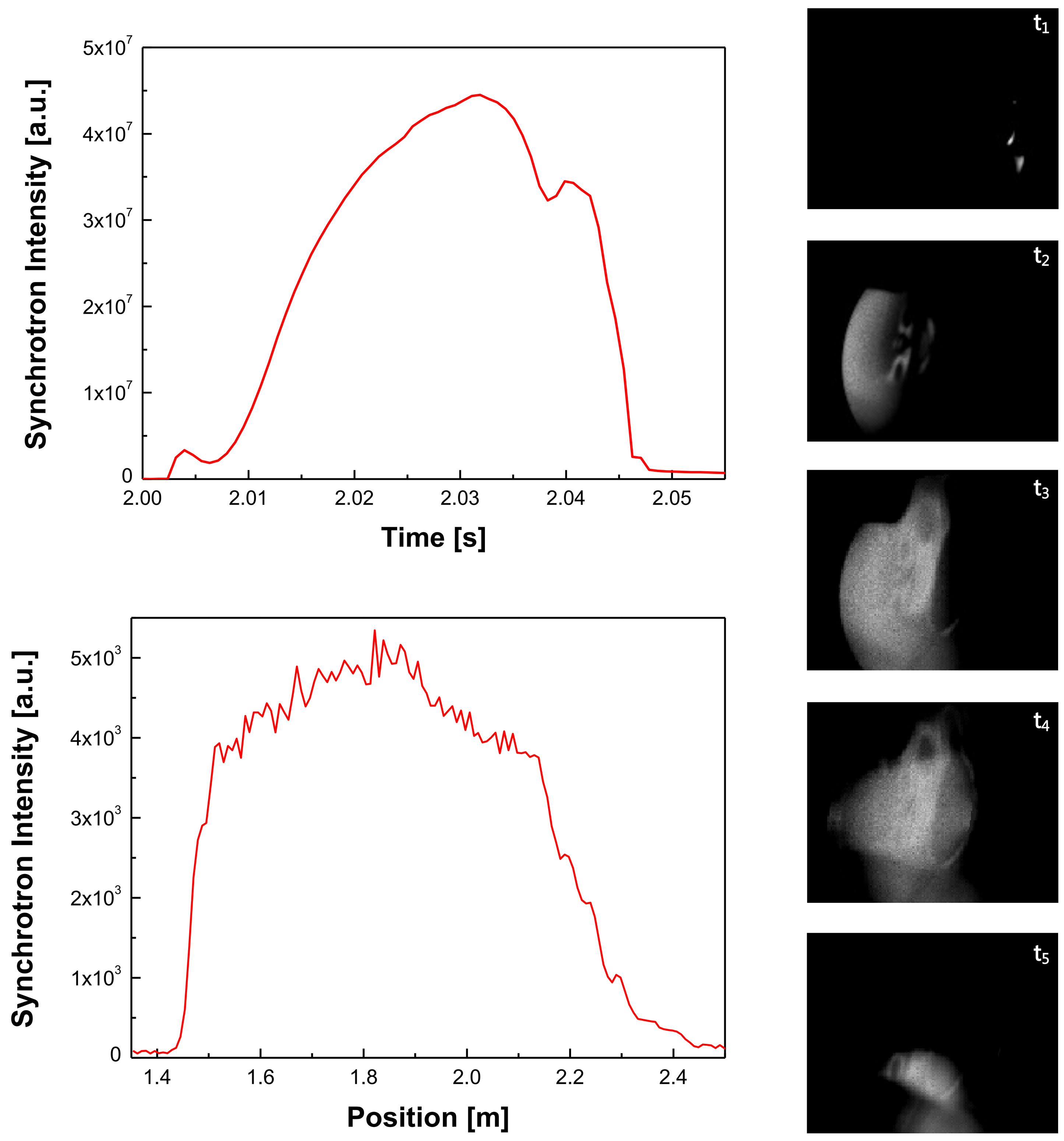


Figure 4 - Left : (top) Temporal evolution of the synchrotron intensity summed over all pixels. (bottom) Spatial distribution of the sychrotron intensity at t= 2.040 s

Right: Observation of synchrotron radiation during disruption. Picture taken at (top to bottom) t_1=2.013 s , t_2=2.022s , t_3=2.031 s , t_4=2.040 s and t_5=2.049s

Runaway Electron Parameters

Pitch Angle [3]	24	mrad
Radius of RE beam	0.32	m
Number of high energy REs	1.0×10^{16}	
Maximum Runaway Current	108	kA
Total number of REs	2.5×10^{16}	
Energy of REs	24	MeV