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Max Planck Institute for Plasma Physics

First experience with the W7-X Fast Interlock System

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Motivation

The first practical experiences with the central Fast Interlock system (cFIS) have been gained during the operation phase 1.2b in summer 2018. Next to the proof of a satisfactory reaction, scalability and operability, the focus also was on the assessment of the response times resulting from various safety-relevant plasma diagnostics.

Success

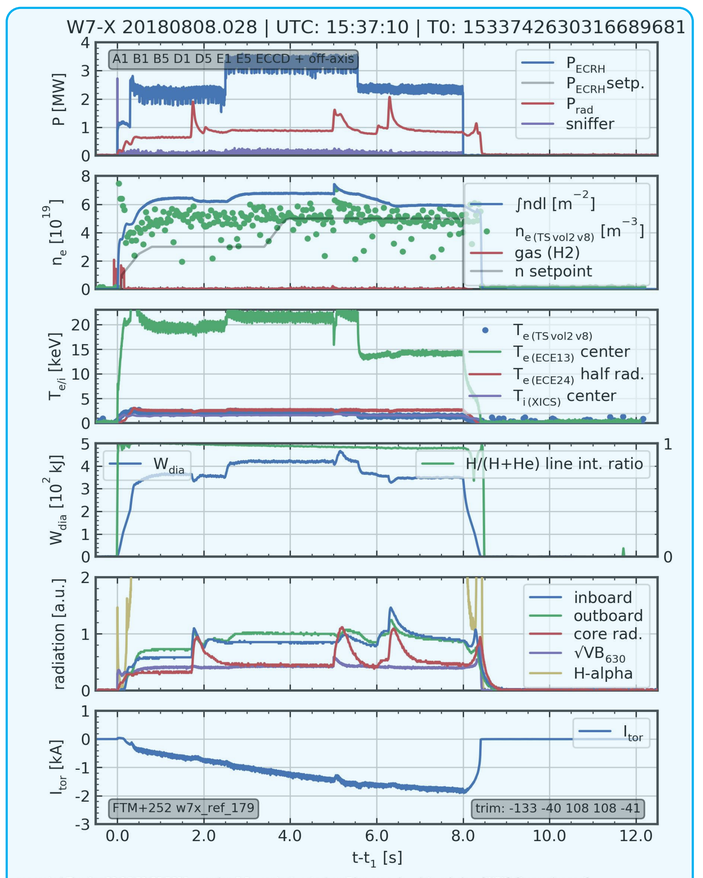
- Already during the first week after activation 22 of 115 plasma discharges were stopped by the intervention of the cFIS.
- The response time of the cFIS is sufficient.
- The fast shut-off of the heating systems within 5 µs by blocking the insulated-gate bipolar transistor (IGBT) in the high voltage modules worked reliably.
- All interventions by the cFIS were well-founded. False alarms were not observed.
- Usability for the cFIS operator was satisfactory; parameter setting concept is safe and convenient.
- Diagnostics for ECRH stray radiation, diamagnetic energy, and plasma density worked very reliable.

Improvements

- ECE-diagnostic could not communicate with the cFIS due to a missing connection via the fast control station, but worked stand-alone properly.
- Some temperature drift and signal artefacts (after the discharge) at the diamagnetic loops must be eliminated.
- It seems that there were sometimes jitters in the signal generation of the diagnostics; a detailed analysis was not possible

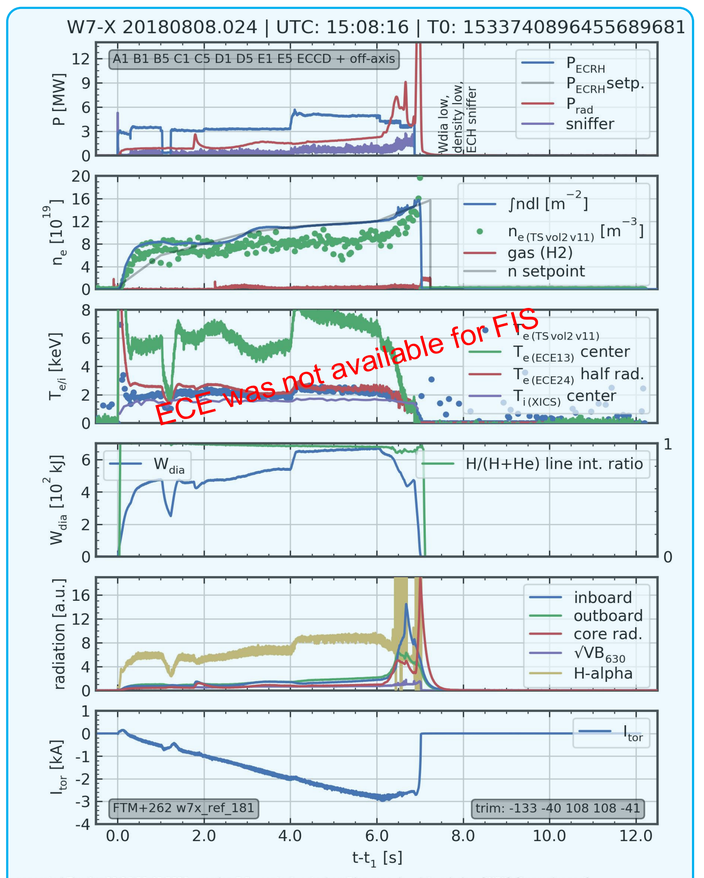
  → Add real time recording of data and events in the cFIS for subsequent analyses
- Unification of the interfaces between heating systems and cFIS (unified "request ←→ release"-mechanism)
- Removal of some timing constraints in the cFIS (implemented as a precaution into the first version)

  → aiming at a strict focus on safety-relevant parameters



Magnetic field Main field: FTM Main field reference: 1-AA78-T1067
Heating ECRH: 5,05 MW energy: 34,9 MJ planned duration: 8 sec

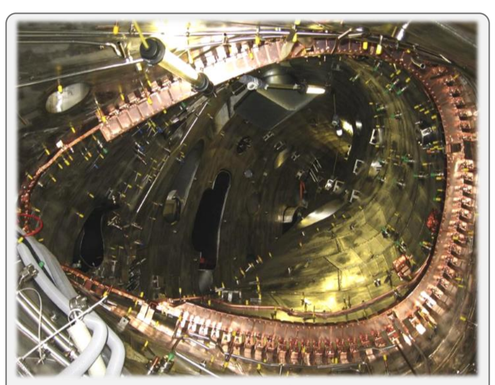
Plasma decay after end of ECRH heating (w.o. cFIS intervention)



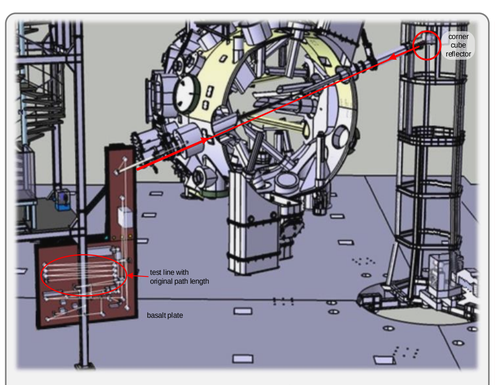
Magnetic field Main field: FTM Main field reference: 1-AA78-T1067
Heating ECRH: 5,67 MW energy: 34,5 MJ planned duration: 8 sec

radiation from the plasma gets too high at 6 sec. → the electron temperature drops (but ECE was not active) → fast drop of diamagnetic energy → ECRH shut-off by cFIS

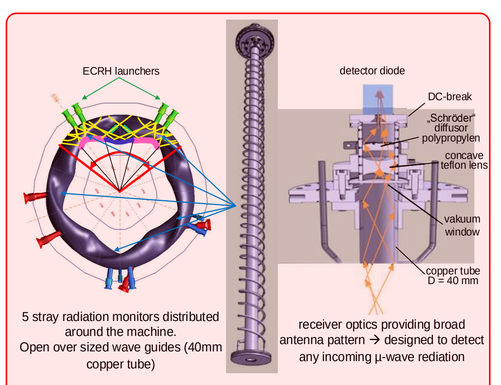
Radiation collapse with intervention by the cFIS



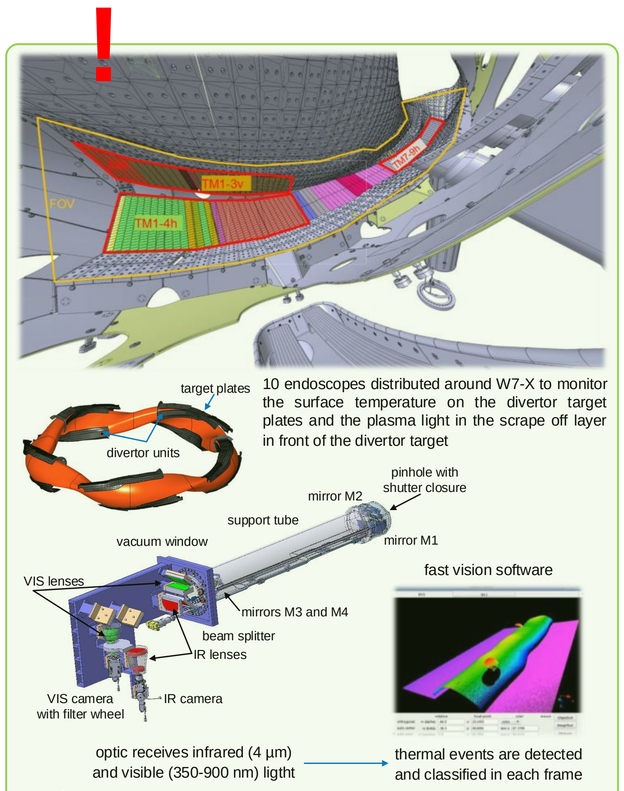
Diamagnetic Energy



Single Channel Interferometer (dispersion interferometer)



ECRH Stray Radiation

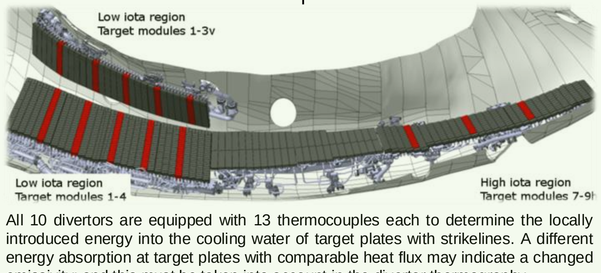


pre-alert
→ move the strike-line or reduce heating power

typical interlock scenario
→ T exceeds a certain threshold (different from target to target)
→ interlock within ≤ 100 ms

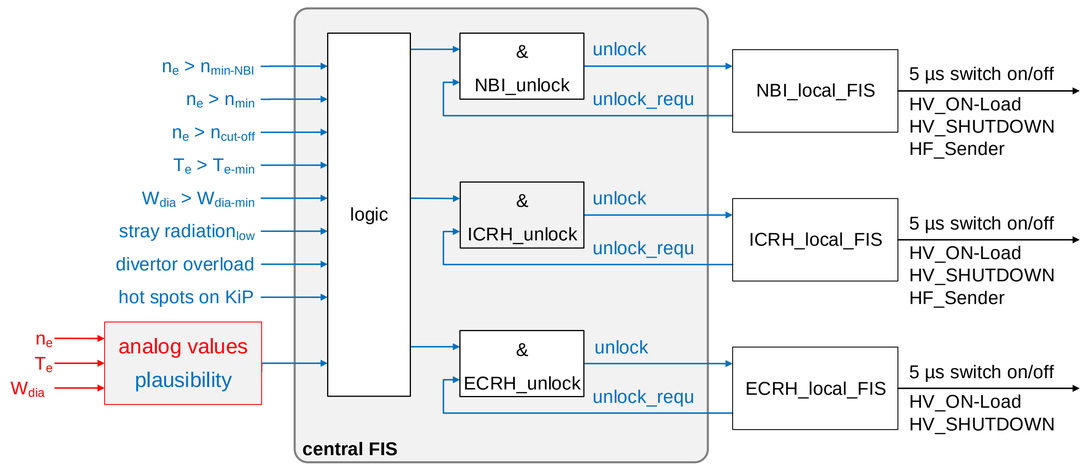
Divertor Thermography

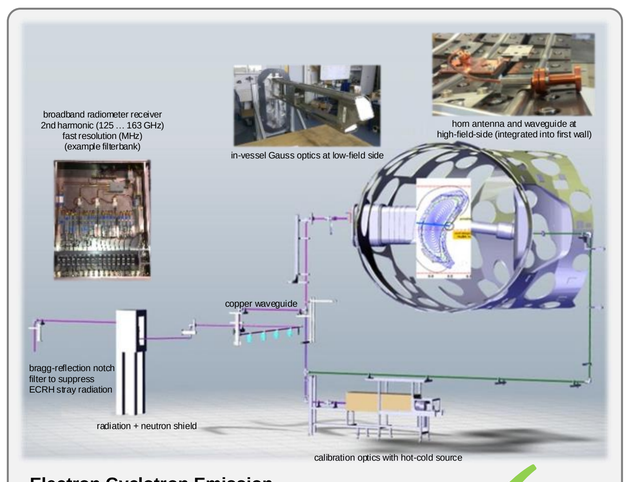
estimated emissivity ε



All 10 divertors are equipped with 13 thermocouples each to determine the locally introduced energy into the cooling water of target plates with strikelines. A different energy absorption at target plates with comparable heat flux may indicate a changed emissivity; and this must be taken into account in the divertor thermography.
Asymmetrical behaviour may be induced by increasing delamination or deposition processes.

Divertor Calorimety

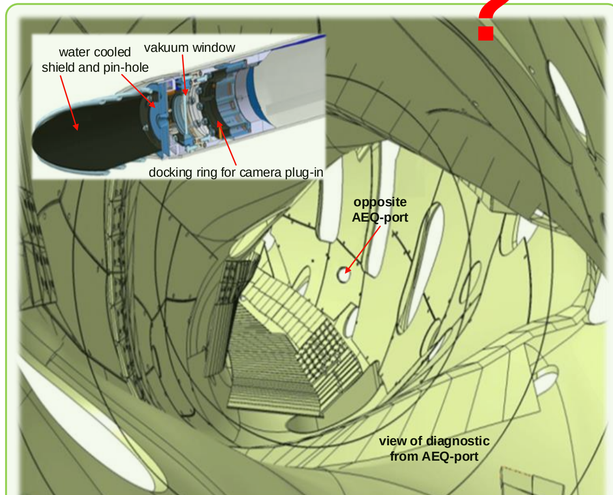




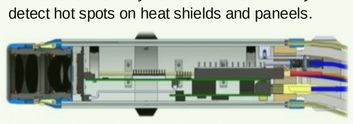
Electron Cyclotron Emission

Upgrade

- New heating system ICRH (Ion Cyclotron Resonance Heating) must be connected to the cFIS
- Implementation of Divertor Thermography to avoid overload of plasma facing components
- The increasing number of heating systems and safety-relevant diagnostics demands
  - either to cascade the used Boolean processor,
  - or to change the system in general;
    the XFC-Sytem – eXtreme Fast Control Technology by Beckhoff with ultra high speed I/O terminals, EtherCAT and software TwinCAT is under investigation, I/O response time < 100 µs.
- Integration of Video Diagnostic is under discussion due to the question, whether safety-relevant data can be extracted fast enough.



10 video camera systems are distributed symmetrically around W7-X (AEQ-Ports) to detect hot spots on heat shields and paneels.



Plug-in with optics and EDICAM video camera system

The "EDICAM Image Processing and Control Unit" directly behind the CMOS chip controls the camera head and performs real time analyses of video data.

Video Diagnostic

[1] *R. Vilbrandt et. al., First version of the W7-X Fast Interlock System, Poster P1.011, 30th SOFT, Sept. 16-21, 2018, Giardini Naxos, Italy*

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