Real-Time Machine Protection at ASDEX Upgrade with Near Infrared Cameras

S. Martinov, B. Sieglin, T. Lunt, R. Drube, A. Herrmann, and the ASDEX Upgrade Team

Max-Planck-Institut für Plasmaphysik, EURATOM Association,
Boltzmannstr. 2, 85748 Garching, Germany

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Outline

• Introduction
• Hardware
  – Cameras
  – Data Acquisition System
• Software
  – Acquisition Framework
  – Neutron Filter
  – Offline Data Analyse Tool
• Summary and Outlook
Introduction / motivation

- The first wall in ASDEX Upgrade is exposed to high heat fluxes from the plasma. In order to protect the first wall from overheating a real time system surveilling the entire surface is needed.

- Visible cameras are used.
  - Sensitive in near infrared (NIR) area (from 900 K)
  - Cheap and widely available

- Currently a system based on analog cameras is used. Replacement is needed due to deprecation of cameras.

- Change to fully digital cameras
  - Remote and real time configuration of cameras
  - Higher spatial, temporal and dynamic resolution compared to analog cameras
  - Flexible use of camera types due to industry standard connection (CameraLink)

- Development and commissioning of new real time protection system
System Overview
System Overview

- Live view
  - Streaming
- Configuration system & offline post-processing
- Real-time systems
- Discharge Control System
- Central storage
- Offline video analysis
- Augtv
- Central timer
- Triggers & Alarms
- CameraLink
- Galvanically isolated torus hall
- Cameras
Environment in the ASDEX Upgrade torus hall

Magnetic fields
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Radiation

Limited space

Thermal load

40 mm
Hardware

Camera

JAI CM-030PMCL-RH

- 120 fps
- 10 bits
- monocrome
- 800 €

Camera head  Ø 17 mm

Controller

open/digital  NIR/digital

open/analog  NIR/analog

water cooling
System Overview

[Diagram showing the system overview with blocks for live view, configuration system & offline post processing, real-time systems, Discharge Control System, central storage, offline video analysis, augtv, central timer, and cameras. The connections include streaming, config files, data, Triggers & Alarms, and CameraLink.]
Software / Hardware

Challenges

• Large amounts of data (30 cameras x 659x494 pixels x 120 fps x 2 bytes/Pixel = 2.4 Gb/s) need to be processed in real time.

• Neutrons induce noise
  → Filtering of the image is required

• High reliability, suppression of
  – false positive alarms
  – false negative alarms

• Interaction with the ASDEX Upgrade discharge control system.

• Graphical user interface to check when and where alarm occurred.
Software / Hardware

System

- Standard industry computer
  - Timing Card (ASDEX Upgrade Timing Distribution System)
  - 2x PCIe FrameGrabber Cards (NI-1430)
  - SSD Hard Drive

- As Operating System LabVIEW RT is used.

- LabVIEW is a commercial framework which contains standard video acquisition components and drivers. No hardware-near programming is required.
Software
Data Processing Algorithms

- Time critical code written in C.
- Supports visible, NIR, IR cameras.
- Set of different correction and evaluation functions are available.
Software
Data Processing Algorithms

RAW Correction Functions
- Copy
- Byte Swapping
- Value Inversion

SSD

Frame

RAW Correction Buffer

Correction Functions
- Neutron Filter
- Gain Offset Correct
- Dead Pixel Correct

Evaluation Functions
- Hotspot detection
- Histogram
- Adapt Integration Time
- Temperature profile

DCS
Top-down view of the divertor
1. Find the minimum of:
   - Current pixel value
   - Neighboring pixel values
   - Previous frame pixel value

2. Result is stored into the correction buffer
Software
Correction – Neutron Filter

Without Neutron Filter

With Neutron Filter

Hotspot
System Overview
Software

augtv

• Offline tool for experiment leader to investigate alarms.

• Overview of 30 cameras.

• Region of Interest color coding
  – Blue: defined but deactivated.
  – Green: defined and activated.
  – Red: defined, activated and triggered an alarm.
Summary

• Suitable camera type selected and tested.

• Developed a real time protection system for operating digital cameras.

• Real time monitoring of plasma facing components.

• Filtering of noise induced by neutron radiation.

• Graphical user interface for accessing video and alarm status data.
Outlook

• Testing and commission of system on ASDEX Upgrade.

• Validate reliability of the system for robust machine protection.

• Unified acquisition configuration for visible, NIR and IR cameras.

• Switching to NI Linux RT Operating System.