Wendelstein 7-X

NEWSLETTER

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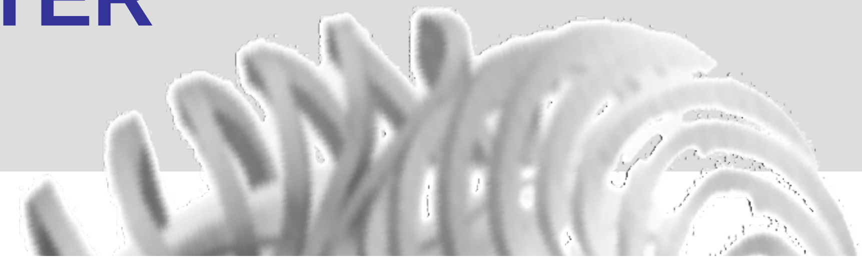

Europe and Wendelstein 7-X

An example of European collaboration

Collaboration in European fusion research has a long history: In 1961, IPP became an associate of the European Fusion Programme, which comprised the fusion laboratories of the European Union and Switzerland. In the 1970s, the European fusion laboratories decided to build and operate the Joint European Torus (JET). In 2014, the programme was restructured and EUROfusion formed as a consortium of 29 national fusion laboratories (Research Units). A goal of this reorganization is to efficiently implement a roadmap to the realization of fusion energy. The roadmap has been developed within a goal-oriented approach articulated in eight different missions – mission 8 focuses on the stellarator. It also prioritises the financing of the Fusion Programme.

In mission 8, the stellarator line as an alternative concept for fusion electricity is being developed. The European works concentrate on optimised stellarators based on the HELIAS principle – a stellarator line which was invented and developed at IPP. Wendelstein 7-X is a cornerstone of this line which is decisive for mission 8 and which will give answers to fundamental questions in plasma physics at the same time. Consequently, the project has taken over a leading role in the field of three-dimensional confinement and related technological developments. The scientific appeal, the strategic role as synergy carrier (e.g. for ITER) and alternative solutions of the stellarator for potential scientific risks in other fields, make the Wendelstein 7-X an integral component of the European fusion research.

The stellarator work package also includes theory and modelling and the preparation of experimental programmes, benefitting from the smaller, but easier-to-access device TJ-II in Spain.

Map: cc by www.euro-fusion.org

The members of the EUROfusion consortium are 29 national Research Units representing Europe's fusion laboratories. www.euro-fusion.org

A backbone of European participation in W7-X is the delivery and operation of scientific instruments and diagnostics. At this point, the project W7-X benefits from the European expertise for the development of specialized, high-tech components. More than twelve European Research Units are participating in the work programme of W7-X in 2015. For more than 20 years, there has been collaboration between the IPP and the Hungarian partners at the Plasma Physics Department of the Wigner Research Centre for Physics. The Hungarian video camera system is a prominent example of how Wendelstein 7-X benefits from European high-tech.

Event Detection Intelligent Camera (EDICAM) for real-time plasma diagnostics and control at Wendelstein 7-X

Safety first

Wendelstein 7-X will allow quasi steady-state operation – very long discharges are considered to be a prerequisite for any economic fusion reactor. Though expected to be quiescent, long pulses over tens of minutes may give rise to local overheating. The detection of such pulse-limiting events will allow protective measures to be implemented and operational problems to be avoided.

The aim of the EDICAM project is to develop and operate a special fast camera system for Wendelstein 7-X. The main challenge the Hungarian scientists faced was the versatility such a system requires: It has to provide an overview video about the full cross-section of the stellarator; it has to be fast enough to record plasma phenomena changing in less than one-thousandth of a second; and the film has to cover the whole plasma discharge, lasting up to half-an-hour. The camera system must be able to protect the W7-X machine by detecting unwanted operational states when the plasma touches structural elements and communicating this to the plasma control system. Additionally, the cameras have to operate in the harsh environment of a high magnetic field and irradiation by hot surrounding surfaces.

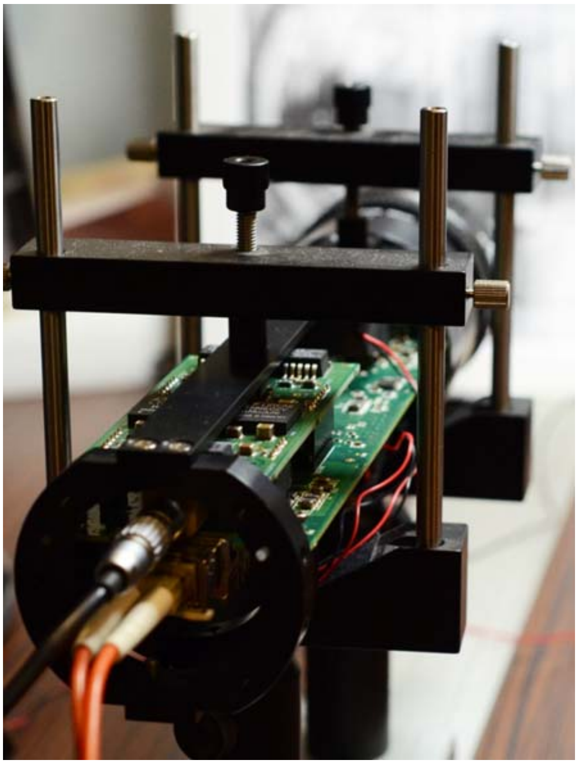

Photo: Wigner Research Centre for Physics

The camera head of the EDICAM diagnostic system will be situated close to the plasma. This hardware is responsible to take the images from the inside of the W7-X and will transfer image data through a 100 meters long optical cable to the diagnostic hall where one computer for each camera gathers the data and processes it for transfer to a live video stream in the control room.

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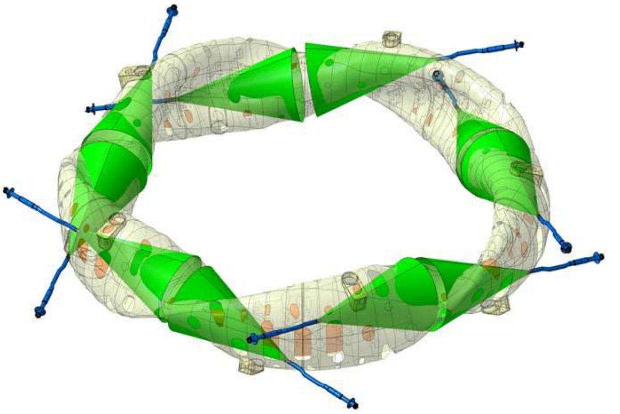
Intelligent surveillance

Even if one had such a camera, the problem of storage space would be overwhelming. Fast cameras are usually used for very short-time intervals, fractions of a second, but even then they can produce 10 GB of data – and W7-X will operate for 1800 seconds. To make things even worse, not only one but 10 cameras are necessary to be able to monitor all inner surfaces of the machine. These problems were overcome by two innovative ideas.

The first idea was to completely change the way how the fast camera should work: instead of collecting the data passively and then processing it off-line after the experiment, a real-time analysis should be carried out while the camera is running. In fact, events happening in the plasma at the very moment should be able to *influence* the camera operation. Given such a system, the problem of storage space is also handled: the camera can detect interesting events and can be set up to store only these, dropping all other frames containing no valuable information. This functionality inspired the name of this device, the Event Detection Intelligent CAMera, EDICAM. The detected events, if regarded as relevant, can be communicated to the plasma control system, which can take measures to protect the fusion plant.

The other unique idea is to use a special CMOS sensor with the so-called non-destructive readout (NDR) capability. A normal camera sensor is erased when the image is read out from it, and then the recording of the next frame is started. Such a sensor is also erased even when only a small part of the sensor, the “region-of-interest” or “ROI”, is read out.

In EDICAM, it is possible to read out a small part of the sensor. This is possible several times without affecting the recording of the full frame. This means that a small-sized movie can be recorded *simultaneously* while the full-sized movie is recorded too.
The small movie will contain only a part of the whole picture which is interesting to the scientists. The EDICAM is capable of handling up to four ROIs. This is as if a TV-camera, transmitting a football game, had four built-in slow-motion cameras, zooming into different areas of the playing field.



Graphic: CAD, IPP-Greifswald DC

The videodiagnostic system at W7-X: Ten cameras in the blue marked ports, will have the green shaded viewing-cones and observe the complete inside of the vessel.

This feature solves the speed problem: while the whole inner wall of Wendelstein 7-X is monitored at a low speed, some components of the machine can be viewed 100 -1000 times faster, providing an extremely short reaction time for the event detection. Speed, light intensity and the NDR capability are much more important for scientists than colour; therefore, the special camera sensor gives a black-and-white image. However, it can differentiate between 4096 brightness levels, instead of the 256 in everyday cameras.

Processing fast camera video streams in real-time requires very high computational power. Therefore, the EDICAM system uses Field Programmable Gate Arrays (FPGAs) for data processing, as well as for the camera. These advanced microchips are as fast as real hardware chips, but their internal structure and resulting functionality are determined by a programme code loaded upon start-up. This enables the development and application of new features without hardware modifications.

The most important challenge the Hungarian scientists face now is to install the 10-camera system at W7-X, and get it running by the time the first plasma is generated.

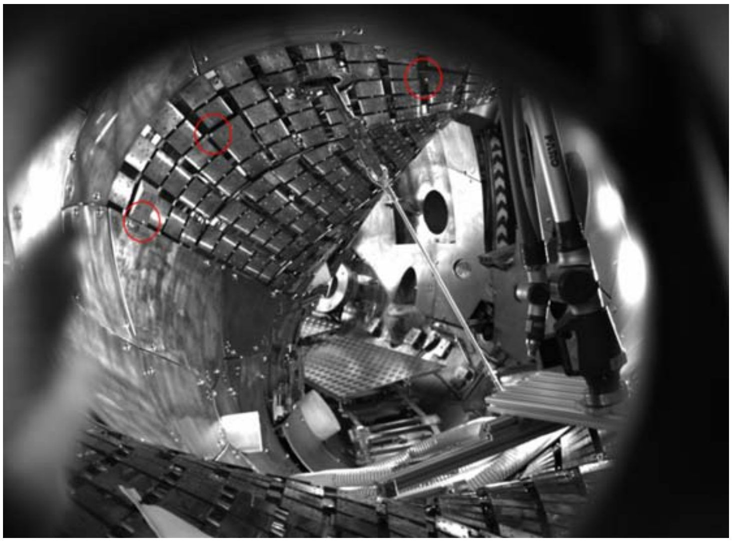


Photo: IPP Greifswald

Text EDICAM: T. Szepesi,
Wigner Research Centre for Physics,
Budapest, Hungary

View from the perspective of one camera taken during the assembly.

On the left you can see the heat sinks of the plasma vessel wall. The rod in the center is for the manipulator of the magnetic flux surface measurement. The three circles mark fiducial points for calibration.

Status Wendelstein 7-X

On 10th of March the Wendelstein 7-X was cooled down for the first time to 4 Kelvin, minus 269 degree Celcius. This is the precondition for the superconductivity of the magnetic coils and, thereby, an important milestone in the commissioning process was reached.

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