EFDA JET

JET Insight

Quarterly News & Views of Europe's largest Fusion Device

June 2010

The scientific outcome of JET is only as good as the participation of its members. Some 120 scientists from the European Associations, ITER and international collaborations joined the "1st General Planning Meeting" in March

Participation is important

JET is currently undergoing a vast refurbishment, installing a new ITER-Like Wall (ILW), together with neutral beam heating and diagnostic enhancements. Preparations for Experimental Campaigns to exploit these new capabilities had a successful launch at the "1st General Planning Meeting", held at JET on 1-5 March 2010.

EFDA Associate Leader Francesco Romanelli welcomed some 120 scientists to the meeting which was extremely well attended. In his opening remarks he stressed that "This meeting is the first step into the preparation of the experimental programme in 2011 and beyond through the input from the European Fusion Laboratories" while the meetings organiser George Sips emphasised "It's your programme, your participation is important!"

Scientists from the European Associations, ITER and international collaborations discussed the main topics for research with the ILW for 2011 and beyond. The status of the JET shutdown and enhancements were reported, followed by discussions on priority areas and general discussions, allowing input on all relevant topics.

> *"This meeting is the first step into the preparation of the experimental programme in 2011 and beyond through the input from the European Fusion Laboratories."*
>
> *Francesco Romanelli*

It is clear from the 1st General Planning Meeting that JET, with its new enhancements, will provide conditions and constraints very similar to those expected in ITER. There will be unrivalled scientific opportunities from the very start of wall conditioning right through to full power operation. Hence, key results are expected in 2011 and 2012 will provide timely input to ITER.

Now the challenge is to draw up a detailed plan of the 2011 campaigns and an outline of the programme beyond 2011. Following the General Planning meeting, the two Task Forces E1 and E2 have started regular meetings, often in smaller working groups, to develop coherent proposals for experiments to exploit the new JET capabilities fully. It is planned to finalise the ideas and proposals by October and a "2nd General Planning Meeting" is scheduled for 15 -19 November 2010. So active participation of the European partners is vital to the success of this extraordinary European experiment.

George Sips

Main article in this issue
" Protect the **ITER-Like** Wall"

JET is currently in shutdown to maintain and refurbish the experiment and to install the new ITER-Like Wall. The new wall requires an accompanying programme to establish operational procedures such as to avoid damaging the tiles. That is why in October 2009 the "Protection of the ITER-Like Wall" (PIW) project was launched. It includes the development of improved temperature measurements, real time analysis and adjustments in plasma and heating system control software. The JET operator has taken on most of the tasks and a call for proposals has been sent out for additional expertise from the associations.

Protect the **ITER-Like** Wall

Paradigm shift in protection

The ITER-Like Wall being installed in JET's vessel changes the main characteristics of the experiment. The new tiles are made of beryllium or tungsten instead of carbon, in order to avoid the drawback of tritium retention by the formation of hydrocarbons. These metal tiles are, unlike carbon, prone to melt when exposed to excessive local heat loads. In addition, most of the tungsten tiles in the divertor are in fact not bulk tungsten, but Carbon Fibre Composites coated with tungsten, which can crack and flake off. Such damage would expose the carbon.

In JET's former carbon age protection of the experiment was highly developed. Since April 1997 we have not had to open the vessel to recover and replace damaged or dislocated tiles. To maintain this high level of safe and efficient operation, additional protection strategies are being developed for the new quality type of wall materials.

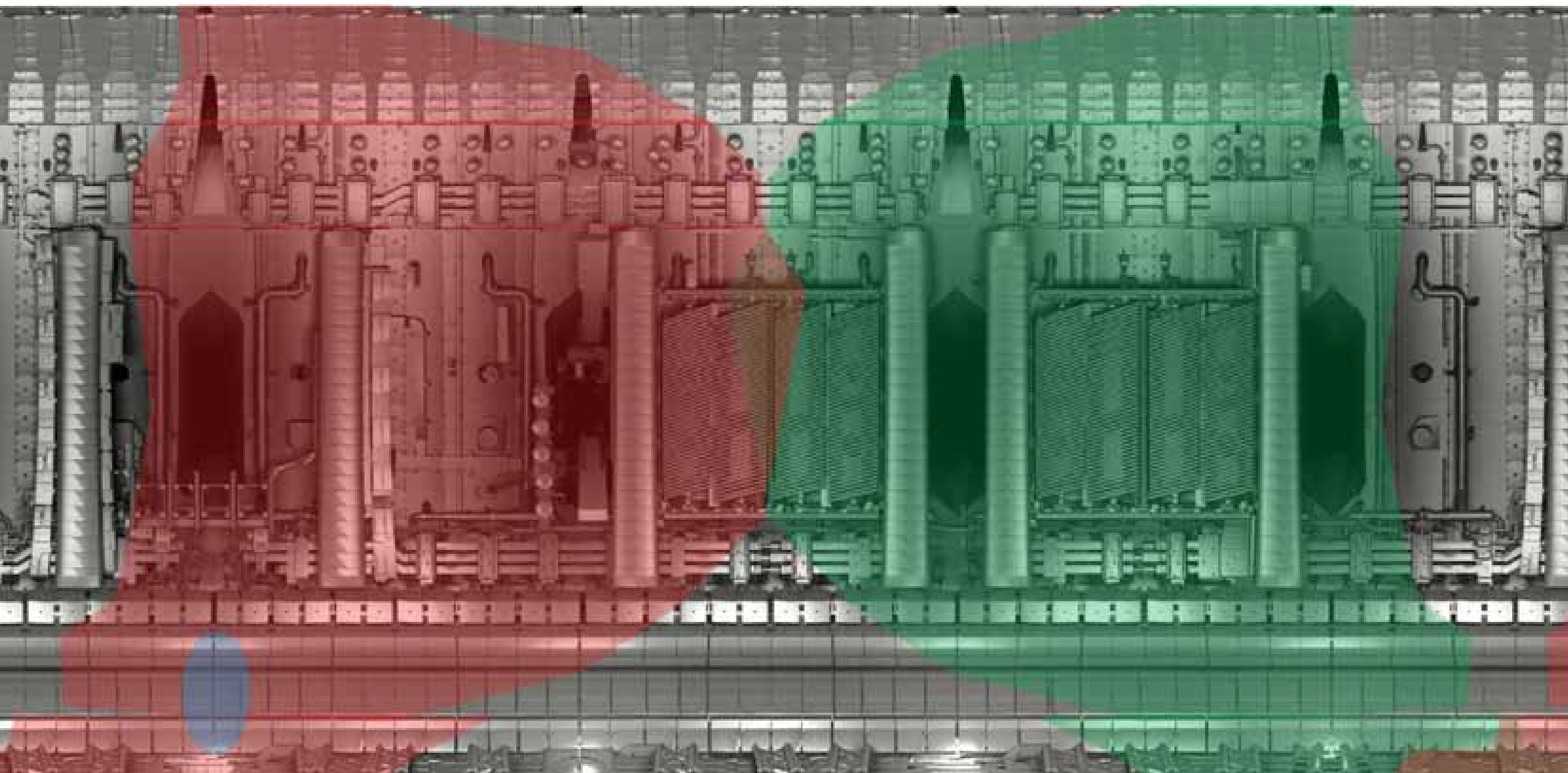
In general the protection software is based on simple, validated diagnostic data and plasma models. The protection is fairly draconian: If the software detects characteristics of plasma disruptions for example the experiment is stopped immediately. On the one hand, some erosion of the wall is accepted to protect against more severe events like disruptions and coil overheating. In these cases the plasma is extinguished deliberately on the inner wall. On the other hand, each "stop" represents a risk in itself and must be avoided as far as possible.

Advanced stop sequences are being developed to protect JET's new metal wall. These stops involve a degree of control not previously required. In other words, there will be an additional layer of control software running on top of the old one. The new protection philosophy is key to achieve the given experimental goals and moreover to minimise down time. In an early stage of the ITER-Like Wall programme, it will be essential to avoid exposure of the bulk Carbon Fibre Composites due to erosion or melting of the tungsten coating. Diagnostic data and plasma models to support this protection philosophy are more sophisticated and thus inherently less robust.

Detecting temperatures

In addition to the data based on observation, the protection includes surface temperature measurements. With the help of several infrared (IR)

The computer generated picture shows a view of the unfolded outer wall of JET through the eyes of infrared cameras. Green, turquoise and purple areas represent existing views of different quality, red earmarks the planned systems.



cameras a stop is initiated in real time if an area is about to reach a predefined limit. These limits are defined by beryllium melt thresholds, recrystallisation of bulk tungsten and damage to tungsten coatings.

A conservative approach with lower limits will probably be adopted initially, and raised later to 1,200° Celsius in most areas and potentially 2,200° Celsius for some of the divertor tiles much later in the programme. The IR cameras foreseen observe about half of the divertor and limiters, and all of the antennae in the vessel. This is sufficient since the surface temperature is expected to follow a repetitive symmetry.

To save money and time, cameras are fitted, wherever possible, to existing periscopes. For the same reason the cameras are of a different type from the far IR cameras presently used for physics studies. Instead simple cameras are used that are only sensitive in the near IR. This choice has some consequences for operation as these cameras have a low dynamic range: As a result the images are mostly black, and the wall appears gradually, as the temperature approaches the limits.

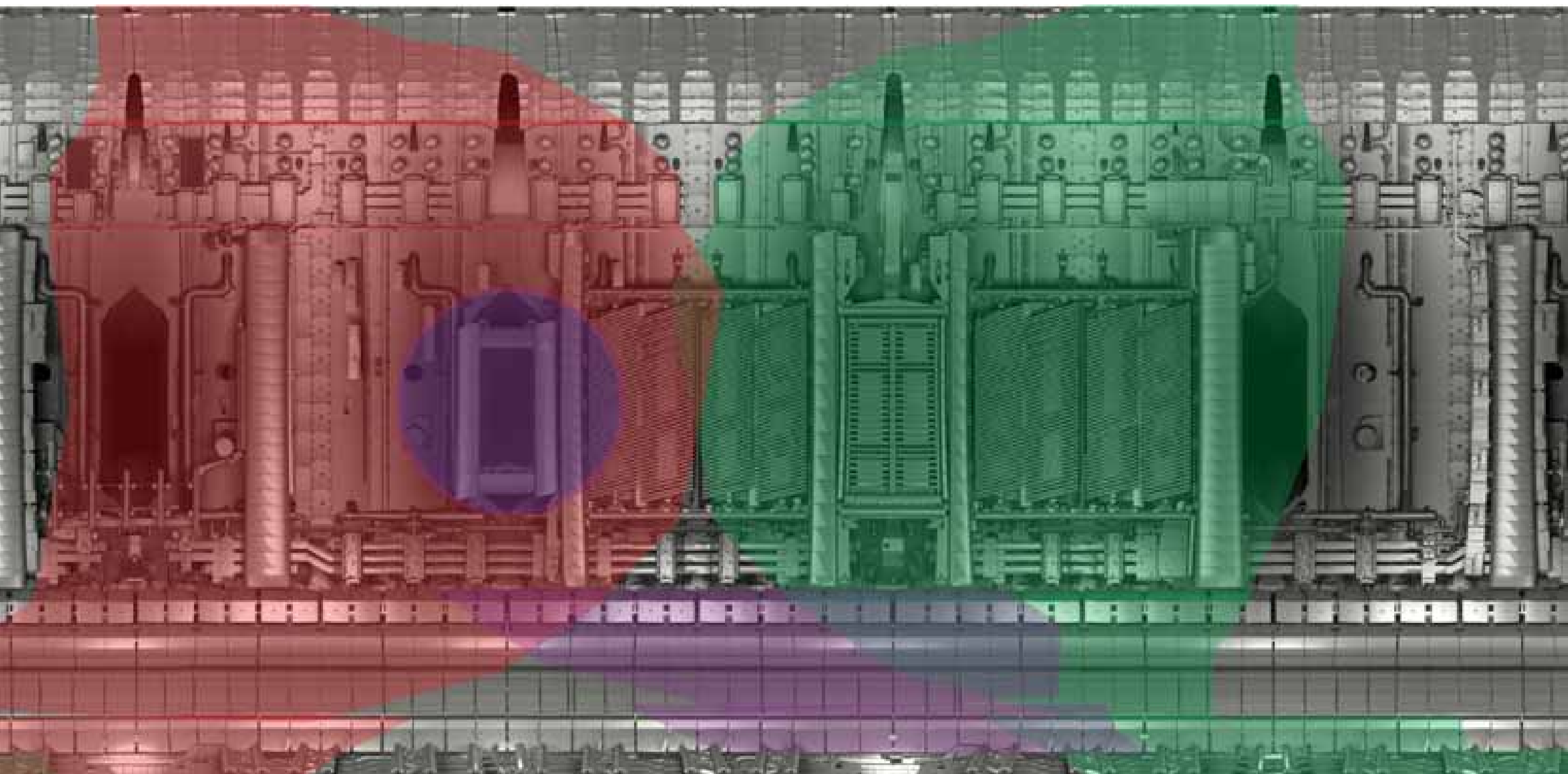
A long-term project

JET's first plasma with the ITER-Like Wall is expected in the spring of 2011. Not everything can and will be available on day-one. It would not even be useful!

Essential for day-one are the new stop sequences required to protect the wall. The experimental programme will proceed cautiously, with wall temperatures not getting near the limits for several months. The new visible cameras will start without the IR filters for commissioning, and be converted later in the year. More sophisticated control sequences are planned taking into account the experience gained while working with the new wall. Some of these sequences will probably become available only after the next Shutdown.

Many other projects are coming to an end with the first plasma in 2011. This is not true for the project "Protection of the ITER-Like Wall". It will continue for at least another two years to supply the control room team with all the necessary tools and to adjust the software in light of the experience gained operating with the new wall in its first year.

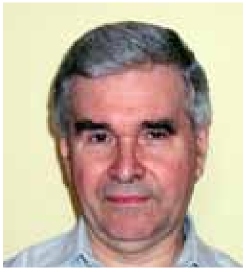
Klaus-Dieter Zastrow



Definitely a **success** story

The ITER-Like Wall, now being installed tile by tile in the JET vessel has produced many challenges. When the project "ITER-Like Wall" started, no reliable procedure was available to add tungsten or beryllium coatings to a porous Carbon-fibre composite (CFC) surface. Industry could not fulfil this need. Cristian Ruset and his colleagues from the National Institute for Laser, Plasma and Radiation Physics (NILPRP) of the Romanian Association MEdC, attended the very first project meeting. He and his team had been working in this research field for many years and they immediately recognised the opportunity to add their expertise to the project.

Because of the time pressure the project had to face, action was taken straightaway: Cristian and his colleagues proposed a method of coating CFC tiles with tungsten layers. With his proposal accepted, all that was needed at this stage was to find a test stand. With the help of Hans Maier and the IPP test stand GLADIS in Germany the first Romanian-made coatings passed the test easily. Encouraged by the positive results Cristian was asked to produce coatings twice as thick, which he did in a very convincing manner. Undoubtedly the "coating story" is a success demonstrating the advantage of working in a strong community. JET Insight talks to Cristian Ruset and Hans Maier.



Cristian Ruset

The physicist Cristian Ruset is the Responsible Officer for tungsten coating of CFC tiles for JET. He also worked in the field of plasma surface engineering and plasma nitriding.

Which challenges did you have to face in order to coat the tiles?

JET was looking for the best technology to be applied at industrial scale for tungsten coating of approx. 2,000 CFC tiles with layers of 10 and 200 micrometres. These coatings had to survive without delamination to intense thermal loading when the surface temperature reached 2,000 degree Celsius. This was a real challenge even for the 10 micrometre coatings. The reasons are the strong anisotropy of the material and the big difference in the thermal expansion coefficients between tungsten and substrate. These problems have been solved for the 10 micrometre coatings by using a technique called Combined Magnetron Sputtering and Ion Implantation (CMSII) which has been developed in my institute since 2001 for producing nano-structured coatings. In 2009 we faced a another challenge, when the 200 micrometres tungsten coating for divertor tiles had to be replaced by 20-25 micrometres deposited by CMSII.

You started your research at a bench scale. How difficult was it to change later on to an industrial scale?

It was not easy. The experimental coating unit had a small chamber and one magnetron. In order to handle tile dimensions and productivity we designed a new chamber approximately ten times as large equipped with 24 magnetrons and the corresponding power supply. Our team designed, built and commissioned the new industrial coating unit in approx. 18 months, which was a real record! That was possible with a great team of dedicated specialists in plasma physics, material science, mechanical and electrical engineering, vacuum technique and electronics. Talking about people, I have to mention the particular support from Hans Maier from IPP who deals with the high heat flux tests and Guy Matthews, ITER-Like Wall project leader at JET.

Do you think that these excellent results have any impact on other projects?

Yes. The CMSII technology was applied and successfully tested for tungsten coating of approximately 350 tiles for the ASDEX Upgrade tokamak at IPP Garching. As far as ITER is concerned, the current strategy for the divertor includes only bulk tungsten. It is possible that the future strategy will be influenced by the results obtained with the ITER-Like Wall at JET.

Hans Maier

Hans Maier, technical leader in the project, has been gathering experience on tungsten coatings at IPP since 1996. Since early 2005 he has been working on tungsten coatings on CFC for the ITER-Like Wall Project.

What did you see as the ingredients, for these successful results?

There was no technical solution available because of the thermo-mechanical incompatibility between tungsten and CFC. So the necessary activities were a combination of technology development and scientific work. Therefore experience in both science and technology was necessary. The whole scope of our abilities was required – from high heat flux testing via electron microscopy to analysis even with more specialised tools like X-ray photoelectron spectroscopy or nuclear reaction analysis.

What were your thoughts when you received the first sample of the tiles?

That depends on what you consider to be the "first sample". Actually the first tile material I received 5 years ago was a batch of 100 kilograms of CFC to be machined into test tiles at IPP for the research and development phase. We were under extreme pressure due to lack of time, the whole initial R&D phase had to be rushed through in just a few months. When we received the first "real" JET tiles with coatings applied for high heat flux testing, we had already gone a long way together with our colleagues in Bucharest and also at JET. At that time we were really confident.

Do you think that these excellent results have any impact on other projects?

In fact coatings from our Romanian colleagues are already in use in ASDEX Upgrade. Also their performance in the ITER-Like Wall at JET is crucial for allowing useful predictions for ITER. I assume that there may be a need for tungsten coatings in future fusion reactors: Coating the plasma-facing surface of breeding blanket modules with 1-2 millimetres of tungsten deposited by vacuum plasma spraying or chemical vapour deposition could be a very economic solution.

A lesson learned for ITER may be that up-scaling from prototypes to full-size components may reveal surprises, so a team with scientific experience should accompany such activities. Flexible high heat flux testing and advanced analysis tools will be indispensable.

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