Recent results and developments in fusion research in Europe

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In preparation of ITER, JET has implemented the ITER like wall project (2011) using the same plasma facing component (PFC) configuration as ITER during its active phase, namely Be in the main chamber and tungsten in the divertor. Operation with all metal/ tungsten PFCs requires quite some adjustments in the way the devices are operated, mainly for the following reasons: (i) the amount of low-Z material which radiates at the plasma edge and in the divertor can be much reduced, leading to high power loads at the PFCs in steady state as well as during transients showing the need for radiative scenarios; (ii) in constrast to C that undergoes sublimation with thermal overloading, metal PFCs melt; (iii) hydrogen retention with metal PFCs is quite different from those of C PFCs and (iv) the collisional transport of (high-Z) tungsten differs strongly from low-Z materials potentially leading to (central) accumulation of W. An outstanding benefit of the Be PFCs is the very small low-Z content (reduction of C and O by at least a factor of 10) from the beginning of the operation, which allowed operating JET for one year without any surface conditioning.

In JET with a carbon wall (JET-C), baseline ELMy H-mode plasmas (q95=3-3.6, βN~1.2-1.6) achieved good normalised confinement with H98≈1 in unfuelled plasmas. Gas-fuelled low triangularity plasmas showed a degraded confinement due to pedestal cooling, whereas, high triangularity plasmas could be fuelled up to the Greenwald density without reducing H98. Gas fuelling was required in JET with a metallic wall (JET-ILW) to avoid W contamination. Good confinement in JET-C for high triangularity plasmas could not be sustained in JET-ILW at high gas levels; a 20-30% reduction in pedestal and core confinement was observed. The observed loss in confinement with the metal wall appears to be caused by a reduction in the C concentration in the edge: the edge temperature could be recovered in JET-ILW high triangularity baseline plasmas by nitrogen seeding, which appears to replicate the role of intrinsic carbon. However, this effect has not been reproduced in JET-ILW low triangularity baseline plasmas suggesting a shape dependence.

The Wendelstein 7-X (W7-X) stellarator (average minor and major radius a = 0.55 m and R0 = 5.5 m, average magnetic field on axis 2.5T) with superconducting coils, will be the first “fully-optimized” stellarator. It is currently under construction in Greifswald and will be the largest device of this class in the world. The mission of the project is to demonstrate the reactor potential of the optimized stellarator line. To demonstrate that reactor relevant plasma parameters can be achieved in steady-state, the W7-X experiment is designed for plasma pulses with 30 minutes duration at a heating power of 10 MW, with Electron Cyclotron Resonance Heating (ECRH) at 140 GHz as main heating system. This is complemented by Neutral Beam Injection (NBI) and Ion Cyclotron Resonance Heating (ICRH) for shorter pulse durations (up to 10s). One of the main aims of W7-X is to demonstrate good fast ion confinement at fusion-relevant  values of about 4%. To mimic the behaviour of alpha particles in a future stellarator reactor, a source of sufficiently energetic ions with energies in the range of 50 – 100 keV is needed in W7-X. Installation of an ion cyclotron resonance heating (ICRH) system is foreseen to ensure the creation of such populations. The Wendelstein 7-X project is on schedule for the last 5 years: commissioning will start in 2014 with first plasma in 2015.

In collaboration with Japan under the Broader Approach agreement, important efforts are undertaken to define the International Fusion Materials Irradiation Facility (IFMIF). Presently in its Engineering Validation and Engineering Design Activities (EVEDA) phase a validation is going on for the main technological challenges of the accelerator, target and test facility with the construction of full scale prototypes (a deuteron accelerator at 125 mA and 9 MeV; three different lithium loops (Brasimone (ENEA, Italy), Oarai (JAEA, Japan) and Osaka University, Japan); a High Flux Test Module and He cooling gas prototype in KIT (Karlsruhe, Germany) and Small Specimens Test Technique in Japanese Universities). Concurrently, an IFMIF Intermediate Engineering Design Report has been prepared to allow the construction of IFMIF on time and schedule within less than one decade whenever the Fusion community demands a fusion relevant neutron source indispensable for the next steps after ITER.

A reorganization of fusion research in Europe is taking place. The Commission's Horizon 2020 proposal states that Euratom will support the joint activities of the EFDA members, and will provide this support through a programme co-fund action. A consortium (EUROFUSION), made up of the EFDA Associates, has defined a five-year Work Plan defining the activities to be undertaken. EU Funding will be provided to EUROFUSION, which the in turn will organize and manage the funding of the EFDA Associates based upon Calls by the Consortium. EUROFUSION will start in Jan 2014.