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Opening address

Ladies and Gentlemen, it is a pleasure to welcome you at this 12th International Conference on 'Plasma–Surface Interactions in Controlled Fusion Devices'. To introduce this meeting, I should like to make a few remarks:

* The fusion programme is a significant part (about 20%) of the Research of the Direction des Sciences de la Matière in the French Atomic Energy Commission, which covers our basic research in Physics and Chemistry.

* My personal experience in Astrophysics makes me well aware of the necessity to be patient and to persevere during very long periods of time in fields like space programmes and controlled thermonuclear fusion.

* I am happy that you chose our country to come and discuss (and hopefully progress) on one of the most challenging aspects of the whole fusion field, i.e., the plasma–surface interactions and the divertor issues.

The context of fusion research is at a very particular stage. The continuous progress made is evident. At least two tokamaks, JET and TFTR, have been operated with a deuterium–tritium mixture. The fusion relevant performance parameters are or will reasonably approach those expected in a future step: ITER, a device where ignition should be achieved; indeed, JET will carry out experiments using D–T plasmas in an ITER-like configuration, serving as a basis for the D–T operation of ITER. The technical progress has reached a very high level and the integration of various and complicated technologies is achieved in present machines; let me mention here the superconducting toroidal field coils in Tore Supra, an ITER like divertor in JET and various first wall components in different high power machines.

The divertor concept is well known by your community. Your conference has been a privileged forum where this concept has been extensively presented, discussed and improved since the end of the 1970s. It now culminates in the proposal for the ITER divertor; two concepts, the so-called Mark II A and Mark II GB (gas box) will be tested in JET to demonstrate the viability for ITER. These experiments will be done during the extension phase of JET which has just been announced. Dr Parker will have the opportunity to analyse in detail the various challenges that this key component offers to scientists and engineers. As you know, the radiative divertor should prove its ability to radiate about 1/3 of the power flux from ITER. The necessity to inject extrinsic impurities should not result in a significant plasma bulk contamination. The compatibility with the confinement regimes envisioned today remains to be proved. The details of the configuration of the divertor is a key point which should be tackled on existing machines; in that respect, the European programme should provide an essential contribution from JET and ASDEX-Upgrade. The general particle circulation is the subject of intense and specific efforts dealing with the divertor geometry, pumping technology and pellet injector development.

I should add that there is now a growing interest towards other plasma edge configurations as a possible alternative to X-point divertors but also in view of the continuation of the stellarator experimental studies in Europe after the approval by EURATOM and the German government of the W7X project. Tore Supra with its ergodic divertor, upgraded this year, will contribute to this effort: by providing more open and less volume-demanding configurations, it should have enhanced capabilities provided the divertor assets are retained. The trapping of impurities at the edge appears as one of the most promising features of the Tore Supra ergodic divertor. The effect of the divertor on the injection of extrinsic impurities resulted in a much lower contamination of the plasma.

Beside the divertor issue, the type of material for the first wall (including the divertor itself) and the tritium retention are still the main open problems remaining. The promoters of the first Conference of this series were well inspired, more than 20 years ago, to create a forum where such questions could be addressed encompassing the community of surface physicists. I urge you to continue this essential exchange. This meeting is also an excellent opportunity for peripheral laboratories which are not exploiting their own device to continue to actively participate in the progress of the research in controlled fusion. The integration of the technological requirements in the plasma–wall interaction control system is more and more a prerequisite to the achievement of any progress towards larger fusion machines. The increased interaction between physicists and engineers is a key to the success in this field where the goal is to reach a sufficient reliability for the various systems needed along with the confining device.

Moreover, the high performance results, generally obtained in transient conditions, should be proven to persist in steady state. Tore Supra is an essential tool in this quest. The superconducting toroidal field magnet has been in operation now for 7 years. An important part of the physics program is aimed towards the control of long plasma discharges. A typical long discharge in Tore Supra lasts more than 60 seconds. These discharges are now characterised by a feedback control of the toroidal flux providing a zero loop voltage. Lower hybrid waves are used to induce non-inductively the plasma current. You should know that the other parameters of the discharge such as the density or the internal inductance are constant except at the very end of the pulse. Steady-state discharges are now approaching 2 minutes in our device; the main limitations are due to the heat and particle exhaust capabilities of the plasma-facing components. From the very beginning, Tore Supra was equipped with actively cooled components and you may note the complexity which remains attached to such an implementation. In this respect, the installation of a new toroidal pump limiter in 1998 should allow one to extend the length of the pulse in high heat flux exhaust conditions (2.5 to 10 MW/m2). Specific developments have been done to achieve actively cooled plasma facing components to be installed in the tokamak: this task proved to be more difficult than expected. The progress made in developing bonding techniques for CFC composites on cooling structures, and in industrialising them, has lead to prototypes of the toroidal limiter, which are adequate for the purpose at hand.

In Europe, as you know, we have co-ordinated our efforts towards fusion since the very beginning. I want to stress here that, in addition to ITER, Europe through EURATOM supports a full line of devices and I am sorry not to have quoted them all. The expectation is that the trend towards a broader international collaboration will continue to develop in the years to come. Concerning ITER, as you know, the ITER EDA phase, now in progress up to July 1998, highlights the maturity of controlled fusion research, and the possibility of implementing such a world wide collaboration. The ITER interim design report showed that the fusion community is able to pool its forces in an organised way. Yet, many conclusions from ITER-Intermediate Design Report are in fact questions directed to your community and decisive answers are expected from you before your next meeting in 1998. The requests involve essentially the question of heat and particle exhaust, the clarification of the density limits and H-mode access and the disruption control processes.

I extracted from the findings and recommendations of the TAC-8 about the Interim Design Report, some of the sentences which are listed hereafter.

* ''Physics program is to provide systematic experimental testing, of ITER-like divertors (... including the choice of the impurity radiating species ...)''
* ''Validation of divertor codes is required ...''
* ''The TAC supports the Joint Central Team position of keeping open the options for material choices (BE,C,W)''.

This gives clear evidence that existing controlled fusion devices must yield a significant contribution towards the design of ITER, so that a clear perspective can be given for the Next Step and that a large part of it is expected from you. From an even broader perspective, you are concerned by at least two of the seven major R&D projects for ITER EDA, namely the divertor and the first wall. These technical elements cannot be built without a sound physics basis.

In conclusion, I wish you a very interesting and effective conference and I expect from your creativity and from your hard work significant progress in one of the key fields for the future of fusion, namely the plasma–surface interactions.

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