Diagnosing the Fusion Roadmap

A.J.H. Donné

EUROfusion, Boltzmannstrasse 2, D-85748 Garching-bei-München, Germany

The final milestone in the present European Fusion Roadmap [1] is the achievement of electricity from nuclear fusion. The roadmap leads us from fusion research in contemporary devices, via research in almost reactor-like conditions in ITER, to operation of the first demonstration reactor, DEMO. This presentation will take the audience from diagnostic applications on present devices, all the way to doing measurements and control on DEMO.
Over the last 50 years high temperature plasma physics research has evolved from relatively small, almost table-top, experiments to large, factory-size, fusion experiments with as flag-ship the international ITER tokamak. In the meantime our understanding of a great variety of plasma properties has also gradually improved. Very often breakthroughs in our understanding are directly attributable to the implementation of new or improved diagnostic instrumentation; in particular systems based on new concepts, systems with higher spatial and/or temporal resolution as well as systems with a better spatial coverage [2]. A recent trend in fusion research is the application of imaging diagnostics, featuring high spatial and temporal resolution as well as good plasma coverage. With these diagnostics it possible to measure certain plasma parameters and their fluctuations in a two-dimensional plasma cross section, and to directly compare the two-dimensional measurements with predictions from advanced theoretical models.
Apart from the development of diagnostics for obtaining a better physics understanding, a relatively new trend is the systematic use of diagnostics as robust sensors for plasma control. Dedicated and comprehensive control processes are required to be able to operate the future generation of fusion reactors, especially in the so-called advanced tokamak regimes. During steady state and hybrid operation of the ITER tokamak about half of the more than 50 diagnostic systems will be used in active control systems [3]. This has large consequences on the diagnostics as they need to have the ability to give real-time information on (profiles of) plasma parameters to a range of actuators [4].
DEMO, the test fusion power plant, will have to demonstrate reliability and very long pulse/steady-state operation, which calls for unprecedented robustness and reliability of all diagnostic systems. But DEMO will have higher levels of neutron and gamma fluxes, and fluences, nuclear heating, and fluxes of particles than ITER, and the physical access will be strongly reduced. As a consequence, some diagnostics that marginally will work in ITER are likely to be not feasible in DEMO. It is important, therefore, to develop a new way of thinking with respect to that employed to date in which diagnostics are added after the machine has been basically designed: if certain diagnostics are deemed essential for the control of DEMO, they will have to be taken into account during the entire design phase. Moreover, modelling needs to become an integral part of the complete plasma control system to be able at all to run and control the tokamak plasma based on a relatively sparse set of diagnostic data.

[1] EFDA, Fusion Electricity: a roadmap to the realisation of fusion energy,
https://www.euro-fusion.org/wpcms/wp-content/uploads/2013/01/JG12.356-web.pdf
[2] Donné A J H 2006 Plasma Phys. Control. Fusion 48 B483.
[3] Donné A J H 2013 Plasma Fusion Res. 8 2102084.
[4] The July issue of Nucl. Fusion **52** (2012) is fully dedicated to plasma control.