Comments on research requirements/strategies for addressing “Plasma Modification by Auxiliary Systems” with RF waves

Cynthia K. Phillips, PPPL

Experimental studies coupled with the development of advanced simulation codes over the past 40 years have led to an unprecedented understanding of the physics of RF heating and current drive in the *core* of axisymmetric toroidal magnetic fusion devices. Nevertheless, there are serious gaps in our knowledge base that continue to have a negative impact on the success of ongoing experiments and that must be resolved as the program progresses to ITER, to other next generation devices and ultimately to “demo’ and “power plant”. The most serious gap, at least in the ICRF and lower hybrid frequency ranges, is the lack of a predictive understanding of the amount of power that can be coupled into a fusion plasma with a given launcher and source design. The negative impacts of this knowledge gap are clear: (i) significant and variable loss of power in the edge regions of confined plasmas and surrounding vessel structures adversely affects the core plasma performance and lifetime of a device; (ii) the launcher design is partly “trial and error”, with the consequence that launchers almost always have to be reconfigured after initial tests in a given device, at an additional cost. Over a broader frequency range, the second most serious gap is a quantitative lack of understanding of the combined effects of nonlinear wave-plasma processes, energetic particle interactions and non-axisymmetric equilibrium effects on determining the overall efficiency of plasma equilibrium and stability profile control techniques using RF waves. This is complicated by a corresponding lack of predictive understanding of the time evolution of transport and stability processes in fusion plasmas.

It is difficult to imagine that significant and rapid progress can be made in developing a predictive understanding of power coupling with the resources currently available in the fusion community. While some limited but focused effort is being made on the domestic and international facilities, there is a serious lack of run-time, associated diagnostics, and dedicated personnel to adequately address these issues in a coherent manner by combining experimental studies with the development of quantitatively accurate simulation codes. To further complicate matters, once the RF systems on a given device obtain a certain level of performance and reliability, run time and resources are more likely to be dedicated to utilizing the RF waves for various scenario studies, than on developing the knowledge base needed to understand power coupling issues.

The last time the fusion program had a facility dedicated to studying RF wave plasma interactions was in the mid-1980s in the final years of operation of the PLT device. If sufficient resources were available, probably the best way to address the issue of power coupling into a fusion plasma would be to have a dedicated PLT-scale facility with modest but fairly reproducible plasma performance and with rf source power levels on the order of about 4 MW. A range of diagnostics would be required to obtain detailed measurements of the wave fields in the core and edge regions, to measure the effect of the interaction of the waves with the edge plasma and the vessel structure, and to characterize the relevant plasma conditions (density and temperature and rotation profiles, MHD stability, impurity production, for example). The objective would be to diagnose and simulate the coupling of power into the plasma under conditions that allow ready access to the plasma. In order to quickly modify the launcher or a diagnostic in response to the ongoing measurements and simulations, some dedicated engineering support would be required. A key part of this effort would also involve the extension of existing full wave codes to include a detailed model of the plasma edge regions and to integrate these models with a detailed launcher analysis code, such as the TOPICA code under development in Italy. Such a facility could also be used for detailed, dedicated studies of other edge phenomena that impact the overall plasma performance. With fewer program resources, one could still make some progress by increasing the RF- dedicated available run time and experimentalists on the three existing domestic toroidal facilities, by adding a significant number of wave diagnostics for both the edge and core regions, and by doubling the simulations efforts to include the development and integration of detailed launcher and edge region modules into the full wave code.