Measurement needs for the alternates, with broader connections

D. J. Den Hartog
2009-03-14

Increased and improved diagnostic capability is recognized as an urgent need for toroidal alternates. Here is the relevant quote from Sec. 1.1.4 of the TAP report:

> "Alternate concept research requires similar tools to other parts of the fusion program, but it has uniquely urgent needs in two areas: (1) theory and simulation, which are particularly challenged by complex 3D resistive MHD physics, kinetic effects, and anomalous transport seen in these experiments; and (2) diagnostic capability, which is especially vital for developing physics understanding of the less mature concepts. These areas deserve priority emphasis and support to strengthen scientific contributions and solidify projections to next step experiments."

This is a cross-cutting issue, almost by definition. At the most basic level, experiments exploring the less-mature concepts sometimes lack a diagnostic set sufficient to measure equilibrium and confinement. Basic physics understanding is held back by the inability to measure profiles of basic plasma parameters, using diagnostic techniques that are proven and well-understood. Usually this is simply due to a lack of resources. Addressing this need should received priority emphasis, as relatively small investments in diagnostics will result in large increases in capability for less-mature concepts.

But toroidal alternates also have measurement needs that are not addressed by the straightforward application of standard diagnostic techniques. Typically this is because the plasma under investigation has some characteristic or range of parameters that render standard techniques inapplicable. For example, the spherical torus, reversed-field pinch, and compact tori are all relatively low magnetic field compared to the tokamak. This means that some diagnostic techniques applied to many tokamak plasmas are difficult or impossible in these low-field devices. An important example of this is electron cyclotron emission (ECE), which is a standard diagnostic for electron temperature profiles in many tokamaks. It has good spatial and time resolution. However, electron cyclotron emission does not propagate in overdense ($\omega_{pe} >> \omega_{ce}$) plasmas, so this technique simply cannot be applied to low-field plasmas. Thus these devices lack a tool analogous to ECE for spatially and temporally resolved measurement of electron temperature. This is a specific opportunity for diagnostic development that would have cross-cutting impact.

Another diagnostic in widespread use in tokamaks is polarimetric motional Stark effect (MSE) to measure the safety factor q profile, a parameter critical to equilbrium reconstruction. In low-field plasmas, the splitting of the motional Stark manifold is small and thus polarimetric analysis of the Stark components is very difficult. An alternative approach is recording of the entire MSE spectrum, and analyzing it to measure $|\mathbf{B}|$ directly. This technique has been implemented on the MST RFP at the University of

Wisconsin, and is in regular use. It has the distinct advantage of not relying on polarization measurement, and could be applied to other low-field plasmas.

However, this spectral MSE technique may have larger cross-cutting application than low-field plasmas. The standard polarimetric MSE technique may not work in ITER because mirror characteristics will change during a discharge, making polarization analysis difficult. Thus the spectral MSE technique or a variation is being examined for applicability to ITER. As this technique is developed further for toroidal alternates, there may be specific opportunity for input to its development for ITER and burning plasmas. An example of this is a small-scale collaboration MST has just begun with DIII-D and ADAS to further develop the spectral model for this technique. An improved model will increase measurement accuracy, with possible benefit ranging from low-field to burning plasma research.

As a cross-cutting action item, the toroidal alternates research community should identify the developments in diagnostic capability needed to further understanding of high-priority physics problems. In addition to the examples given above, there are priority needs in turbulence and fluctuation diagnostics, fast ion diagnostics, and almost certainly other areas. Proposed diagnostic developments will have the most resonance if they relate to needs in the burning plasmas research community.