New Measurements Lead to an Improved Understanding of Alfvén Waves in Fusion Plasmas

Everyone can imagine banging on the side of a cup of water and watching the wave patterns that ensue on the surface. However, it takes complicated hardware, fast computers running sophisticated programs, and a stretch of the imagination to predict and measure the patterns of the many waves that can exist in 10-100 million degree fusion plasmas when researchers "bang" on them with energetic particle beams. One such wave that can be excited in these plasmas is the Alfvén wave; specifically, the toroidicity induced Alfvén eigenmode or toroidal Alfvén eigenmode (TAE). The TAE is of interest for many reasons, but paramount is the possibility that it may cause loss of the fast fusion product alpha particles that will be required to sustain fusion burn in future tokamak reactors. Previous experiments on several devices around the world have documented the ability of these waves to decrease fusion power output. Despite their potential importance, very few measurements of the spatial patterns of TAEs and other Alfvén waves in a tokamak exist, making validation of the calculated wave structures very difficult or impossible. Validation of the existing modeling programs is extremely important so as to gain confidence in our ability to make predictions for the impact of Alfvén waves in future fusion devices such as the International Thermonuclear Experimental Reactor (ITER). Recently, detailed measurements of TAEs on the DIII-D tokamak in La Jolla, California have provided researchers with the necessary information for comparison to theoretical predictions of the wave spatial structure as well as their ability to redistribute the plasma particles. The spatial structure measurements are made by monitoring microwave emission from the plasma in many narrow frequency bands with each band corresponding to a particular location in the plasma. Linked to the plasma temperature, the microwave emission in these bands increases or decreases by an exceptionally small amount as the wave crests and troughs pass by. The predicted shape of a TAE temperature perturbation from the magnetohydrodynamic code NOVA [Fig. 1(a)] suggests that the mode has a complicated 2D structure. Comparisons with the actual measured perturbation [Fig. 1(b)] show very good agreement and provide additional credibility as to the ability to predict TAE activity in ITER.

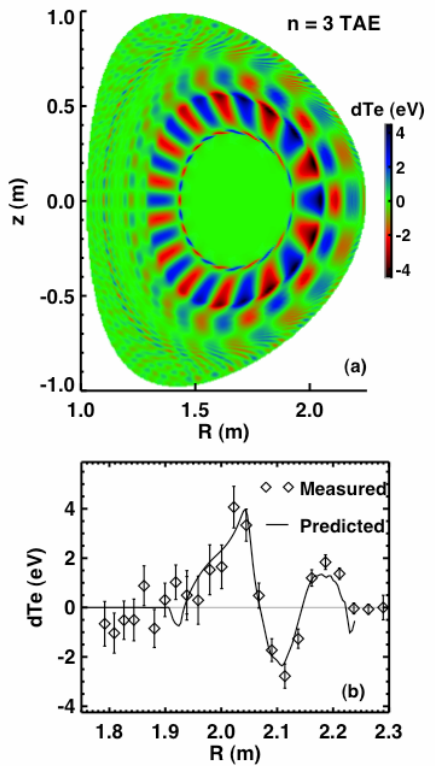

Fig. 1. (a) 2D shape of the temperature perturbation for an $n=3$ TAE in DIII-D discharge 122117. Red/blue represent increases/decreases in the plasma temperature. (b) Diamonds = ECE radiometer measured temperature perturbation, solid line = NOVA prediction for ECE radiometer temperature perturbation. Predicted eigenmode amplitude obtained by least squares fit to ECE data.

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Contacts: M.A. Van Zeeland, General Atomics, (858) 455-3315, vanzeeland@fusion.gat.com
M.R. Wade, General Atomics (858) 455-4156, Mickey.Wade@gat.com