Real-time measurement of toroidal rotation (abstract)[a]

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(Presented on 21 June 2000)

One of the important goals in Columbia's HBT-EP tokamak program is the improvement in the stability of tokamak plasmas by controlling the bulk plasma flow relative to the conducting wall. The method for active plasma flow control in HBT-EP is the application of oscillating resonant magnetic perturbations to oppose the velocity of magnetic islands at the $q=2$ surface. Real time (10 kHz) feedback control without inserting a material probe necessitates the use of an optical toroidal rotation measurement whose data is available during the shot. This is being accomplished in a novel way by seeding the deuterium plasma with 5%–10% helium and measuring the Doppler shift of the chord-integrated emission of the He II ($n=4\rightarrow3$) line at 4686 Å. Since the electron temperature is expected to be about 30 eV at the $q=2$ surface, helium is not fully stripped. The shift in wavelength is calculated by measuring the change in intensity as the line moves across the passband of an interference filter that varies linearly. Filters with less than 0.2% variation from a perfectly linear slope have been obtained. Fluctuations in the plasma emission are removed by having two detectors observe the same volume of plasma. This is achieved by splitting the optical view with a 'Y' composed of randomized optical fibers. One detector views the plasma through a filter whose passband has a negative slope and the other channel views it through a positive-slope filter. Systematic differences such as detector sensitivity, amplifier gain, fiber losses, etc. are compensated by normalizing each signal to the signal at a particular reference time. The *ratio* of signals at two different times does not depend on any detector or circuit characteristic that remains constant. The Doppler shift, relative to the reference time, is a function only of the slope of the filter's transmission. The Doppler shift at the He II impurity emisson line is 0.25 Å for a toroidal rotation of 3 km/s, and the slope of the filter passband is 8%–10% per Å, resulting in a 4% variation in signal level relative to the other channel.
[DOI: 10.1063/1.1323495]

[a]Supported by the U.S. DOE Grant No. DE--FG02--86ER53222 and Contract No. DE-AC02-76-CHO-3073.
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