Benchmark of Competing Theories for Stark Broadening against Experimental Data from DIII-D Diagnostics*

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Spectroscopy of high-n, Balmer line transitions provides a means of measuring n_e and T_e in recombining plasmas [1]. The relative intensities of Rydberg series lines near the ionization limit are a sensitive diagnostic of T_e, for T_e < 1.5 eV. Stark broadening of these same lines provides a measure of local n_e and, with less accuracy, of T_e. For future machines like ITER, which will rely heavily on detached divertor operation to control heat loads to divertor components, Balmer (or Paschen) line spectroscopy provides a relatively simple technique to measure divertor parameters.

The accuracy of different theoretical models for Stark broadening [2,3] are evaluated by comparing predictions from Balmer line spectroscopy of DIII-D plasmas against those from Divertor Thomson Scattering (DTS). While Oks' theory has received extensive experimental validation in the high electron density regime obtained in arc plasmas, the recent extension of his theory to the lower densities typical of detached tokamak plasmas has not. Spectroscopic and DTS measurements were conducted for a series of 18 identical, high density, ELMing H-mode discharges in a lower-single-null divertor configuration. Both inner and outer divertor legs were detached; observations of the recombining plasma in the private flux region were made along a vertical path through the X-point. Relative intensities of the Balmer lines were measured with a low resolution spectrometer ($\Delta\lambda$ = 1.5 nm), detailed profiles with a high resolution spectrometer ($\Delta\lambda$ = 0.02 nm). With a divertor DTS system, n_e and T_e were measured at eight points along a vertical laser path through the X-point.

Oks' Stark broadening theory agrees better with the Thomson-derived n_e value than Griem's, but the predictions of both theories lie within experimental uncertainties. The more compelling distinction between the two models is the detailed dependence of line width on principal quantum number. By this metric, Oks' theory clearly accords better with the experimental data.

[1] J.L. Terry, et al., Phys. Plasmas **5**(5), 1579 (1998).
[2] H.R. Griem, *Spectral Line Broadening by Plasmas* (Academic Press Inc., U.S., 1974).
[3] E. Oks, *Stark Broadening of Hydrogen and Hydrogenlike Spectral Lines in Plasma: The Physical Insight* (Alpha Science International, Oxford, UK, 2006).

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