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ANALYSIS OF THE ACCURACY OF COMPUTER SIMULATIONS IN CALCULATIONS OF THE STARK BROADENING OF HYDROGEN Ly_α, Ly_β AND Ly_γ LINES IN PLASMAS

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Abstract—An analysis of the accuracy of numerical methods and physical models, applied in computer simulations of hydrogen line profiles, formed in plasmas, has been carried out. An electric microfield model has been proposed, reproducing the real microfields not worse than other hitherto existing models. The use of our model allows shortening the calculation time for a profile by a factor of three. The numerical code developed for this purpose allows one to control the accuracy of the simulation procedure. We present line profile results for Ly_α, Ly_β and Ly_γ, which have been calculated with an accuracy being not worse than 3%. The results have been compared with other theoretical and experimental data. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Study of Stark profiles of spectral lines of hydrogen and of hydrogenic ions is one of the basic problems in plasma spectroscopy. The great interest arises, e.g., from the possibility of using the half-width of a line, $\Delta\lambda_{1/2}$, for a simple and precise determination of the electron density, N_e, in plasmas. Thus, the knowledge about the dependence of $\Delta\lambda_{1/2}$ on plasma parameters T, N_e and the accuracy of theoretical calculations is very important for experimenters. Currently the comprehensive tables of hydrogen Stark profiles[1,2] are used for establishing the relation between $\Delta\lambda_{1/2}$ and the plasma parameters. The basic reason for the discrepancy between the calculated[1,2] and the measured[3,4–8] values of $\Delta\lambda_{1/2}$, is the negligence of ion motion in the calculations. In plasmas of moderate densities ($N_e > 10^{15}\,\mathrm{cm}^{-3}$), in the case of Balmer lines this discrepancy is of the order of several per cent;[4,5] in the case of Lyman lines, however, the discrepancy is considerably greater. For example, in Refs. 6 and 8 it is shown that the measured values of $\Delta\lambda_{1/2}$ for Ly_α in a H + Ar plasma are 2.5 times greater than the calculated ones.[1,2] In all calculational models, in which the time variability of the ionic field is taken into account, this discrepancy diminishes drastically.[10–20] To date the best agreement between the calculated and measured data has been achieved (i) within the Model Microfield Method (MMM) approximation,[12] and (ii) applying computer simulation methods.[14–20]

The construction of our numerical code is based mainly on experiences of computer simulations described in Refs. 16 and 18. Results computed in Ref. 17 differ essentially from measured results Ref. 6 (e.g., for Ly_α about 37%), because of adiabatic attributes of the theory. We therefore do not analyse Ref. 17 in our paper. In Refs. 14–16 the electric field arising only from ions has been simulated, whereas the electronic contribution to the line broadening has been described within the impact approximation. In Ref. 18 this approach has been generalized, i.e., the field resulting from ions as well as from electrons has been simulated. In this manner the development operator could also be taken into account quite generally and the assumption on the binarity of collisions has not been used. However, such generalization causes multiple extension of the computer calculation time. Therefore, in the case where conditions of the impact approximation are satisfied, one can recommend the approach of Ref. 16 as being useful too.