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STARK BROADENING PARAMETERS IN THE Mn I SPECTRUM

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Abstract. The shapes and shifts of the astrophysically interesting neutral manganese (Mn I) resonance spectral lines (403.075, 403.306 and 403.448 nm) have been observed in the laboratory helium plasma at a 47 000 K electron temperature and 6.6×10^{22} m^{-3} electron density. At the mentioned plasma parameters the Stark broadening has been found as important mechanism in the Mn I line shape formation. Our measured Mn I Stark widths (W) and shifts (d) are the first data in the literature. The W values are compared with splitting ($\triangle_{hfs}$) in the hyperfine structure (hfs). At the above mentioned helium plasma conditions the line splitting in a hyperfine structure has been overpowered by Stark and Doppler broadenings in the case of the investigated Mn I lines. We have found negative line shifts that lie into the hfs splittings.

1. INTRODUCTION

The neutral manganese (Mn I) resonance spectral lines are useful for astrophysical plasma diagnostics and modeling, especially for mercury- manganese (HgMn) stars (Doron et al., 2002; Johnson, 2002; Ariste et al., 2002; Dessauges-Zavadsky et al., 2002; Doyle et al., 2001; Welty et al., 1999; Luttermoser, 2000; Jomaron et al., 1999; Lobel and Dupree, 2000; Vitas, 2005). However, their Stark widths (W) and shifts (d) are unknown. No experimental or theoretical Mn I Stark broadening parameters exist (see NIST, 2005; Konjević et al., 2002, and references therein). On the other hand, experimental and theoretical investigations of the splitting in the hyperfine structure (hfs) of the Mn I lines have been performed by Blackwell et al. (2005), Booth et al. (1983), White and Ritschl (1930) and Vitas (2005) (see, also, references therein). The above mentioned works refer hfs splitting ($\triangle_{hfs}$) in a range from 1 pm up to 21 pm depending on the particular transition. Thus, for cold plasmas the hfs can be more prominent than the Doppler or Stark contributions to the line width caused by considerably high electron temperature (T) and electron density (N). Consequently, it is of interest to investigate plasmas with electron density sufficiently high to cause Mn I Stark widths higher than the splitting in hfs.

The aim of this paper is to present the first Stark FWHM (Full-Width at Half of the Maximal intensity W) and the Stark shifts of three resonance Mn I lines in an

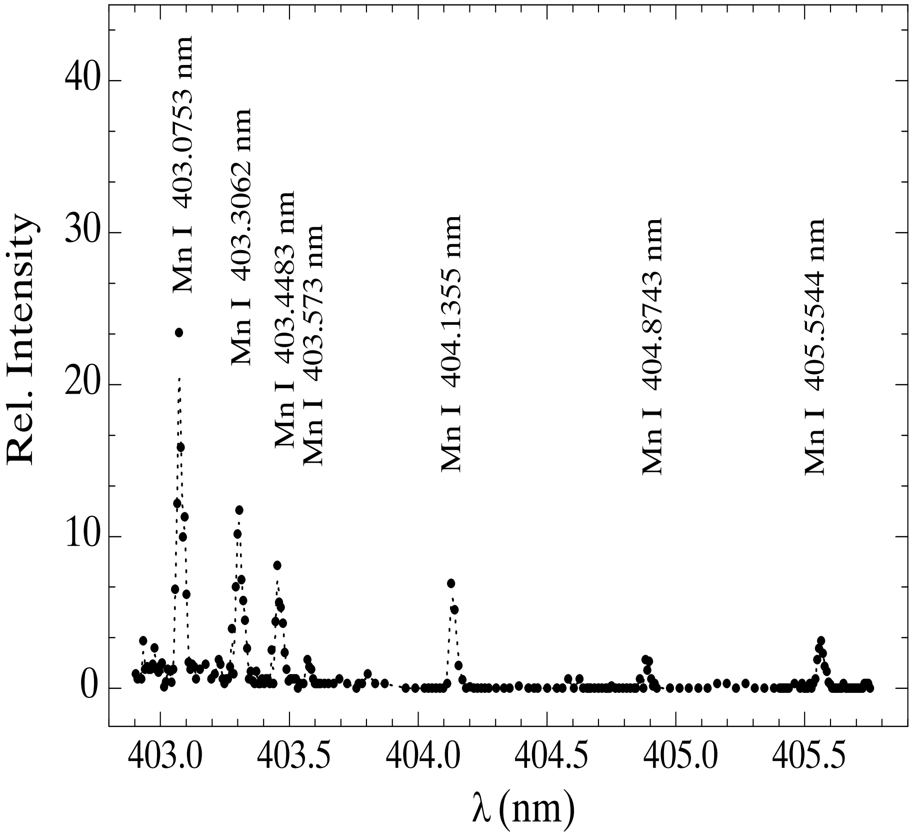

Figure 1: The Mn I line profiles in helium plasma recorded by using a step-by-step technique (five shots at the same position)

optically thin laboratory helium plasma at an electron temperature of 47 000 K and electron density of 6.6×10^{22} m^{-3} (see also Srećković et al., 2005).

2. THE EXPERIMENT

A linear, low-pressure, arc was used as a plasma source. A pulsed discharge was driven in a pyrex discharge tube of 5 mm inner diameter and 14 cm plasma length (Djeniže et al., 1998, 2005, 2006). The tube has end-on quartz windows. Manganese atoms were introduced by eroding the manganese metal bands fixed on discharge electrodes (see Fig. 1 in Djeniže et al., 1991, 1998) providing conditions free of self-absorption. The absence of self-absorption in the resonance transitions are checked by using the method described in Djeniže and Bukvić (2001). The working gas used was helium flowing at 665 Pa. A capacitor of 14 μF was charged up to a 34 J bank energy. The line profiles were recorded using a step-by-step technique with the experimental set-up system described in our previous reports (Djeniže et al., 1991; Bukvić et al., 2004a,b; Srećković et al., 2002). The averaged photomultiplier signal (five shots at the same wavelength) was digitized using an oscilloscope interfaced to a computer. Some of the recorded Mn I spectral line profiles are shown in Fig. 1.

The plasma parameters were determined by using standard diagnostics methods. The electron temperature was obtained using the relative line intensity ratio method for the He II P_α 468.6 nm and the He I 587.6 nm lines within ±8% accuracy (Griem, 1964). The electron density decay was obtained using well-known Stark widths of the He II P_α 468.6 nm line (Griem, 1974) with an estimated error of ±9%. The line width and shift measurement techniques are described in Djeniže et al. (2006) and Srećković et al. (2000, 2005). The estimation of the spectrum baseline is based on the method described in Bukvić and Spasojević (2005) and in Bukvić (2005). The W and d values are obtained within ±20% and ±0.8 pm errors, respectively.

3. RESULTS AND DISCUSSION

Our measured Stark widths (W_m) and shifts (d_m) of the Mn I lines are given in Table 1. In order to compare the measured Stark widths, the estimated Doppler widths (W_D) at a 47 000 K electron temperature are tabulated together with the $\triangle_{hfs}$ values in Table 1.

Table 1: Measured Mn I Stark FWHM (W_m) and Stark shift (d_m) with their estimated accuracies at a 47 000 K electron temperature and 6.6×10^{22} m^{-3} electron density. W_D denotes estimated Doppler widths calculated at a 47 000 K electron temperature. Atomic data are taken from NIST (2005). Wavelength represents the hfs−free value. $\triangle_{hfs}$ represents the obtained splitting in the hyperfine structure (Booth et al., 1983; Vitas, 2005). Negative shifts are shown toward blue.

Configuration Term	λ (nm)	W_m(pm)	$\triangle_{hfs}$(pm)	W_D(pm)	d_m(pm)
$3d^5 4s^2 - 3d^5(^6S)4s4p(^3P^0)$	403.0753	14.8 ± 2.5	5.22	8.4	-2.6 ± 0.8
$a^6S - \ z^6P^o$	403.3062	16.0 ± 3.2	4.37	8.4	-2.0 ± 0.8
	403.4483	12.0 ± 2.0	3.32	8.4	-2.0 ± 0.8

One can conclude that at our helium plasma conditions the line splitting in a hyperfine structure has been overpowered by Stark and Doppler broadenings in the case of the investigated Mn I lines. We have found negative line shifts with magnitudes lower than the hfs splitting.

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