Publ. Astron. Obs. Belgrade No. 91 (2012), 57 - 59 *Contributed paper*

BEHAVIOR OF THE 398.4nm Hg II SPECTRAL LINE IN THE HELIUM AND ARGON PLASMAS

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Abstract. The astrophysically important 398.4 nm Hg II spectral line was investigated in the laboratory helium and argon plasmas. The mercury atoms were sputtered from the amalgamated gold cylindrical plates located in the homogenous part of the pulsed discharge. We have found that strong intensity of the 398.4 nm Hg II line is due to excessively high density of the helium metastable atoms.

1. INTRODUCTION

The neutral (Hg I) and ionized mercury (Hg II) spectral lines are present in emission spectra of many astrophysical light sources. The 398.39 nm Hg II line is particularly interesting. Its line shape, defined by components in hyperfine structure and isotope effect (Gavrilov et al. 2011; Catanzaro et al. 2003), depends on the plasma parameters and density ratios of seven Hg isotopes. Mercury is found in the atmospheres of the chemically peculiar stars of the upper main sequence up to 10^6 times the solar system levels (Adelman et al. 2004). In the work (Dolk et al. 2003) spectra of HgMn stars have been studied for the abundance and isotope mixture of mercury using the 435.8 nm Hg I and 398.39 nm Hg II line characteristics. Presence of the 398.39 nm Hg II line is found in the spectra of the normal late-B and HgMn stars (Smith et al. 1997). Its profile is investigated in spectra emitted from the rapidly rotating HgMn stars (Kochukhov et al. 2005). The absolute oscillator strength of this line, determined from various astrophysical light sources, is summarized by Dworetsky (Dworetsky, 1980). It should be mentioned that in spite of relatively low transition probability of $3.2\ 10^6\ s^{-1}$ (NIST, 2011) its intensity is very strong (NIST 2011; Dworetsky, 1980; Michaud et al. 1974) (and references therein). The aim of this work is to consider possible origin of the strong intensity of 398.39 nm Hg II line in the helium plasma.

2. EXPERIMENT

A linear low-pressure pulsed arc (Gavrilov et al. 2011) (and references therein) was used as an optically thin plasma source. A pulsed discharge was produced in a Pyrex discharge tube with a 5 mm inner diameter, the length of plasma column was 14 cm. As a working gases helium and argon were used at 665 Pa and 133 Pa respectively, in

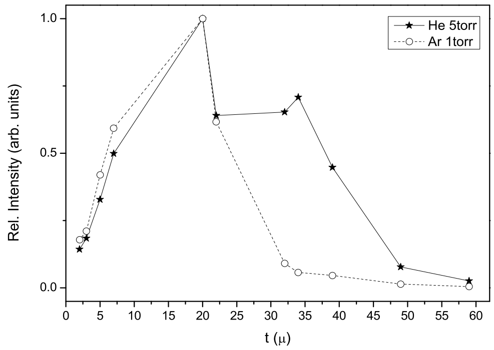

Figure 1: Temporal evolutions of the intensities (I_n), normalized to the maximum line intensity.

flowing regime. Mercury atoms were sputtered from the amalgamated cylindrical gold electrodes placed at the ends of the axial part of the discharge tube. The discharge was created using a capacitor of 14 μF charged up to 45 J of stored energy. The time flow of the discharge current is presented in (Djeniže et al. 2011). The spectroscopic observations were made end-on along the axis of the discharge tube. A McPherson model 209 spectrograph (with a 1.33 m focal length) equipped with a holographic grating containing 2400 grooves/mm was used over wavelengths ranging from 200 to 640 nm. This spectrograph has a reciprocal linear dispersion of 0.28 nm/mm in the first order. An Andor DH740-18F-03 iStar intensified CCD camera was employed as a detection system. The camera was triggered at a specified moment with exposure time (0.1 μs) adapted to the specific experimental conditions. To reduce thermal noise, the ICCD detector was kept at a temperature of -25^{o}C

3. RESULTS

We have monitored the 398.39 nm Hg II line intensity during the decaying helium and argon plasmas. Temporal evolutions of the intensities (I_n), normalized to the maximum line intensity, are presented in Figure 1. One can see evident difference between two curves. In the argon plasma (curve Ar) only one peak exist. It is realized at the moment when our plasma is in the most ionized state with maximum of the electron density (N). In the case of the helium plasma (curve He) two maxima exists. The first one is similar as in the argon plasma, but the second is realized later, at 30th μs after the beginning of the discharge, when the electron density is about 3 times smaller than in its maximum.

One can see that first peak shows approximately the same intensity in both cases. This means that electron collisions play a leading role in population of the parent (upper) state of the 398.39 nm Hg II transition. In the helium plasma beside electrons, the helium triplet metastables (He*I, with 19.82 eV excitation energy) contribute also in population of mentioned state. We suppose that the 5d^{10}6p $^2P^0_{3/2}$ parent level of this transition, with 7.51 eV excitation energy, is extra populated by helium metastables (2s $^3S_1$) due the Penning effect (Kruithof & Penning, 1937):

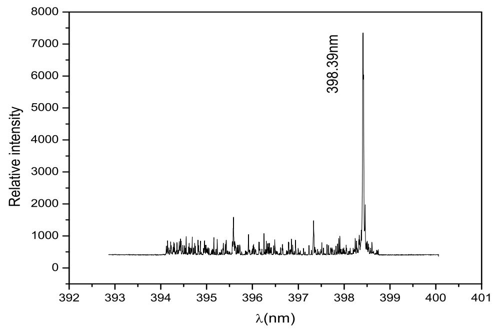

Figure 2: The recorded 398.39nm HgII line.

$$\text{He I}(2^3S_1) + \text{Hg I}(5d^{10}6s^2) \rightarrow \text{He I}(1^1S_0) + \text{Hg II}(5d^{10}6p^2P^0) + e. \quad (1)$$

providing high intensity of the 398.39 nm Hg II line. Only the $5d^{10}6p^2P^0$ Hg II level has the energy (7.51 eV) necessary for the Penning effect. All other excited Hg II levels lie above the energy limit of 9.39 eV and can not participate in the Penning effect, Eq. (1).We suppose that prominent intensity of the 398.39 nm line in our discharge, in a late stage of the plasma decay when recombination processes dominate, is due to the Penning effect (Djeniže, 2007, Djeniže et al 2011).

Acknowledgements

This work is part of the "Determination of atomic parameters on the basis of spectral line profiles" (ON 171008) project supported by the Ministry of Education and Science of the Republic of Serbia.

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