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COMPARISON OF OPTICAL-EMISSION BASED MEASURMENTS OF ELECTRON DENSITY IN ATMOSPHERIC PRESSURE LASER-INDUCED HE PLASMAS

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The use of allowed lines and their forbidden components has been of interest in the measurement of electron density in plasmas due to their high sensitivity to small changes in electron density, and their insensitivity to self-absorption and experimental artifacts. In this work we measure electron density in atmospheric pressure laser-generated He plasma. A Q-switched Nd:YAG laser with wavelength of 1064 nm, pulse rate of 20 Hz, pulse energy of 250 mJ and pulse width of 10 ns was used to generate the plasma in a small stainless-steel chamber filled with Atmospheric pressure He and He-H_2 gases. Light emitted from plasma then was directed to a 1-meter monochromator with entrance slitwidth 30 μm and later to an ICCD camera to record the spectrum. The range of our measurments is between about 5×10^{14} and 1×10^{17} cm^{-3}, corresponding to delay times ranging from 1 to 20 μs after plasma initiation. We use two different methods to find the electron density: (i) line splitting between the allowed ($^2p^3P$-$^4d^3D$) and forbidden ($^2p^3P$-$^4f^3F$) component of the 4471 Å HeI emission line, and (ii) Stark broadening of the two ($3p^1P$-$3s^1S$) and ($5d^3D$-$2p^3P$) HeI emission lines at 5015 Å and 4026 Å, respectively.

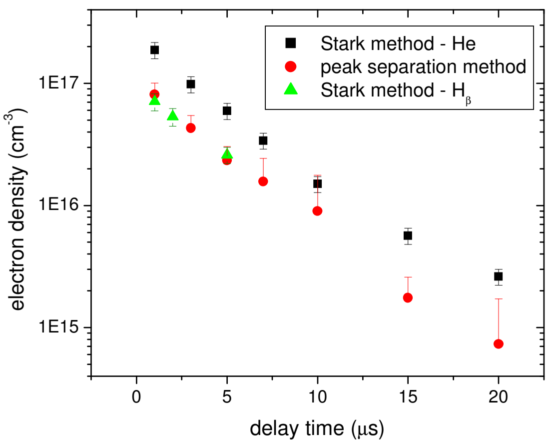

Fig.1: Electron density in atmospheric He plasma as a function of delay time obtained from Stark broadening using 5015 Å and 4026 Å emission lines. (squares), and the splitting between its allowed and forbidden components (circles), as well as Stark broadening of the H-β line (triangles).

Conversion of measured splittings into electron denisty is accomplished using the relations published by Czernikowski et.al [1] and Perez et.al [2] for electron density ranges of $1.5x10^{16}$-$1.45x10^{17}$ cm^{-3} and $2x10^{14}$- $2x10^{16}$ cm^{-3}, respectively [1,2]. For the second method we use the appropriate Stark broadening parameters [3] adjusted to the independently established temperature in our plasma. As Fig. 1 shows, electron density values using the Stark method are systematically higher than those using the peak separation between the allowed and forbidden components.

In an attempt to resolve these differences we added a small fraction (10:750) of H_2 to the He plasma to use the H_β line broadening as an alternative method for electron density measurements. The values obtained from the H_β line are also shown in figure 1. As can be seen, they agree well with the electron density values found from the peak separation approach.

In an additional experiment we investigated more systematically the influence of H_2 concentration on the time dependent electron density in the laser plasma. Figure 2 shows the result of 3 different mixtures with H_2 abundances of 0.001, 0.006, and 0.01, respectively, and total pressure of 760 Torr. The preliminary results show that the electron density increases with increasing amount of hydrogen and that at the highest levels used here the the agreement with the splitting obtained results are quite good (this is the case shown in figure 1). This issue is under further investigation.

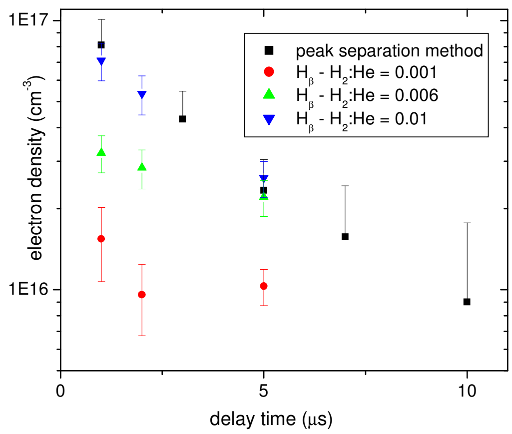

Fig.2: A comparison between electron densities obtained from H_β line broadening (with H_2 to He ratio of 0.01, 0.006, and 0.001), and the 4471 Å peak separation method.

Reference

[1] A. Czernichowski, et.al, 1985, J. Quant. Spectrosc. Rad. Transfer, **33**, p. 427-436.
[2] C. Perez, et.al, 1996, Jpn. J. Appl. Phys., **35**, p. 4073-4076.
[3] H.R. Griem, 1974, *Spectral Line Broadening by Plasmas* (Academic Press, New York).