ESCAMPIG XXI, Viana do Castelo, Portugal, July 10-14 2012

Topic number: 12, 5

# Thomson scattering and emission spectroscopy of laser sparks induced in pure He and He-$N_2$ mixtures at 1atm

E. Nedanovska [(*)1], D. Riley [1], T. Morgan [2], L. Hüwel [2], W. Graham [1]

[1] *Centre for Plasma Physics, Queen's University Belfast, BT7 1NN, Belfast, Northern Ireland, UK*
[2] *Department of Physics, Wesleyan University, Middletown, Connecticut, 06457-6036, USA*
[(*)] enedanovska01@qub.ac.uk

In this communication we present an experimental study of a laser induced breakdown in atmospheric He and He-$N_2$ mixtures with 0.2, 1, 10 and 50torr of $N_2$. The temporal evolution of the plasma sparks has been investigated with the help of Thomson scattering. The electron density was found to decay from $1.3\times10^{17}$ cm$^{-3}$ down to $1.6\times10^{16}$ cm$^{-3}$ in the time between 1μs and 10μs after breakdown and was not much affected by the mixture composition. These values were found to be in relatively good agreement with the values rendered by the 447nm and 501nm He I emission line analysis.

Emission spectroscopy is the most common diagnostic technique used for plasma characterization. However the interpretation of the line emission spectra depends on equilibrium and modeling assumptions and relays as well on the knowledge of Stark widths and atomic rates [1,2]. Additionaly self-absorption of the lines can be an issue and result in incorrect determination of electron density values.

The Thomson Scattering (TS) is one of the most powerful non-intrusive methods for plasma diagnostics. The detected elastic scattering from the free electrones is relatively easy to analyze and yield unambigous values of the electron density and temperature. The later gives the TS the supremacy over emission based techniques and can be used to test their reliability. However there are only a few studies where the TS has been used to investigate laser induced breakdown in gases [3,4].

We have used both the TS and emission spectroscopy to study the temporal evolution of laser-induced sparks in He and He- $N_2$ at 1 atmosphere, at time delays between 1μs and 10μs after breakdown. The gas mixtures investigated contain 0.2, 1, 10 and 50torr of $N_2$.

The experimental set-up used, shown in Fig. 1(a), is based on a perpendicular scattering geometry. The gas breakdown was realised by 1064nm, 9ns laser pulses from a Nd:YAG laser. The laser delivered 140mJ in the focus of a 10cm lens. A second, frequency doubled (532nm) Nd:YAG laser (80mJ in 7ns) was used to probe the plasma. The scattered signal was collected at 90° and with a set of collecting optics, the scattered photons were imaged onto the entrance slit of an imaging double grating spectrometer (SPEX 750, 1200 l/mm, dispersion 5.7*Å/*mm) which had a gated ICCD as a detector. The images obtained are both spectrally (horizontal axis) and spatially (vertical axis) resolved. The same experimental arrangement, only with the probing laser off was used to acquire the HeI emission spectra at 447nm ana 501nm.

The Thomson scattering collected, at the time delays of interest here, is in the collective regime since the values of the scattering parameter ⍰ are greater or close to 1. This means that we are probing the group motion of the electrons which is manifested with plasmon features in the scattering spectrum. The electron temperature and density are obtained through the Salpeter approximation. Typical Thomson scattering image and spectrum are shown in Fig. 1(b) where the He-$N_2$ ($p(N_2)$=50torr) laser spark is probed at 7.5μs after breakdown.

Fig. 2(a) shows the time history of the electron density, determined with the TS, in the central region of plasma sparks with different composition. We can see that, from 1μs to 7.5μs after breakdowm, the density drops from $1.3\times10^{17}$ cm$^{-3}$ to $2.4\times10^{16}$ cm$^{-3}$ and that the presence of $N_2$ does noth have a great influence on these values.

In Fig. 2(b) the values obtained from both the Thomson scattering and HeI line emission, for He-$N_2$ mixture where $p(N_2)$=50torr, are presented. For the 501nm emission the $n_e$ was determined through the Stark broadening of the line, while the spectrum at 447nm has an allowed and a forbidden line component and it was analyzed through several approaches that rely on these lines separation. We can see that there is a relatively good agreement between the scattering and emission approaches. The 447nm line separation methods agree better with the TS results in He-$N_2$ mixtures than in pure helium. Understandig of the latter demands investigation of the effects that $N_2$ has on the He emisssion, and further work in this is necessary.

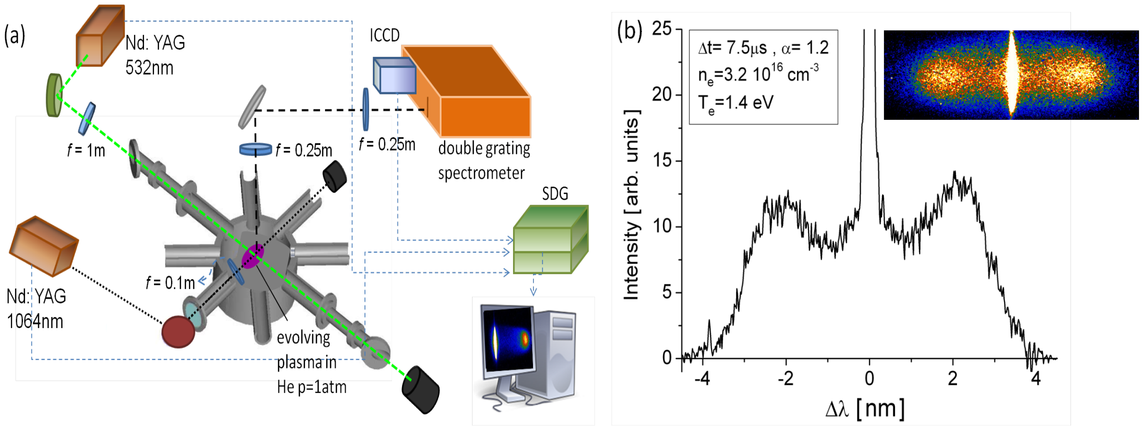


Fig. 1: (a) Schematic of experimental arrangement, (b) Thomson scattering image and spectrum at 7.5μs after breakdown.

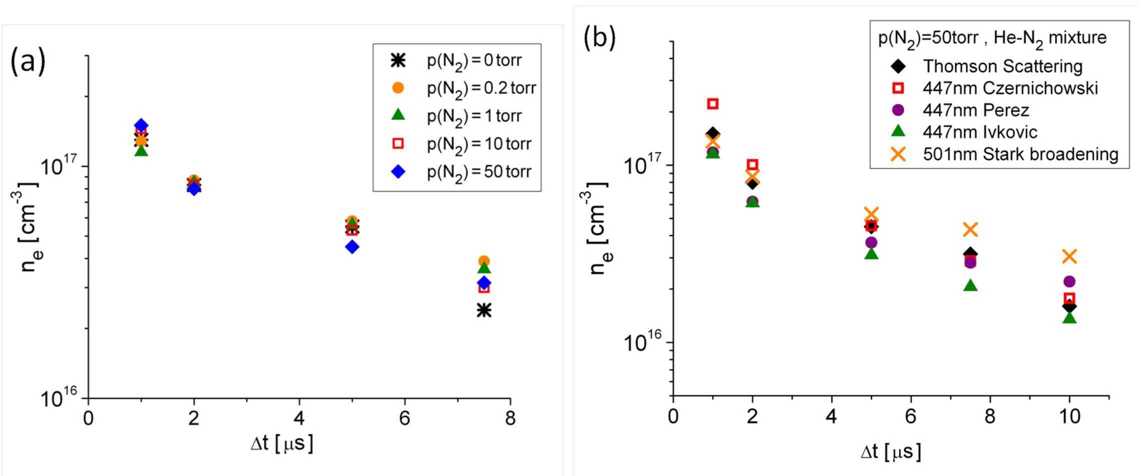


Fig. 2: Comparison of electron density, at different time delays after breakdown: (a) from TS at different $N_2$ partial pressures, (b) for He-$N_2$ mixture with p($N_2$)=50torr, from the TS and the line emission approaches.

## References

[1] S. K. Monfared, W. G. Graham, T. J. Morgan and L. Hüwel, *Plasma Source Sci. Technol.* 20 (2011) 035001.
[2] M. Ivkovic , M.A. Gonzalez, S. Jovicevic, M.A. Gigosos, N. Konjevic, *Spectrochimica Acta Part B* 65 (2010) 234–240.
[3] E. Nedanovska, G. Nersisyan, T. J. Morgan, L. Hüwel, C. L. S. Lewis, D. Riley, and W. G. Graham, *Appl. Phys. Lett.* 99 (2011) 261504.
[4] K. Dzierzega, A. Mendys, S. Pellerin, E. Thouin, G. Travaille, B. Bousquet, L. Canioni and B. Pokrzywka, *Journal of Physics: Conference Series* 227, (2010) 012029.