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ELECTRON DENSITY MEASUREMENTS IN A LASER INITIATED Nd PLASMA PULSE DISCHARGE

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Abstract. In this paper we present the preliminary results of diagnostics of laser initiated rare earth's plasma pulse discharge. The time dependence of the change of electron concentration was determinated from the shape of the He I 447 nm spectral line.

1. INTRODUCTION

The investigation of the radiation properties of the rare earth's plasmas are very significant for astrophysical research, in particular for understanding the physical processes in some stars atmosphere. These investigations are also of importance for laser emission studies from rare earth's plasmas in gas phase (Cahuzac, 1968; Bohan and Egorov, 1984; Bohan and Zakrevski, 1991). The main difficulties in these studies are the technical problems related to the high temperatures required for rare earth's evaporation and achievement of high enough concentrations of analyzed elements in plasma without other impurities. In this experiment the problem was solved by pulsed Nd-YAG laser evaporation of the Nd_2O_3.

2. EXPERIMENT

Block diagram of the experimental set-up is presented in Fig.1. The discharge tube, equipped with the quartz windows, has two hollow Al electrodes 13 cm apart. Pressure of the helium inside the discharge tube was 12 mbar. Radiation from the Nd -YAG laser, Molectron MY 34, with pulse duration of 15 ns, was focused by the lens f = 80mm focal length on the surface of the Nd_2O_3 pill, settled inside the discharge tube. Creation of plasma during the interaction of laser radiation with energy of 90 mJ with neodymium oxide pill initiate a pulse discharge energized by capacitor previously charged at voltage U = 980 V. Radiation from the discharge tube was focused on 10μm wide entrance slit of 0.5m Ebert type spectrograph/spectrometer (Jarrell Ash 82-025) with inverse dispersion 1.6 nm/mm.

In the first phase of the experiment the spectral lines in the wavelength region from 210 to 750 nm are recorded on film (Fomapan 400). The analysis of the recorded spectra was performed by the photodensitometer (Joyce Loeble).

In the second phase, spectra analysis was done by the use of photomultiplier EMI 9659QB mounted on the exit slit of the spectrometer. Photomultiplier was supplied

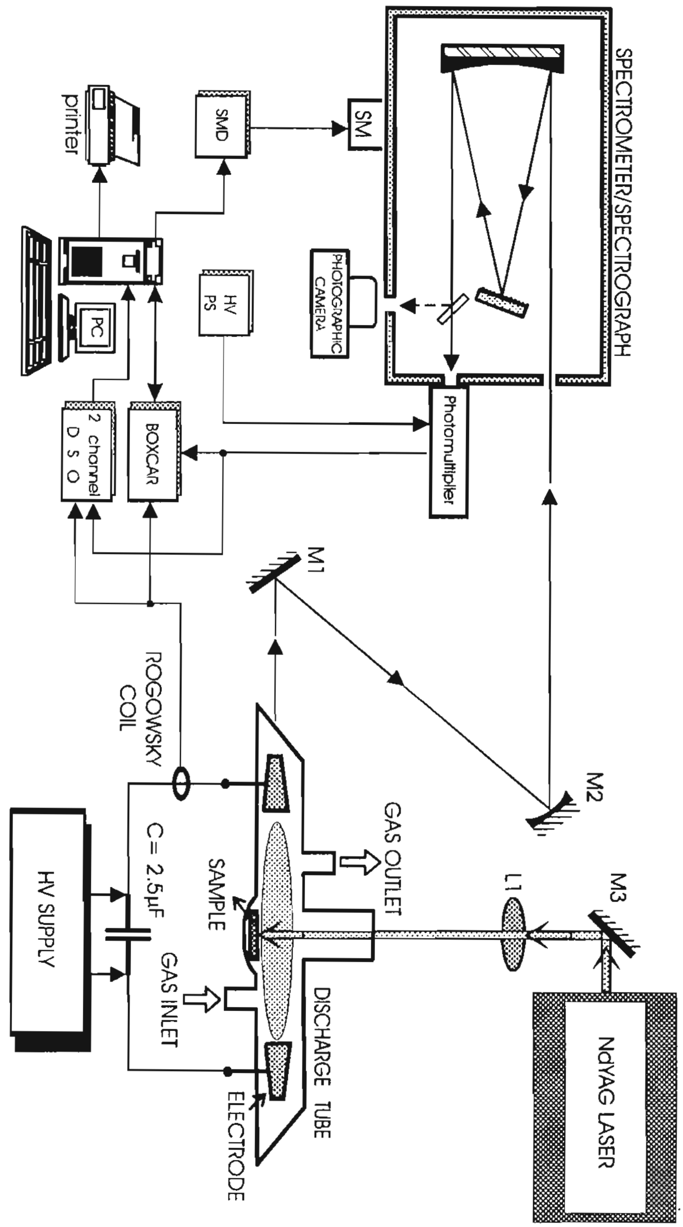

Fig. 1. Block diagram of the experimental set-up.

by the Keithley 244 High Voltage Power Supply. The wavelength scanning is performed by the step motor and step motor drive (Isert ID 3304) controlled with PC AT computer. Spectral line shapes are recorded by box-car averager (Stanford Research Systems SR 250) and the same computer. Triggering of the box-car averager was done with the signal from the Rogowsky coil. For enhancement of the signal to noise ratio, averaging of 10 samples with gate width of 30 ns was performed at each step of the motor. Time dependence of the current pulse, measured with Rogowsky coil (0.01 A/V) and intensities of spectral lines He I 447.1 nm and Nd II 401.27 nm are measured with the photomultiplier and recorded by two-channel digital storage oscilloscope (Gould 4050).

The copper target instead of the Nd_2O_3 pill is also used, for the investigation of influence of neodymium vapor on electron concentration.

3. RESULTS AND DISCUSSION

The qualitative analysis of the spectra of the discharge in pure helium (without pill) and discharge initiated by interaction of the Nd-YAG laser radiation with Nd_2O_3 pill are performed. Besides the helium and aluminum lines observed in both cases, a lot of Nd II spectral lines in laser initiated discharge are identified. The three lines of neutral neodymium, some oxygen and silicon lines are also identified. The most pronounced neodymium lines are obtained in spectral region from 385 to 435 nm, see Figure 2. Wavelengths, energy levels and transition of the strongest Nd II lines in this region are given in Table 1. (Martin *et al.*, 1978; Kuzuya *et al.*, 1993).

Table 1. Wavelengths, energy levels and transition of Nd II spectral lines in the region 385 nm - 435 nm

Wavelength λ [nm]	Energy levels [cm^{-1}]	Transition
410,946	20586-26913	$4f^4(^5I)6s(^6I) - 4f^4(^5I)6p(^4I^0)$
401,225	5086-30002	$4f^4(^5I)6s(^6I) - 4f^4(^5I)6p(^6K^0)$
406,109	3802-28419	$4f^4(^5I)6s(^6I) - 4f^4(^5I)6p(^6K^0)$
397,330	5086-38741	$4f^4(^5I)6s(^6I) - 4f^4(^5I)6p(^6I^0)$
395,745	13479-38741	$4f^3(^4I^0)5d^2(^3F)? - 4f^3(^4I^0)5d(^5L^0)6p(^6M)$
392,096	3066-28563	$4f^4(^5I)6s(^6I) - 4f^4(^5I)6p(^4K^0)$

The time dependence of the discharge current and intensities of He I 447.1 nm and strongest Nd II (401.22 nm) spectral lines recorded by oscilloscope are presented in Figure 3. The recording is a result of averaging eight successive pulses. From Fig. 3 we can see that current pulse duration is around 12 μs and that He I line starts increasing at least 5 μs from the beginning of the current pulse and lasts more than 40 μs. We can also see that Nd II 401.22 nm line appears a few microseconds before the beginning of the current pulse and lasts around 5 μs with a 30 μs long tail. Peak current I_{max} is around 800 A.

Shapes of the He I 447.1 nm at different times from the beginning of the discharge (10, 15, 20, 25, 30, 35 and 40 μs) are recorded. From these line shape recordings the electron density Ne is determined by empirical using formula (Czernichowski and Chapelle, 1985).

$$\log Ne = 23.056 + 1.586 \log (S - 0.156) + [\log (S - 0.156)]^2$$

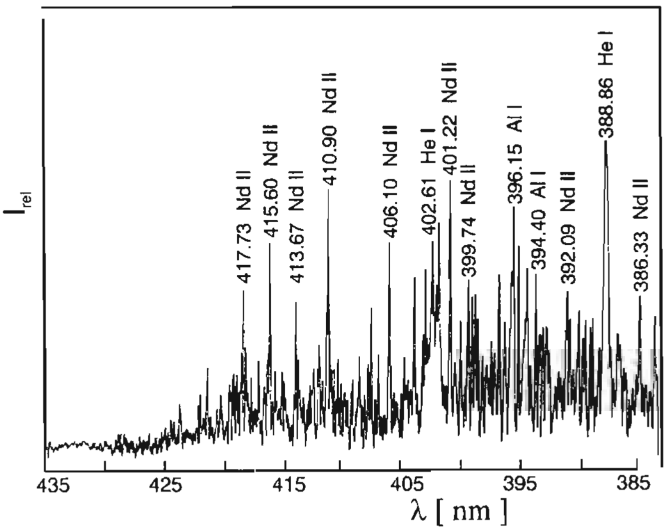

Fig. 2. Spectrum of the discharge in wavelength region 385 - 435 nm with laser interaction with Nd_2O_3 pill.

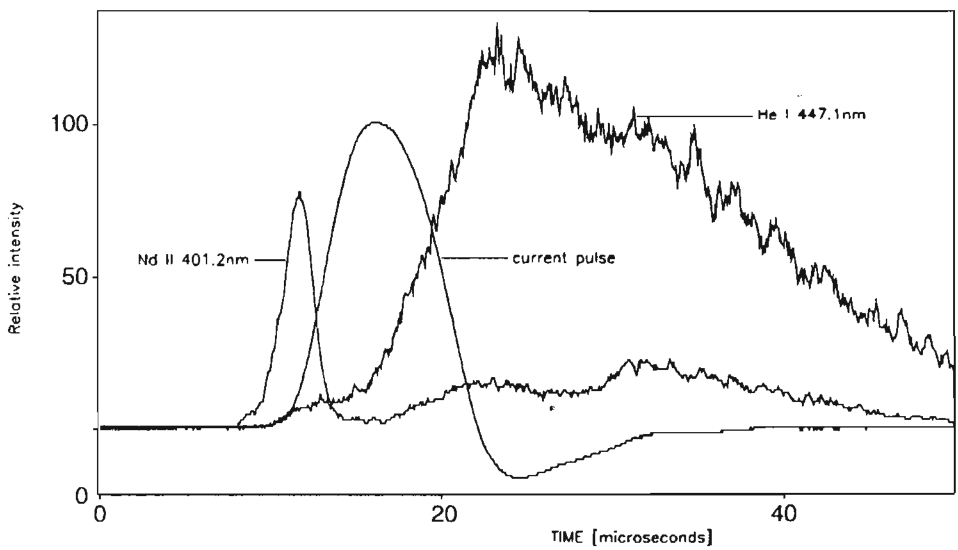

Fig. 3. Time dependence of current (1), and maximum intensities of He I 447.1 nm (2) and Nd II 401.22 nm spectral line.

Separation S between forbidden and allowed component of this line is used for electron density diagnostics to overcome difficulties caused by line selfabsorption. The obtained results with Nd_2O_3 and Cu target are presented in Figure 4.

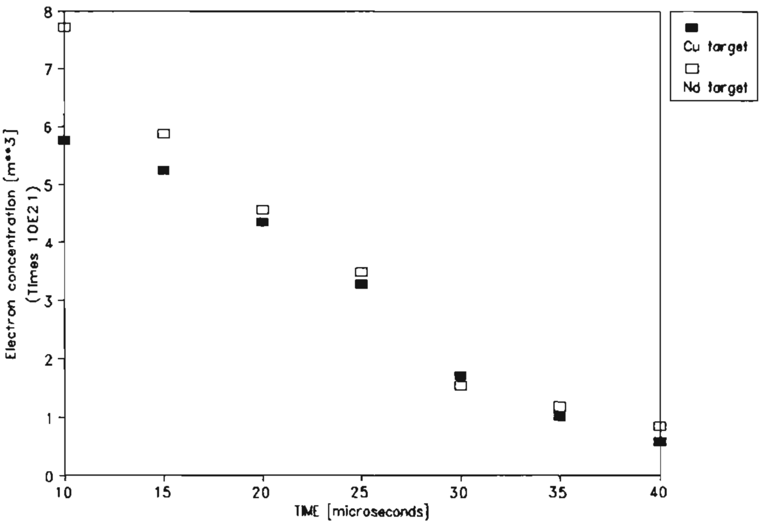

Fig. 4. Decay of the electron density Ne in time for two target materials.

4. CONCLUSION

On the basis of the obtained results, we conclude that, Nd evaporation can be achieved by means of Nd-YAG pulsed laser. Furthermore it was proven that He I 447.1 nm line can be used for electron density diagnostics in our experiment. In further investigations independent triggering of the pulse discharge and rare earth's evaporation by laser pulse after variable delay will be provided. Also, reproducibility of the Nd lines will be enhanced by laser evaporation only from previously non-irradiated part of the pill.

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