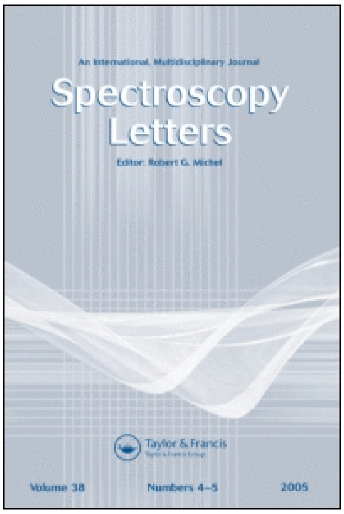

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ON THE POPULATIONS OF NEON LEVELS IN THE LOW TEMPERATURE PLASMA OF A HOLLOW CATHODE DISCHARGE

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Atomic levels population measurements constitute an essential contribution to various aspects of plasma research: balance and cross-section of inelastic processes, admixtures effects on level excitation mechanism , purposeful optimisation of plasma parameters etc. Atomic level populations in the negative glow of a hollow cathode discharge are of utmost interest in view of the peculiarities of the spectral source: a rich spectrum consisting of gas lines , lines of the cathode material and also lines of the substances introduced in the discharge; intensive atomic and ionic lines of high excitation potentials; small spectral linewidth, convenient for analytical purposes .

This paper contains results of population measurements on the S_2 , S_3 , S_4 and S_5 levels of the state $2p^5 3s$ of neon in an uncooled hollow cathode discharge.

1 . Population measurements were carried out by the method of reabsorption in one of its modifications - an emitting column of varying length [1]. A spectral line was selected for each of the examined levels , ending on that level. Intensities of the selected lines I_1 and I_2 were measured at two different lengths l_1 and l_2 of the column. Then reabsorption coefficients $\varkappa_0$ were determined for each of the lines , utilizing the relation

$$\frac{I_1}{I_2} = \frac{S(\varkappa_0 \ell_1)}{S(\varkappa_0 \ell_2)} \cdot \frac{\ell_1}{\ell_2}$$

where $S(\varkappa_0 \ell)$ is the Ladenburg-Levy function, presented graphically and numerically in [1] .

The product of f_{ik} (oscillator strength of the line) and N_i (population of its lower level) can then be found from

$$f_{ik} N_i = 1{,}21 . 10^{19} \frac{\Delta \lambda_D}{\lambda^2} \varkappa_0$$

where λ and $\Delta \lambda_D$ are the wavelength and Doppler width of the line in nanometers while $\varkappa_0$ is in inverse centimeters. Utilizing the values for f_{ik} given in [2] absolute values were found for $N_i (cm^{-3})$.

Populations of the investigated levels were determined by the lines Ne 585,2 nm , Ne 626,6 nm , Ne 607,4 nm and Ne 640,2 nm . We used a discharge tube with an aluminium hollow cathode , supplied with a movable bottom (Fig.1) ; diameter of the

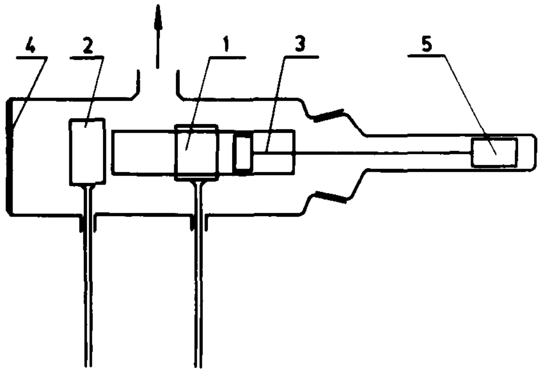

FIG.1

Hollow cathode discharge tube: 1 - hollow cathode; 2 - anode; 3 - movable bottom; 4 - observation window; 5 - iron core(attached to movable bottom).

cathode tube 10 mm , maximum effective length 67 mm. Using a magnet the length of the emitting column may be varied. Sensibility of the method depends on the choice of the ratio l_1/l_2 [1] . The type of discharge tube we employed, allows for selecting a suitable ratio l_1/l_2 .

The correct application of the method of reabsorption involves maintenance of two conditions: axial homogenity of the emitting column and Gaussian shapes of the spectral lines. Fabry-Perrot interferograms, corrected for apparatus broadening demonstrated the Gaussian shape of the profiles, while studies on the discharge in a perforated hollow cathode were indicative of the axial homogenity as regards line intensity.

2 . Populations of the levels S_2 , S_3 , S_4 and S_5 were measured at pressures P_{Ne} = 0,5 ; 1 ; 2 ; 3 ; 4 Torr and for densities of the discharge current j = 1,7 ; 3,4 ;

4 mA/cm^2 . On FIG.2 is presented the dependence $N_{S_{2-5}}(P)$ for a fixed current density 1,7 mA/cm^2 .

Increasing pressure, $N_{S_{2-5}}(P)$ decrease after passing through a maximum at $P = 1$ Torr.

For the greater discharge current densities the dependence $N(P)$ intensifies its descending character, especially N_{S_2} , N_{S_4} .

Table 1 contains data about the function $N_{S_{2-5}}(j)$ at $P = 0{,}5$ Torr. Populations are seen to grow with increasing j . This tendency is stronger in N_{S_2,S_4} which was also the case in [5] at $P = 1{,}1$ Torr. The observed dependence $N(j)$ may be interpreted through the variations in the conditions at which the direct electron-atom excitation takes place: increased electron concentration and enriched with fast electrons distribution function of the electrons with energy [3] .

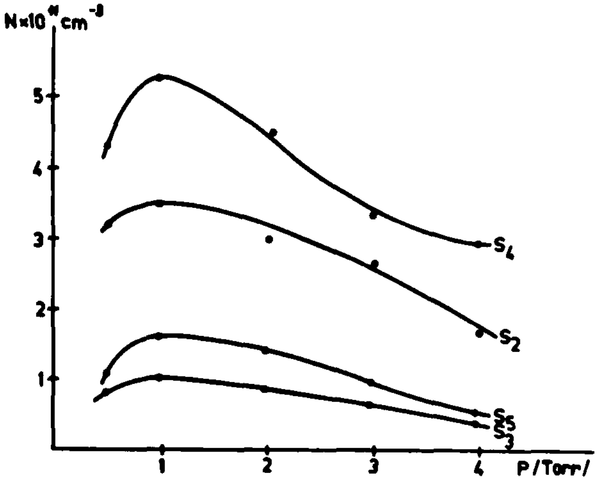

FIG.2
Pressure dependence of populations.

TABLE 1

Dependence of populations on the discharge current density at P_{Ne} = 0,5 Torr .

$j (mA/cm^2)$	$N_{S_2} \cdot 10^{-11}$	$N_{S_3} \cdot 10^{-11}$	$N_{S_4} \cdot 10^{-11}$	$N_{S_5} \cdot 10^{-11}$
1,7	3,231	0,768	4,281	1,092
3,4	4,982	1,169	6,781	2,114
4,0	5,102	1,369	7,761	2,423

This excitation mechanism should be considered as fundamental for the studied discharge. A consideration in this respect is the experimentally observed correlation between N(P) and the cathode voltage drop U_c for $j = 1,7\ mA/cm^2$ (Fig.3) .

U_c determines the electron energy distribution F(E) and provides an upper limit for their maximum energy at fixed j and P [4] . As the studied levels have comparatively high

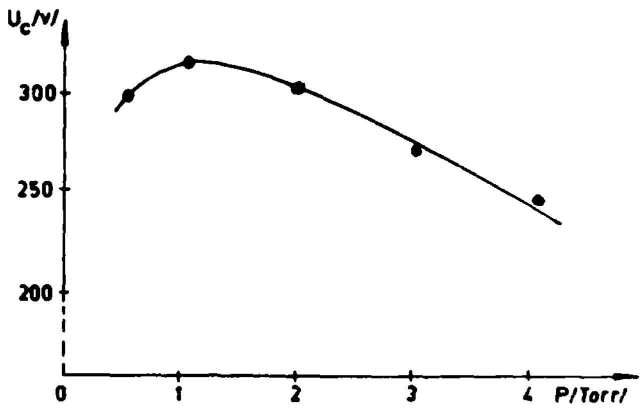

FIG.3

Pressure dependence of the cathode voltage drop.

excitation potentials they are sensitive towards any redistribution in F(E), caused by changes in P , which is demonstrated by our experiment.

Following features can be pointed out when considering the level populations in the whole range of varying conditions (keeping in view that S_3 and S_5 are metastable while S_2 and S_4 - resonant).

-- $N_{S_4} > N_{S_2}, N_{S_3}, N_{S_5}$ (in [5] $N_{S_2} > N_{S_3}, N_{S_4}, N_{S_5}$).

-- $N_{S_2} > N_{S_3}, N_{S_5}$ for $j = 1,7\ mA/cm^2$ but with increasing j populations of all three levels assume similar values (in the range 1,5 - 3 Torr).

-- for $j > 1,7\ mA/cm^2$ and $P > 3$ Torr a tendency for increasing N_{S_2}, N_{S_4} is observed while N_{S_3}, N_{S_5} preserve their inverse dependence on P in the whole range of j and P .

3 . Helium was introduced in the discharge and its influence was studied on population of the levels S_{2-5} . We worked with gas mixtures $P_{Ne}:P_{He}$ = 1:1 , 1:2 , 1:3 , 1:5 , 1:7 at total gas pressures and discharge current densities same as reported above. Analogical experiments in positive glow for the 3S and 2S levels of Ne are closely related with the observed laser action of the transitions 2s 2p, 3s 3p and $3s_2$ $2p_4$ which is interpreted by the energy resonance between the metastable levels $He(2^1S)$ and $He(2^3S)$ from one side and the groups Ne(2S) and Ne(3S) from another. Of principal interest is the total effect of the He-Ne interaction on the populations $N_{S_{2-5}}$. For that reason total populations $\sum N_{S_{2-5}}$ are only being discussed.

An increase in $\sum N_{S_{2-5}}$ was observed on passing from Ne to the mixture $P_{He}:P_{Ne} = 1:1$. Data for pressure $P_{Ne+He} = 3$ Torr and $j = 3,4$ mA/cm^2 are presented in Table2

TABLE 2
Pressure dependence of the populations for $j = 3,4$ mA/cm^2

$P_{He}:P_{Ne}$	$N_{S_2}\cdot 10^{-11}$	$N_{S_3}\cdot 10^{-11}$	$N_{S_4}\cdot 10^{-11}$	$N_{S_5}\cdot 10^{-11}$	$\sum N_{S_{2-5}}$
0	1,062	0,178	1,293	0,434	2,967
2:1	2,935	0,337	3,351	0,435	7,058
5:1	4,063	1,042	6,174	0,954	12,233
7:1	1,882	0,337	3,352	0,216	5,787

It can be seen that the greatest contribution to this increase is due to the resonance levels S_2 and S_4 . A monitoring measurement was also carried out on the population of the helium level 2^1S by the line He5016 Å. It was found that N_{2^1S} most strongly diminishes for the transition Ne:He = 1:1 ⟶ 1:2 i.e. where $\sum N_{S_{2-5}}$ grows most considerably. The influence of helium is not solely reduced to the discussed energy interaction between He and Ne. We made an evaluation by the method of relative intensities of the kinetic energy of electrons that shows that this grows considerably on addition of helium (use has been made of the lines He 5047 Å and He 4713 Å while data on effective cross-sections and optical excitation functions were taken from [6] .

We maintain that the latter mechanism also contributes to the increase in $\sum N_{S_{2-5}}$.

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