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INVESTIGATION OF THE DISSOCIATIVE RECOMBINATION OF Ne_2^+ IONS BY THE OPTICAL METHOD[1)]

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By using the "sampling" method we have measured time dependences of relative intensities of the spectral lines emitted from the Ne afterglow plasma at the pressure of 2.66 kPa. We have determined partial recombination coefficients α_k ($k=1, \ldots, 10$) and distribution fractions f_l ($l=2, \ldots, 5$) for the dissociative recombination of Ne_2^+ ions. The measured densities of the $2p_k$ levels do not satisfy the Boltzmann distribution in the afterglow plasma.

ИССЛЕДОВАНИЕ ДИССОЦИАТИВНОЙ РЕКОМБИНАЦИИ ИОНОВ Ne_2^+ ОПТИЧЕСКИМ МЕТОДОМ

Используя «выборочный» метод, в работе приведены результаты измерений временной зависимости относительных интенсивностей спектральных линий, излучаемых из послесвечения неоновой плазмы при давлении 2,66 кПа. Получены коэффициенты парциальной рекомбинации α_k ($k=1, 2, \ldots 10$) и коэффициенты распределения f_l ($l=2, 3, 4, 5$) для диссоциативной рекомбинации ионов Ne_2^+. Измеренные плотности $2p_k$ уровней не удовлетворяют распределению Больцмана в послесвечении плазмы.

I. PRINCIPLE OF THE METHOD

Dissociative recombination process of Ne_2^+ ions with electrons can be described by the scheme [1, 2]

$$Ne_2^+ + e \rightarrow (Ne_2)^* \rightarrow Ne^*(2p_k) + Ne \rightarrow Ne^*(1S_l) + Ne + h\nu \qquad (1)$$

where $(Ne_2)^*$ is the unstable molecular complex, Ne^* $(2p_k)$ and $Ne^*(1s_l)$ are excited Ne atoms. The value of the recombination coefficient α of the total process (1) was measured by many authors [3]. The partial recombination coefficient α_k is

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the rate constant for such a channel of the process (1) which leads to the formation of $Ne^*(2p_k)$ atoms. According to this definition $\sum_{k=1}^{10} \alpha_k = \alpha$. If we assume that transitions between various $2p_k$ levels induced by the collisions with electrons and neutral atoms are negligible, then the continuity equation for the density n_k on the $2p_k$ level gives (if $n_e \simeq n_i$)

$$\frac{\partial n_k}{\partial t} = \alpha_k n_e^2 - \sum_{l=2}^{5} A_{kl} n_k , \qquad (2)$$

where n_e is the electron density, A_{kl} is the transition probability from the $2p_k$ to the $1s_l$ level. For the intensity of each spectral line is valid

$$I_{kl} = \eta_{kl} A_{kl} n_k , \qquad (3)$$

where $\eta_{kl} \sim h\nu_{kl}$ is the detection efficiency of the experimental set up. In the afterglow plasma there becomes $\partial I_{kl}/\partial t \ll I_{kl} A^*_{kl}$ (see f. e. [2]), where $A^*_{kl} = \sum_{l=2}^{5} A_{kl}$. Then after substitution of Eq. (3) into Eq. (2) the spectral line intensity is given by

$$I_{kl} = K \alpha_k n_e^2, \qquad (4)$$

where K indicates $A_{kl}\eta_{kl}/A^*_{kl}$.

In the neon afterglow plasma at a pressure of 2.66 kPa the solution of the electron density equation is the "recombination solution"

$$\frac{1}{n_e(t)} - \frac{1}{n_e(0)} = \alpha t. \qquad (5)$$

Substitution of Eq. (4) into Eq. (5) gives

$$I_{kl}^{-1/2}(t) \times I_{kl}^{-1/2}(0) + \alpha t \left(\frac{A_{kl}}{\alpha_k \eta_{kl} A_{kl}} \right)^{1/2}. \qquad (6)$$

Now we have the possibility to determine α_k by using Eq. (6) if η_{kl}, A_{kl}, A^*_{kl} and α are known. To determine the relative densities of the $2p_k$ levels we used the expression

$$\bar{n}_k = \frac{n_k}{\sum_{j=1}^{10} n_j} = \frac{\dfrac{I_{kl}}{\eta_{kl} A_{kl}}}{\sum_{j=1}^{10} \dfrac{I_{jl}}{\eta_{jl} A_{jl}}}. \qquad (7)$$

The excited $Ne^*(2p_k)$ atoms create $Ne^*(1s_l)$ atoms after a spontaneous emission.

The production of $Ne^*(1s_l)$ atoms characterizes recombination distribution fractions f_l, defined by [2]

$$f_l = \frac{\sum_{j=1}^{10} \dfrac{I_{jl}}{\eta_{jl}}}{\sum_{l=2}^{5} \sum_{j=1}^{10} \dfrac{I_{jl}}{\eta_{jl}}}. \qquad (8)$$

The quantities f_l give the fraction of the recombination yield produced in $1s_l$ levels.

II. EXPERIMENTAL APPARATUS

The sampling method was used to determine the time dependences of the relative intensities of the spectral lines. The block diagram of the experimental apparatus is given in Fig. 1. The method is as follows: by the first pulse the generator monitored the gatting of the photomultiplier. The second pulse was used

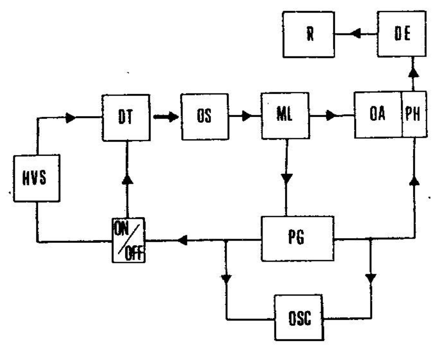

Fig. 1. Block diagram of the experimental apparatus (HVS – high voltage source, ON/-/OFF-switching, DT – discharge tube, OS – optical system, ML – mechanical light modulator, OA – optical analyser, PG – pulse generator, PH – photomultiplier, DE – dynamical electrometer, R X–Y recorder, OSC – osciloscope).

to monitor the excitation of the periodically pulsed dc glow discharge. We have chosen the time in the afterglow period in which the emitted light was detected by the change of the pulse delay to the synchronization pulses (generated by the photodiode from mechanically modulated light). The monochromator SPM 2 was used as an optical analyser and the photomultiplier FEU 79 as a detector. The photocurrent was measured by the dynamic electrometer MEK 100. The curve of the spectral efficiency was measured by using a W lamp. The linearity of our apparatus and the reproducibility of our measurements were tested. The inner diameter of the cylindrical Sial discharge tube was 17.6 mm. The distance between the cylindrical Ni electrodes was 12.7 cm. A Ba getter was used to purify the gas filling.

III. RESULTS OF MEASUREMENTS

We have measured the time dependence of the relative intensities of 22 spectral lines ($2p_k \to 1s_l$) in the afterglow plasma. The discharge current was 50 mA. For each spectral line we can write $I(t) = I_0 f(t)$, where $I_0 = I(0)$ and $f(t)$ is the form function of the time dependence of the spectral line intensity. Therefore it is suitable to express log $I(t)$ to compare the shape of $f(t)$. All the measured lines had the same shape of the time dependence, i.e. the same function $f(t)$. This confirms our conclusion that the dissociative recombination process [1] is a dominant excitation process in the Ne afterglow at 2.66 kPa. In addition, induced excitation and deexcitation by collisions with electrons and neutral atoms can be neglected.

By using Eq. (6) we have determined the partial recombination coefficient α_k ($k = 1, \ldots, 10$) from the time dependences $I^{-1/2}(t)$. The obtained α_k were normalized to α. In Table 1 there are shown the obtained α_k and the wavelengths of the used spectral lines. Values of A_{kl} were taken from [4].

We have calculated using Eq. (7) the relative densities of the $2p_k$ levels at the time $t = 0.2$ ms. The results are given in Table 2. The obtained distribution does not satisfy the Boltzmann distribution.

Table 1

k	1	2	3	4	5	6	7	8	9	10
α_k/α	0.06	0.1	0.03	0.15	0.09	0.09	0.07	0.12	0.14	0.15
λ [nm]	585.2	659.8	607.4	609.6	626.6	614.3	638.3	650.6	640.2	703.2

Table 2

k	1	2	3	4	5	6	7	8	9	10
n_k [%]	6.4	6.8	0.8	17.2	6	10	4	8.8	8	32

Table 3

f_2	f_3	f_4	f_5
0.295	0.075	0.24	0.39

The recombination distribution fractions f_l ($l = 2, \ldots, 5$) have been determined from the same measurements by using Eq. (8). The results obtained are presented in Table 3. They show that process (1) leads mainly to creating $Ne^*(1s_5)$ atoms. The results given in Tables 1—3 are in agreement with Steenhuysen's data [2].

IV. CONCLUSION

In the present paper there was tested the method of the measurements and evaluating time dependences relative intensities of spectral lines. The results obtained in the Ne afterglow plasma give information about the role of the dissociative recombination of Ne_2^+ ions in the production of the excited Ne atoms in various states.

REFERENCES

[1] Sauter, G. F., Gerber, R. A., Oskam, H. J.: Physica *32* (1966), 1921.

[2] Steenhuysen, L, W. G.: *Investigations of afterglow of neon gas discharge.* PhD Thesis, TU Eidhoven 1979.

[3] Smirnov, B. M.: *Iony i vozbuždonnije atomy v plazme.* Atomizdat, Moskva 1974.

[4] Kasabov, G. A., Jelisejev, V. V.: *Spektroskopičeskije tablici dla niskotemperaturnoj plazmy.* Atomizdat, Moskva 1973,

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