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Introduction. The relative and absolute densities of the various neon 1s levels were studied, by means of optical fluorescence, in cilindrical discharge tubes (d = 31 mm) [7]. A multi-mode CW dye laser (Spectra Physics model 370) was used as excitation source.
The relative densities and their ratio's were measured in the active discharge and in the afterglow of a neon discharge.
The absolute densities were measured in the positive column of the neon discharge by means of a modified absorption method; the absorption of the laserlight in the plasma was derived from the measured attenuation of the fluorescence signal along the path of the laser beam. In this case only that part of the laserlight spectrum that can be absorbed contributes to the measuring signal; disturbing effects at the entrance and the exit of the tube are eliminated; the accuracy is enhanced because the absorption can be measured for a large number of different path lengths in the same tube.

The relative densities. The fluorescence radiation ϕ_i originating from the $2p_2$-$1s_2$ transition (Paschen notation) after optical pumping of a level $1s_i$ to $2p_i$ is given by:

$$\phi_i = \sum_k J_i(\nu_k) B_{i2} n_i g_i(\nu_K) A_{22}/A^* \qquad (1)$$

i= M, R, S, T for respectively the $1s_5$, $1s_4$, $1s_3$ and $1s_2$ level. B_{i2} is the Einstein coefficient [1,2,3,4]; n_i is the density of level $1s_i$; A_{22} is the spontaneous transition probability for the $2p_2$-$1s_2$ transition; A^* is the total transition probability of the level $2p_2$; $g_i(\nu_K)$ is the value at frequency ν_K of the normalised absorption profile of level $1s_i$ and $J_i(\nu_K)$ the radiative energy density in laser mode k when level $1s_i$ is irradiated. The summation is made over all laser modes. We assume that $J_i(\nu_K)$ is constant for all ν_K within the absorption profile; this is justified because the width of the laser spectrum is about 15 times broader than the width of the absorption profile $g_i(\nu)$. Moreover we assume that the laser mode configuration does not change substantially with a change in the laser wavelength. The slight differences between the various functions $g_i(\nu)$ are neglected because of the small energy gap between the 1s levels. The ratio between the fluorescence radiation when $1s_5$ and $1s_4$ are irradiated is:

$$\frac{\phi_M}{\phi_R} = \frac{B_{M2}\, n_M\, A_{22}/A^* \sum_k J_M(\nu_K) g_M(\nu_K)}{B_{R2}\, n_R\, A_{22}/A^* \sum_k J_R(\nu_K) g_R(\nu_K)} = \frac{J_M(\mathrm{tot})\, B_{M2} n_M}{J_R(\mathrm{tot})\, B_{R2} n_R} \qquad (2)$$

$J_M(\mathrm{tot})$, $J_R(\mathrm{tot})$ are the values of the laser beam power when level $1s_5$ respectively $1s_4$ is irradiated. Corresponding relations with (2) can be derived for other $1s_i$ combinations. From (2) follows that n_M/n_R can be determined from the fluorescence radiation when all other parameters of the experimental set up are kept constant. In this way we have measured for a few values of pressure and discharge current the relative densities of the $1s_5$, $1s_4$ and $1s_3$ levels. This was done in the active discharge as well as in the afterglow. Figure 1 gives the ratios of the relative 1s densities in a 5 torr tube as function of the discharge current. At 30 mA we find n_M/n_R = 1.6 which is in reasonable agreement with the value 1.9 given by Soldatev [6] for a corresponding situation. Figure 2 gives the values of n_M/n_R in the afterglow for pressures 0.5, 1, 2 and 5 torr and a discharge current of 22 mA.
It must be remarked that important failures may arise if the laser mode configuration is not stable or if the laser beam power is too large. The latter condition may be checked carefully. In a number of cases we have checked the mode configuration by analysing the laser line shape with the help of a scanning Fabry-Perot interferometer.

The absolute densities. We have measured the absolute densities with the experimental set up given in figure 3. The laser beam enters the discharge tube at point 0 and may be adjusted parallel with the tube axis. Detection system DSI is fixed, but DSII can be moved parallel to the tube axis. The distance from 0 along the tube axis is denoted by x. We will derive a relation for the ratio of the fluorescence radiation $\phi(x_2)/\phi(x_1)$. $\phi(x_2)$ and $\phi(x_1)$ are emitted simultaneously by P_2 (at $x=x_2$) and P_1 (at $x=x_1$).

The laser energy density per mode and per unit volume $J_M(\nu_K,x)$ is a function of x according:

$$J_M(\nu_K,x) = J_M(\nu_K,o)\exp(-k(\nu_o)g^*(\nu_K)\frac{\nu_K}{\nu_o}x) \qquad (3)$$

with $k(\nu_o)$ is the absorption coefficient for the central laser frequency ν_o; $k(\nu_o) = \sigma(\nu_o)n_M$ with $\sigma(\nu_o)$ is the absorption cross section at $\nu=\nu_o$ [3]; $g^*(\nu_K) = g(\nu_K/g(\nu_o)$.

When $J_M(\nu_K,x)$ is substituted in relation (1) and using $\nu_K \approx \nu_o$ we find:

$$\ln\frac{\phi(x_2)}{\phi(x_1)} = -k(\nu_o)(x_2-x_1) + \ln\frac{1+G(x_2)}{1+G(x_1)} \qquad (4)$$

with $G(x) = 2\sum_K g^*(\nu_K)\exp(k(\nu_o)x(1-g^*(\nu_K)))$.

Figure 4 gives the calculated values of $\ln(\phi(x_2)/\phi(x_1))$ versus (x_2-x_1) for $x_1 = 0.04$ m. Relation (4) may be approximated within 5% for $k^2(\nu_o)x < 2.44$ by:

$$\ln\frac{\phi(x_2)}{\phi(x_1)} = -0.707\,k(\nu_o)(x_2-x_1) + 0.0387\,k^2(\nu_o)(x_2-x_1)^2 \qquad (5)$$

From the slope of $\ln(\phi(x_2)/\phi(x_1))$ at $x_2 = x_1$, we can determine the value $k(\nu_o)$ and from this the $1s_5$ density. Figure 5 gives a few examples of our experimental results. When the measured absorption curve is not a straight one we have $k(\nu_o)$ determined by curve fitting. The inaccuracy is better than 10%. It can be remarked that $k(\nu_o)$ depends on the used spectral transition. So it is possible to measure in the same discharge a different absorption behaviour by using different spectral transitions. Excitation of the $1s_5$ level with $\lambda = 588.2$ nm results in $k(\nu_o) = 21.7$, $n_M = 3.52\ 10^{17} m^{-3}$; with $\lambda = 597.5$ nm results in $k(\nu_o) = 7.14$, $n_M = 3.44\ 10^{17} m^{-3}$.

Figure 5 gives the absolute density with P = 1 torr at various currents. They are in good agreement with measurements from Ricard [5].

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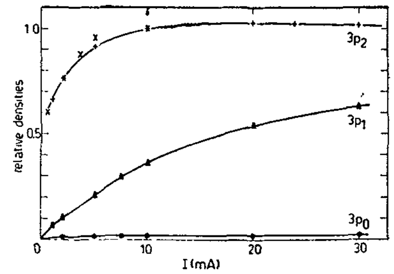


Figure 1: Measured ratios of the densities of the 1s5,1s4,1s3 levels in a 5 torr discharge. The crosses (x) were obtained from Ricard [5].

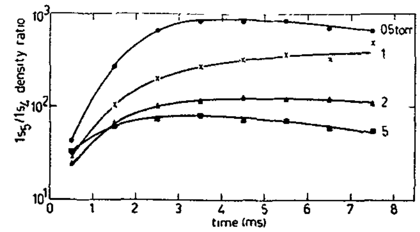


Figure 2: Values of n_M/n_R in the afterglow for various pressures.

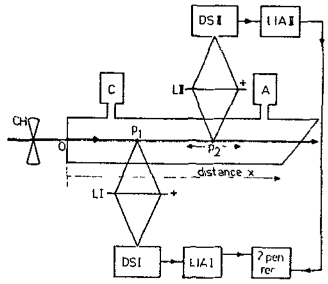
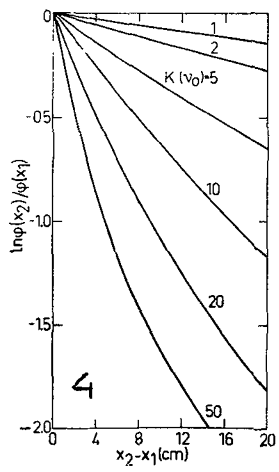


Figure 3: Experimental set up for the absorption measurements.



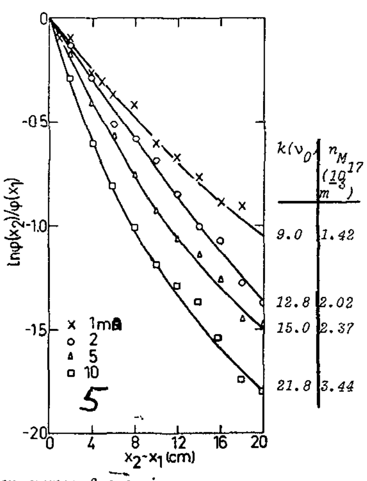


Figure 4: Calculated absorption curves for various values of $k(\nu_o)$.

Figure 5: Measured absorption curves for p=1 torr and λ=588.2 nm at various currents.