CHAPTER 5
SIMULTANEOUS INVESTIGATIONS ON LASER-INDUCED FLUORESCENCE
AND OPTOGALVANIC EFFECT IN NEON DISCHARGE

5.1 INTRODUCTION

Even though, in recent years OG effect has been widely used as a powerful technique for several spectroscopic and analytical applications [1,2], a detailed understanding of the processes governing OG mechanism is restricted only to a very few cases. Quantitative understanding of this effect in a variety of discharges and experimental conditions has improved the potentiality of this detection technique and made it an important tool for the diagnostics of the plasma. The effect, as described in earlier chapters, is produced when a gas discharge is irradiated with light which is resonant with one of the transitions in atoms, molecules or ions present in the discharge. Most of the theoretical models of OG phenomenon reported in the literature are designed for a particular type of discharge and for the specific conditions existing therein [3,5]. The main difficulty in developing a more general model is the existence of a large number of different processes that characterize the discharge system.

The interaction of a laser beam with discharge is a complex process and depends on the balance between all excitations and de-excitations of various species present in the medium.
Optogalvanic effect is basically a change in electrical properties of a gas discharge due to modifications in the population of states caused by the absorption of radiation. It gives information on changes in the population distribution as a result of selective laser excitation.

The interaction of laser with discharge will generate variations in the temperature, population etc. and the combination of OG spectroscopy with other techniques such as absorption, photoacoustics, fluorescence etc. can be utilized to get more detailed informations regarding various processes in the discharge that result into OG effect. The simultaneous investigations of OG effect and absorption can be used to get line shape of spectral lines which reveal the collision process in the discharge while the monitoring of OG effect with photoacoustic effect can be utilized to study the non-radiative decay path in the discharge. Fluorescence emission is another phenomenon which represents a well established technique for obtaining informations on radiative de-excitation path between various energy levels. Variations in emission characteristics is another important consequence generated by interaction of laser beam with the discharge medium. This occurs as a result of modifications in the population of states; resulting in both increase and decrease in emission intensities of certain lines as compared to that without irradiating the discharge. Hence, simultaneous investigations of OG effect and emission
characteristics provide a sensitive method to study the population of states in a discharge and the various factors which influences in generating the OG effect. Simultaneous monitoring of OG effect and other effects like photo acoustic effect [8-9], and optical absorption [9] have been reported to gather information about the laser-discharge interaction in a positive column discharge. However, only limited studies on simultaneous monitoring of OG and fluorescence phenomena have been carried out [10,11]. De Marinus et al [12] have studied the spatial dependence of the fluorescence intensity in a neon negative glow discharge and Dreez et al [13] have studied the change in temperature by monitoring the emission intensity before and after laser illumination of uranium transitions in a hollow cathode discharge. The present chapter deals with the studies on simultaneous monitoring of OG effect for 1s_{5/2} \rightarrow 2p_2 and 1s_{5/2} \rightarrow 2p_4 transitions of neon and the laser induced emission spectrum.

5.2 EXPERIMENTAL DETAILS

A frequency stabilized ring dye laser (Spectra Physics-380D) pumped by argon ion laser (Spectra Physics - 171) was used as the excitation source. Wavelength of the laser was exactly tuned on the line centre of the neon transition (at 5882 Å and 5845 Å corresponding to 1s_{5/2} \rightarrow 2p_2 and 1s_{5/2} \rightarrow 2p_4 transitions of neon respectively) where the OG signal amplitude is a maximum. The wavelength of the laser was fixed with an accuracy of \pm 0.01cm^{-1}.
of the transition. A commercial Ne/Mo hollow cathode lamp with a gas pressure of 10 Torr (Cathodean UK) was used as the discharge source and the laser beam was focused into it. The cell is operated with glow discharge region in the voltage-current characteristics. A 0.5m monochromator (Jarrell Ash) was used for recording the emission spectrum of the discharge with and without laser excitation for various discharge currents up to 5mA. The PMT output was processed by a lock-in amplifier and a computer was used for data acquisition. Since the
range of current used for the operation of the discharge was very low. Molybdenum (Mo) atomic lines were not observed in the emission spectrum. The neon transitions within the scanning range of the monochromator were identified in all cases. The 06 signal corresponding to an increase in the discharge impedance during laser excitation, was measured using an oscilloscope. A schematic of the experimental setup is shown in fig 5.1.

![Fig 2.2 Simplified energy level scheme showing the coupling between levels included in the rate equation analysis.](image)
5.3 ENERGY LEVEL DIAGRAM OF NEON

The first excited state configuration of neon \(2p^53s\) has four components denoted as \(1s_1, 1s_2, 1s_3, \) and \(1s_4\) (\(i = 2, 3, 4\) and 5). Two of these viz. \(1s_3\) and \(1s_5\) are metastable states with a long life time \([14, 15]\) while \(1s_2\) and \(1s_4\) states have strong radiative coupling with the ground state \((1^1S_0)\). The decay rate of the \(1s_5\) and \(1s_3\) levels due to diffusion to the walls are substantially smaller than the decay rate of the \(1s_4\) and \(1s_2\) states as a result of the escape of the trapped radiation. The next excited state configuration is \(2p^53p\) giving rise to ten states represented as \(2p_j\) \((j = 1\) to \(10\)) which are also coupled radiatively to the \(1s_1\) states. We have used a simplified energy level diagram in which the ground state, four \(1s_1\) levels and the ionized state are considered independently while only the prominent effects from \(2p_2\) state due to radiative processes are included (fig 5.2).

5.4 LASER EXCITATION OF \(1s_5 \rightarrow 2p_2\) TRANSITION (5882 Å)

a) Laser induced fluorescence spectrum

Laser excitation corresponding to \(1s_5 \rightarrow 2p_2\) transition of neon will perturb the population density of \(2p_2\) state and the monitoring of fluorescence from \(2p_j\) to \(1s_1\) levels will give information on the upper state population. The discharge tube and the monochromator were adjusted as so to minimize the effect of scattered laser beam at 5882 Å in the spectrum. The emission and the laser induced fluorescence spectrum of the neon hollow
Fig 5.3 A) Emission spectrum of neon discharge at 5mA and B) the same under laser irradiation at 5882 Å, laser power 250 mW.
cathode at a discharge current of 5mA by laser excitation of \(1s_5 \rightarrow 2p_2\) transition in neon are shown in fig 5.3. This shows that laser absorption produces a noticeable change in the emission characteristics of the discharge. These changes are mainly due to modifications in the population of \(2p_2\) state and non-radiative decay from \(2p_2\) state to \(2p_j\) \((j \neq 2)\) state and also depends on the coupling of these levels to the ground state. Measurements of variation in emission intensity of \(2p_2 \rightarrow 1s_1\) \((i = 2, 3, 4\) and 5\) transitions as a function of the discharge current (fig 5.4a,b,c,d) show that in presence of laser beam, the emission intensities are non-linear functions of current while in the absence of laser excitation they have a linear dependence. The enhancement in the intensity of these transitions during laser excitation indicates that the population of the \(2p_2\) state increases considerably. The emission intensity of \(2p_1 \rightarrow 1s_2\) also shows slight increase (fig 5.4e) under laser irradiation due to collisional excitation of atoms from \(2p_2\) to \(2p_1\) level. The emission intensity for transitions \(2p_3 \rightarrow 1s_4\), \(2p_4 \rightarrow 1s_4\) and \(2p_4 \rightarrow 1s_5\) (fig 5.4 f,g,h) shows a slight increase during laser excitation while in the case of \(2p_3 \rightarrow 1s_3\) and \(2p_5 \rightarrow 1s_5\) (fig 5.4i,j) transitions it is approximately equal with and without laser excitation. It has been established that such collisional excitation or de-excitation cross section between two levels with energy difference \(\Delta E\) varies as \(\exp(-\Delta E/k_B T)\) [11]. This implies that atoms in \(2p_2\) level can de-excite to nearby sub levels.
b) $2p_2-1s_3$

d) $2p_2-1s_5$

e) $2p_1-1s_2$

f) $2p_3-1s_4$

Continued
Fig 5.4 Dependence of the emission intensity for $2p_j \rightarrow 1s_1$ as function of discharge current (o - without laser, Δ - with laser at 5882 Å)
Cj=3,4,5) while such collisional de-excitation to 2p_j levels with j = 6,7,8,9,10 will be less probable. It should be noted that population of 1s_5 level will decrease due to absorption of laser light and hence the 2p_j manifolds arising through electron collision from 1s level viz.,

\[ \text{Ne (1s_5)} + \text{e}^- \rightarrow \text{Ne (2p_j)} + \text{e}^- \]

will diminish. In presence of laser irradiation for 2p_6 → 1s_4, 2p_6 → 1s_5, 2p_8 → 1s_4, 2p_8 → 1s_5, and 2p_9 → 1s_5 transitions (fig 5.4 k,l,m,n,o) decrease in intensity is observed, where a reduction in the population of 2p_j manifolds due to above process is large as compared to collisional de-excitation from 2p_2 to these states. This decrease in intensity under laser excitation is predominant in the case of 2p_8 → 1s_4 and 2p_9 → 1s_5 transitions (fig 5.4m,o). However such decrease in population density in 2p_j levels (j = 1,3,4,5) will be compensated by non-radiative transitions from 2p_2 state. This fact is in support of the observations that the emission intensity for transitions from 2p_j levels (j = 1,3,4,5) do not have any decrease under laser excitation. An exception is observed in the case of 2p_7 → 1s_3, 2p_7 → 1s_4 and 2p_7 → 1s_5 transitions where there is an enhancement in intensity at higher current (fig 5.4p,q,r). Observed emission lines along with their transitions and the change in intensity under laser excitation are given in table 5.1.
b) Optogalvanic signal of $1s_5 \rightarrow 2p_2$ transition in neon

In the absence of any external source of excitation, the primary pathway for ionization goes directly through the metastable levels. The radiative relaxation paths of a state diminish the probability for their involvement in ionization. It is well known that the nature of OG signal is determined mainly by the metastable concentrations. In general, the impedance of a neon discharge increases with resonant excitation of transitions starting from $1s_3$ and $1s_5$ levels due to the depletion of these metastables and consequently the electron density and the impedance decreases in the case of transitions from $1s_2$ and $1s_4$ states which may decay radiatively to the ground state (15,16).

![Fig 5.5 OG signal variation with current for $1s_5 \rightarrow 2p_2$ transition](image-url)
OG spectra of Ne is well known and available in the literature [2]. Excitation at 5882 Å corresponds to $1s_5 \rightarrow 2p_2$ and transition in which the lower state ($1s_5$) is a metastable and hence the OG signal of this transition corresponds to an increase in the discharge impedance or an equivalent decrease in current in the circuit. The observed OG signal for this transition as a function of the discharge current is shown in the fig 5.5.

5.5 LASER EXCITATION OF $1s_5 \rightarrow 2p_4$ TRANSITION (5945 Å)

a) laser induced fluorescence spectrum

The emission and the laser induced fluorescence spectrum of neon discharge in the wavelength range from 5800 to 6700 Å at a discharge current of 5 mA are shown in fig 5.6. The emission intensity for both conditions varies linearly with the discharge current for all the observed transitions within this spectral region. The transitions having considerable change in emission intensities during laser-on and laser-off conditions are shown in the fig 5.7. Laser excitation at 5945 Å ($1s_5 \rightarrow 2p_4$) modifies the emission characteristics of transitions from $2p_4 \rightarrow 1s_i$ ($i = 2, 4$ and 5) which is obviously due to a large increase in the population of $2p_4$ (fig 5.7a,b,c). For $2p_3 \rightarrow 1s_4$, $2p_5 \rightarrow 1s_3$ and $2p_7 \rightarrow 1s_4$ transitions also the same behaviour is observed (fig 5.7d,e,f) while for $2p_6 \rightarrow 1s_4$, and $2p_9 \rightarrow 1s_5$ the emission intensity during laser excitation is less than that of the unperturbed discharge (fig 5.7g,h). For other transitions,
Fig 5.6 A) Emission spectrum of neon discharge at 5mA and B) the same under laser irradiation at 5945 Å
Continued
intensities under both the conditions are more or less the same, while for a few transitions change in emission intensity is observed only at higher currents. In this case also for transitions starting from states close to \( 2p_4 \) the emission intensity increases while for those are not close to \( 2p_4 \) shows a decrease in emission intensity (table 5.1). This indicates that, for both cases, processes like the collisional mixing between the \( 2p \) states and electron impact excitation of \( 1s_1 \) states alters the population of \( 2p \) states resulting into the variation in the emission intensity during laser excitation. These changes for \( 2p_j \rightarrow 1s_1 \), \( j \neq 4 \), are mainly arising from the modifications in the population of these states due to non-radiative decay from the \( 2p_4 \) states and the collisional mixing between various \( 2p_j \) states.
Table 5.1. Change in emission intensities under laser excitation at 588.2 nm and 594.5 nm with a discharge current of 5 mA

<table>
<thead>
<tr>
<th>Wavelength  nm</th>
<th>Transition</th>
<th>( \frac{(I - I_0)}{I} )</th>
<th>( 1s_5 \rightarrow 2p_2 )</th>
<th>( 1s_5 \rightarrow 2p_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>588.2</td>
<td>( 2p_1 \rightarrow 1s_2 )</td>
<td>0.17</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>588.2</td>
<td>( 2p_2 \rightarrow 1s_5 )</td>
<td>9.23 ( ^{\beta} )</td>
<td>0.23</td>
<td>22.0 ( ^{\beta} )</td>
</tr>
<tr>
<td>594.5</td>
<td>( 2p_4 \rightarrow 1s_5 )</td>
<td>0.09</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>597.5</td>
<td>( 2p_5 \rightarrow 1s_5 )</td>
<td>0.12</td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>603.0</td>
<td>( 2p_2 \rightarrow 1s_4 )</td>
<td>3.33</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>607.4</td>
<td>( 2p_3 \rightarrow 1s_4 )</td>
<td>-0.03</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>609.6</td>
<td>( 2p_4 \rightarrow 1s_4 )</td>
<td>0.03</td>
<td>5.06</td>
<td></td>
</tr>
<tr>
<td>614.3</td>
<td>( 2p_6 \rightarrow 1s_5 )</td>
<td>-0.12</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>616.3</td>
<td>( 2p_2 \rightarrow 1s_3 )</td>
<td>5.79</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>621.7</td>
<td>( 2p_5 \rightarrow 1s_5 )</td>
<td>0.55</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>626.6</td>
<td>( 2p_5 \rightarrow 1s_3 )</td>
<td>0.04</td>
<td>1.09</td>
<td></td>
</tr>
<tr>
<td>630.4</td>
<td>( 2p_6 \rightarrow 1s_4 )</td>
<td>-0.30</td>
<td>-0.18</td>
<td></td>
</tr>
<tr>
<td>633.4</td>
<td>( 2p_4 \rightarrow 1s_5 )</td>
<td>-0.10</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>638.5</td>
<td>( 2p_7 \rightarrow 1s_4 )</td>
<td>0.18</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>640.2</td>
<td>( 2p_9 \rightarrow 1s_5 )</td>
<td>-0.29</td>
<td>-0.53</td>
<td></td>
</tr>
<tr>
<td>650.6</td>
<td>( 2p_8 \rightarrow 1s_4 )</td>
<td>-0.18</td>
<td>-0.39</td>
<td></td>
</tr>
<tr>
<td>653.2</td>
<td>( 2p_7 \rightarrow 1s_3 )</td>
<td>0.14</td>
<td>-0.04</td>
<td></td>
</tr>
<tr>
<td>659.9</td>
<td>( 2p_2 \rightarrow 1s_2 )</td>
<td>5.85</td>
<td></td>
<td>0.12</td>
</tr>
</tbody>
</table>

\( ^{\beta} \) \( I_L \) and I are emission intensities with and without laser irradiation.

\( ^{\gamma} \) 10 \( \mu m \) and \( ^{\delta} 5 \mu m \) - slit width of the monochromator used for recording the spectrum.

\( ^{\beta} \) Intensity includes scattered radiation from the exciting laser at these wavelengths.
b) optogalvanic signal of $1s_5 \rightarrow 2p_4$ transition in neon

Transition at 5945 Å corresponds to $1s_5 \rightarrow 2p_4$ in which $1s_5$ is a metastable state and hence the OG effect at this wavelength will cause an increase in the discharge impedance or will be an equivalent decrease in current in the circuit. Fig 5.8 shows the variation of the OG signal as a function of the discharge current.

5.8 POPULATION DENSITY IN THE DISCHARGE

A rate equation approach, by considering the prominent excitation and de-excitation processes, can be used to determine the perturbations in the population of states by resonant laser excitation and is useful to explain qualitatively some important
processes in the discharge that lead to optogalvanic effect. A number of papers based on the rate equation formalism have been published, for certain transitions in neon positive column discharges [11,12,14,15,17]. In these models, terms corresponding to multistep ionization, various collisional excitation and decay processes were included to give a correct description of the experimental findings. Van Velhuizen et al [18] have used, the rate equation approach to explain the observed OG signal for certain transitions in a neon hollow cathode discharge (hcd) lamp. In this section we make use of the rate equation approach to explain the OG effect for 1s6 → 2p2 transition.

The excitation and decay processes along with their rate constants are shown in the energy level diagram (fig 5.2). Various rate constants included in the model are as follows.

1. Direct excitation
   \[ \text{Ne}(^1S_0) + e^- \rightarrow \text{Ne}^+ + e^- \]
   This represents the excitation of the ground state atoms by direct electron impact with a rate constant \( \alpha_m \). The rate constant is a strong function of \( E/N_o \) where \( E \) is the field and \( N_o \) is the density of the ground state atoms.

2. Direct ionization
   \[ \text{Ne}^+ + e^- \rightarrow \text{Ne}^+ + 2e^- \]
   This is the ionization by collision of excited atoms and electrons with a rate constant \( \gamma_m \). This process depends on both the direct electron impact ionization of metastables/excited
state and the indirect processes involving electron excitation of higher levels followed by radiative decay to the lower excited state.

3. Spontaneous emission on allowed radiative transitions with a rate coefficients $A_{ij}$.

4. Stimulated absorption of $1s_1 \rightarrow 2p_2$ transition with a rate coefficient $B_I$, where $I$ is the intensity of the laser radiation.

5. The diffusion to the wall with a reciprocal life time $\tau$.

Loss process of the main metastable atom is by diffusion to the tube walls. The loss rate is calculated from the relations [19].

$$\tau_{3,5} = \frac{D_\text{m}}{N_0} \left( \frac{2.4}{r} \right)^2$$  \hspace{1cm} (5.1)

where $D_\text{m} = 7.6 \times 10^{18} \text{m}^{-1} \text{sec}^{-1}$, $T^{0.73}$  \hspace{1cm} (5.2)

and $N_0$ and $T$ are the ground state atom density and the temperature respectively. The gas temperature is assumed to be 300 K throughout. The wall loss of the $1s_2$ and $1s_4$ atoms were taken from ref. Sasso et al [11] and Daughtey et al [14] respectively.

The population of $2p_2$ is denoted by $N_6$ and that of $1s_i$ states are denoted as $N_i$ ($i=2$ to 5). The steady state populations of the $2p_2$ and $1s_i$ levels can be obtained from the rate equations.
\[
\frac{dN_8}{dt} = \alpha_8 N_0 n - \gamma_8 N_5 n + \sum_{i=2}^{5} A_{6i} N_8 + BI \left[ \frac{g_8}{g_6} N_6 - N_5 \right] - \tau_8 N_5
\]  
(5.3)

\[
\frac{dN_5}{dt} = \alpha_5 N_0 n - \gamma_5 N_5 n + A_{65} N_6 + BI \left[ \frac{g_5}{g_6} N_6 - N_5 \right] - \tau_5 N_5
\]  
(5.4)

\[
\frac{dN_4}{dt} = \alpha_4 N_0 n - \gamma_4 N_4 n + A_{64} N_6 - \tau_4 N_4
\]  
(5.5)

\[
\frac{dN_3}{dt} = \alpha_3 N_0 n - \gamma_3 N_3 n + A_{63} N_6 - \tau_3 N_3
\]  
(5.6)

\[
\frac{dN_2}{dt} = \alpha_2 N_0 n - \gamma_2 N_2 n + A_{62} N_6 - \tau_2 N_2
\]  
(5.7)

Contribution of terms due to metastable-metastable collision are neglected in these calculations.

The electron density \(n\) in the discharge with \(n_{on}\) and without \(n_{off}\) laser excitation were calculated from the relation [11]

\[
i = 2h_0 \omega r^2 v_d n
\]  
(5.8)

where \(i\) is the tube current, \(r\) is the radius of the discharge plasma and \(2h_0\) is the Tongs-Langmuir constant, which is for a cylindrical cell, varies from 0.42 to 1 depending on the mean free path. In our calculations \(2h_0\) is approximately taken as one [20]. The drift velocity \(v_d\) for different discharge conditions were evaluated from the reported data [21].
The change in the discharge current due to the perturbations in the electron density by laser excitations is given by,

\[ \Delta I = \text{em} \frac{2}{\nu_d} \Delta n \quad (5.9) \]

\[ \Delta n = n_{\text{on}} - n_{\text{off}} \quad (5.10) \]

Fig 5.9 shows the variation of the change in the electron density as a function of the discharge current, during laser excitation at 5882 Å.

The steady state equations \( \langle dN_m/dt = 0 \rangle \) are solved for laser-off and laser-on conditions and \( N_m \) are calculated for both conditions. The values of various rate constants used in the calculations are listed in the table 5.2.

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**Fig 5.9** Change in electron density with current during laser excitation at 5882 Å
Table 5.2

\[ \alpha_3 = \alpha_5 = 1 \times 10^{-11} \text{ cm}^3/\text{sec} \]  \hspace{1cm} (15)

\[ \alpha_2 = \alpha_4 = 5 \times 10^{-12} \text{ cm}^3/\text{sec} \]

\[ \alpha_6 = 1 \times 10^{-12} \text{ cm}^3/\text{sec} \]

\[ \gamma_{57} = 2 \times 10^{-8} \text{ cm}^3/\text{sec} \]

\[ \gamma_{27} = \gamma_{37} = \gamma_{47} = \gamma_{57} = 6 \times 10^{-9} \text{ cm}^3/\text{sec} \]

\[ A_{62} = 2.32 \times 10^7 \text{ sec}^{-1} \]

\[ A_{63} = 1.46 \times 10^7 \text{ sec}^{-1} \]

\[ A_{64} = 0.56 \times 10^7 \text{ sec}^{-1} \]

\[ A_{65} = 1.15 \times 10^7 \text{ sec}^{-1} \]

\[ r_3 = r_5 = 350 \text{ sec}^{-1} \]  \hspace{1cm} (19)

\[ r_2 = 1.65 \times 10^6 \text{ sec}^{-1} \]  \hspace{1cm} (8)

\[ r_4 = 1 \times 10^5 \text{ sec}^{-1} \]  \hspace{1cm} (14)

\[ B_l = 1.44 \times 10^5 \text{ sec}^{-1} \]

\[ N_0 = 3.218 \times 10^{17} \text{ atoms/cm}^3 \]

\[ r = 0.25 \text{ cm} \]

5.7 MECHANISM OF 06 EFFECT

Calculations show that, laser excitation of \( 1s_5 \rightarrow 2p_2 \) transition, increases the population of the upper level at least by a factor of ten (fig 5.10a). This can also be seen from the experimental observations (fig 5.4a) in which the laser induced emission intensity enhances 5-8 times depending on the discharge
current. Laser irradiation causes an increase in the $1s_2$, $1s_3$ and $1s_4$ states which is due to the radiative decay from various $2p_j$ states (fig 5.10). $1s_2$ and $1s_4$ levels are radiatively coupled to the ground state ($^1S_0$) and are supposed to have least contribution to the 06 effect. The changes for metastable population are much higher than that of $1s_2$ and $1s_4$ states. In the absence of laser excitation, the population of the $1s_3$ and $1s_5$ metastables in the discharge vary slightly with the current. Laser excitation causes considerable decrease in the $1s_5$ density, which was maximum at the low current. In the positive column discharges under laser excitation of the same transition, Kane [15] observed that the population of $1s_5$ is significantly depleted and for all other $1s_1$ levels the population is increased.

These observations indicate that the major factor that influences the generation of the 06 signal is the modifications in the ionization processes as a result of the perturbations in the populations of states. The laser excitations at the above wavelength ($\lambda = 5882 \, \AA$) results an increase in the population of $2p_2$, $2s_2$ and $1s_4$ levels while it decreases in the case of $1s_5$ state.

In the case of $1s_5 \rightarrow 2p_2$ laser excitation, contributions to 06 effect due to $1s_2$, $1s_4$ and $2p_2$ states, which are radiatively coupled to the lower states, are negligible where as the role of $1s_3$ and $1s_5$ metastables are prominent. Even though, the $2p_2$
Fig 10 Population density of 2p$_2$ and 1s$_i$ (i=2,3,4,5) states
(o - without laser, A - with laser at 5882 Å)
state population increases considerably, strong radiative coupling of this state to 1s₁ levels and non radiative decay to 2p₂ (j≠2) levels will enhance the laser induced fluorescence phenomenon and reduce its contribution to ionization. In the range of current studied, the change in the 1s₃ state density is almost independent of current and will support the ionization processes. Thus, overall depletion in the metastables will reduce the ionization and hence increases the impedance of the discharge during laser excitation of 1s₅ → 2p₂ transition in neon is expected.

It is noted from the calculations that the density of 2p₂ state vary linearly during laser excitation (fig 5.10), while that for all 2p₂ → 1s₁ transitions in the presence of laser irradiation the emission intensities are actually non-linear function of the discharge current as shown by experimental observations (fig 5.4). This observation necessitates the modification of the rate equations, and requires the consideration of all the 2p states separately along with the inclusion of all the laser perturbed collisions, radiative and non-radiative processes [11].

The observations described above clearly indicate that the major factors which influences the OG signal are the modifications in the ionization processes as a result of the perturbations in the populations of states. As shown in fig 5.7 and fig 5.8 the current dependence of OG signal corresponding to
5882 Å and 5945 Å excitations differ widely. This indicates that apart from the metastable nature of the lower level, there exists other processes which will affect magnitude of the 0G signal. One such process is due to the change in ionization rate as a result of collisional mixing between 2p<sub>j</sub> states followed by laser irradiation which is different for these two transitions.

Modifications in the emission characteristics of a neon hollow cathode discharge due to resonant absorption of 1s<sub>5</sub> → 2p<sub>2</sub> and 1s<sub>5</sub> → 2p<sub>4</sub> transitions are investigated. In both cases, the emission properties are found to be altered significantly as a result of changes in the population of 2p states by radiative and non-radiative processes. The qualitative analysis of a set of simplified rate equations of states indicate that the 0G effect for 1s<sub>5</sub> → 2p<sub>2</sub> transition in neon hollow cathode is generated as a result of decrease in the ionization due to the depletion of metastable states. Electron impact ionization, population mixing between 2p states and their decay path to 1s<sub>1</sub> states significantly affect the magnitude of the 0G signal.

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