CHAPTER 3

PARAMETRIC STUDIES OF NITROGEN LASER

Abstract

The output power of the nitrogen laser depends on various parameters like cavity pressure, applied voltage, pulse repetition rate and other geometrical factors in the design. These parameters are studied on both the single and double-Blumlein circuits using free-running and triggered spark gap. It is found that the stability in repetition rate as well as pulse intensity is better for the triggered spark gap. The laser with free-running type spark gap at a charging voltage of 6.18 kV gave maximum efficiency of 0.51%, which is the second highest value reported so far. The dependence of the pulse width on spark gap distance and pressure are also described. Variation of efficiency with voltage and E/P ratios are also included in this chapter. The divergence of the beam as well as the variation of the power density distribution over the cross section of the discharge cell are also studied.
3.1. Introduction

A thorough knowledge of the optical as well as electrical characteristics of a laser is essential if one is to build a system with maximum possible efficiency and good long term stability. Many researchers have reported [1-3] that travelling wave excitation of the gas is the ideal method for attaining maximum efficiency.

As explained earlier, in a travelling wave excited laser, the discharge starts at one end of the laser cavity and propagates towards the other end with a velocity nearly equal to the velocity of light [4]. Hence spontaneously emitted photons in the direction of laser axis sees maximum inversion and gets amplified to sufficient power levels in a single pass—which is the main principle behind the superradiant mode of operation of the nitrogen laser. High power buildup is possible by this method because the gain for \( \text{C}^3\Pi_u \rightarrow \text{B}^3\Pi_g \) transition is quite high owing to the short life time (about 20 ns, in effect) of the upper laser level. With a view to understand the nature and characteristics of the \( \text{N}_2 \) lasers
using a Blumlein circuit, two different transmission lines and
spark gaps were built and their performance were studied.

3.1.1. Blumlein circuit and E/P requirements

Blumlein circuit is simply a high voltage pulse
generator (Fig. 1.4) where the energy storage capacitors have
the same value (i.e.; $C_1 = C_2$). Just before the spark gap is
fired, the full charging voltage $V_0$ appears across the spark
gap, while the voltage across the laser tube remains zero.
When the spark gap fires, the LC circuit consisting of the
capacitance $C_2$ and spark gap inductance $L_s$ (plus the stray
inductance) begins to oscillate at $\omega = (L_s C_2)^{-1/2}$. At this
instant the voltage across the laser tube also starts
oscillating at the same frequency and the voltage rises to a
maximum value of $2V_0$ due to the reflection of the voltage wave
at the laser channel. In actual operating conditions, this
voltage will not reach $2V_0$ because the $N_2$ gas will breakdown at
a lower voltage, near $V_0$. For practical purposes, the peak
value of $V_0$ can be taken as the breakdown voltage and can be
used for the calculation of the instantaneous electric field $E$
using the relation,

\[ E = \frac{2^{1/2} V}{d} \quad (\text{Volt/cm.}) \quad \ldots (3.1) \]

where \( d \) is the electrode separation in cm. In the present design, the average value for \( d = 1.18 \) cm.

Once the discharge is struck between the electrodes, the voltage falls off rapidly due to the development of a highly conducting plasma. The electrons in the nitrogen discharge may be assumed to be in a steady state with the instantaneous electric field. Since the maximum output power of nitrogen lasers occur with \( E/P' \) ratios in the range 60-135 volts/cm.torr (Table 3.2), the laser plasma can be described in terms of an electron temperature given by [5],

\[ \alpha \frac{V}{d} = N \int_{\text{gas}}^{\infty} g(T_e,v) \sigma_i(v) 4\pi v^3 \, dv \quad \ldots (3.2) \]

where, \( \alpha \) - Townsend ionization coefficient

\( V_d \) - the drift velocity

\( N \) - ground state gas density

\( g(T_e,v) \) - normalized Maxwell-Boltzmann distribution

\( \sigma_i(v) \) - velocity dependent ionization cross section for the nitrogen molecule.
For nitrogen lasers with E/P in the range 20 to 150 V/cm.torr, Fitzsimmons et al.[5] had shown that,

\[
V_d = 2.9 \times 10^5 \frac{E}{P} \text{ cm/s} \quad \ldots \ldots (3.3)
\]

\[
\alpha/P = 1.4 \times 10^{-8} \left(\frac{E}{P}\right)^{0.7} \text{ (torr.cm)}^{-1} \quad \ldots \ldots (3.4)
\]

and,

\[
KT_e = 0.11 \left(\frac{E}{P}\right)^{0.80} \text{ eV} \quad \ldots \ldots (3.5)
\]

The effective electron temperature calculated using eqn. (3.5) enables one to predict the observed rates of ionization in nitrogen, which would be very much nearer to the excitation rates of the C^3Π_u and B^3Π_g states, as these states lie very close to the ionization limit.

3.1.2. The pulse forming net works

Two typical transmission lines were made that can be used with the same laser cavity. For the first type of the transmission lines, conventional Blumlein circuit configuration \((C_1 = C_2)\) has been employed, while in the second type, two double sided copper clad sheets are used, one above and the other below the cavity, so as to double the storage capacity. The length and width of the line was 57 cm
and 54 cm respectively for the two cases.

The transmission lines were made as described in chapter 2. The capacitance, characteristic impedance and propagation delay time calculated using eqns. (2.1), (2.2) and (2.3), for the two circuits are given in Table 3.1.

Table 3.1 Nitrogen laser characteristics

<table>
<thead>
<tr>
<th>Laser Characteristics</th>
<th>Single Blumlein</th>
<th>Double Blumlein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic impedance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Z$ (ohm)</td>
<td>0.52</td>
<td>0.26</td>
</tr>
<tr>
<td>Capacitance $C$ (nF)</td>
<td>7.99</td>
<td>15.98</td>
</tr>
<tr>
<td>Propagation delay time</td>
<td>8.14</td>
<td>8.14</td>
</tr>
<tr>
<td>$\tau$ (ns)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse width</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>(FWHM) (ns)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored energy at 9.3 kV (mJ)</td>
<td>345.5</td>
<td>691</td>
</tr>
<tr>
<td>Output energy/pulse at 9.3 kV (mJ)</td>
<td>0.084</td>
<td>0.21</td>
</tr>
<tr>
<td>(at 13.7 pps)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak power output at 9.3 kV</td>
<td>335</td>
<td>700</td>
</tr>
<tr>
<td>Efficiency $= \frac{E_{out}}{E_{stored}}$ (%)</td>
<td>0.2</td>
<td>0.31</td>
</tr>
</tbody>
</table>

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The lines and the spark gap were soldered to the laser one after the other and the various parameters were studied. The dependence of output power on parameters such as operating pressure, voltage and repetition rate were studied on both the single and double-Blumlein circuits.

Table 3.2 Nitrogen laser discharge parameters

<table>
<thead>
<tr>
<th>Emission</th>
<th>Applied voltage $V_o$ (kV)</th>
<th>Electric field $E$ (volt/cm.)</th>
<th>Optimum pressure $P$ (torr)</th>
<th>Optimum $E/P$ (volt/cm.torr)</th>
<th>Electron temp. $K_T$ (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>He Free</td>
<td>6.3</td>
<td>7550</td>
<td>80</td>
<td>94.4</td>
<td>4.2</td>
</tr>
<tr>
<td>He runn-</td>
<td>7.8</td>
<td>9348</td>
<td>120</td>
<td>77.9</td>
<td>3.6</td>
</tr>
<tr>
<td>He lit</td>
<td>9.3</td>
<td>11146</td>
<td>110</td>
<td>101.3</td>
<td>4.4</td>
</tr>
<tr>
<td>He lit</td>
<td>10.5</td>
<td>12584</td>
<td>120</td>
<td>104.9</td>
<td>4.6</td>
</tr>
<tr>
<td>He Free</td>
<td>3.9</td>
<td>4674</td>
<td>80</td>
<td>58.4</td>
<td>2.8</td>
</tr>
<tr>
<td>He runn-</td>
<td>6.18</td>
<td>7407</td>
<td>90</td>
<td>82.3</td>
<td>3.7</td>
</tr>
<tr>
<td>He lit</td>
<td>9.3</td>
<td>11146</td>
<td>90</td>
<td>123.8</td>
<td>5.2</td>
</tr>
<tr>
<td>Nl Trig-</td>
<td>7</td>
<td>8389</td>
<td>70</td>
<td>119.8</td>
<td>5.06</td>
</tr>
<tr>
<td>Nl red</td>
<td>9</td>
<td>10786</td>
<td>80</td>
<td>134.8</td>
<td>5.56</td>
</tr>
<tr>
<td>Nl</td>
<td>11</td>
<td>13183</td>
<td>100</td>
<td>131.8</td>
<td>5.46</td>
</tr>
</tbody>
</table>
The laser plasma can be described in terms of an electron temperature given by eqn. (3.5). The maximum output power of nitrogen laser occur with E/P ratios in the range 60-135 V/cm.torr (Table 3.2).

The electron density in the discharge plasma increases rapidly when E/P is greater than about 100 V/cm.torr. As the discharge begins to load the electrical circuit, the voltage across the plasma tube falls suddenly to a very low value with the emergence of optical output when E/P passes through a value of about 80 V/cm.torr (T_e = 4 eV) [5,6]. The electrical power to the laser is a maximum when the impedance of the discharge is equal to the impedance of the driving electrical circuit. The inductance of the plasma discharge changes with the change in the pressure in the plasma tube. It has been observed that the optimum E/P value also changes with pressure. Influence of these parameters gives rise to the variation of pulse energy as a function of plasma tube pressure. A change in the applied voltage changes E/P ratio so that the maximum point shifts to a new value.
3.2. Methods of measurement

In the present work, a pulse repetition rate of 10 pps has been chosen. The important parameters measured in the present work are the pulse width, the pulse energy, the peak power, efficiency, laser beam size and beam divergence. The methods and the experimental procedures adopted are given below.

3.2.1 Pulse width

The pulse width was measured using photodiodes (HP-2-4207 Hewlett Packard) which have a rise time of less than 1 ns, and have wide dynamic range (1% linearity over 100 dB). The photodiode circuit is shown in Fig.3.1. The whole circuitry including the photodiode and the load resistor were soldered onto a printed circuit board and enclosed in an aluminium housing with a window to pass the laser emission. A reverse bias of 15 V is applied to the photodiodes and the outputs are terminated in 50 ohm load for fast response and minimum pulse distortion. The mounts are earthed and the
Fig. 3.1 Photodiode circuit.

Fig. 3.2. Pulse width measurement using photodiode.
output signal was taken out using a shielded cable from the BNC termination on the rear side of the housing.

The experimental setup used to measure the pulse width is shown in Fig.3.2. Nitrogen laser beam is splitted

Table 3.3. Pulse width (FWHM) for various pressures and voltages.

<table>
<thead>
<tr>
<th>Pressure (torr)</th>
<th>Voltage (kV)</th>
<th>FWHM (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>7</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>9.3</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3.6</td>
</tr>
<tr>
<td>70</td>
<td>7</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>9.3</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3.2</td>
</tr>
<tr>
<td>90</td>
<td>7</td>
<td>3.6</td>
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<tr>
<td></td>
<td>9.3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>110</td>
<td>7</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>9.3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>
Fig. 3.3. Nitrogen laser pulse shape.
sweep speed : 5 ns/div and
gain : 0.5 V/div.
using a beam splitter made of plane quartz plate. One part of the pulse falls on the photodiode through a scatterer. The output of the photodiode (signal) is given to the 466 DM 44 Tektronix storage oscilloscope. The other pulse, reflected from the quartz plate falls on another photodiode. The output of the photodiode is given to the oscilloscope for triggering.

The pulse width (FWHM) was measured as a function of pressure and voltage (Table 3.3). The pulse width at FWHM was 3 ns for the double-Blumlein circuit as shown in Fig.3.3. (9.3 kV; 90 torr) The average width of the pulses at the base is about 8 ns, which corresponds closely to the propagation delay time of the storage line ($\tau = 8.24$ ns). The result agrees with those reported by Mehendale and Bhawalkar [4] who also obtained a value of about the same as that of the propagation delay time of the transmission line. Since the propagation delay time of the storage line is smaller than that which is possible with the conventional designs, the laser gave slightly short duration pulses.

3.2.2. Pulse energy and peak power output

The average power of the laser was measured
Fig. 3.4 Output measurement set up.

Fig. 3.5 Nitrogen laser beam size (exit window)
using a Scientech model 38-0101 volume absorbing 1 inch disk calorimeter (thermopile) and displayed by a laser powermeter (Scientech model 362). The experimental set up is shown in Fig.3.4. The energy per pulse was obtained by dividing the average power by repetition rate from which the peak power was obtained by dividing the energy/pulse by the pulse width at FWHM. As the pulse width variation with pressure was not appreciable, we have used the pulse width at 90 torr for the calculation of peak power output. For the double-Blumlein circuit, the output energy/pulse at 9.3 kV was 0.21mJ at a rep. rate of 8.8 Hz and the peak output power obtained was 700 kW.

3.2.3. Divergence and beam size

The laser beam cross section is rectangular with dimensions of (1.7 x 0.8) cm outside the exit window (Fig.3.5). Due to the particular configuration of the laser cavity, two values of divergence appeared in a plane containing the electrodes and in a perpendicular plane. The half-angle divergence is measured in the following way. The beam width
parallel to a particular plane is taken at different points. If the widths of the two points are \( h_1 \) and \( h_2 \) and the distance between them is \( d \), the half angle divergence \( \theta \) can be calculated as,

\[
\theta = \frac{(h_2 - h_1)}{2d} \text{ radian.}
\]

Same procedure is used to measure the divergence for both the planes. The horizontal divergence of the beam at half angle is 2.\( \text{mrad} \) while the vertical divergence is 3.5 mrad at half angle.

3.2.4. Efficiency

The overall efficiency was calculated by dividing the optical output energy per pulse by the stored electrical energy \((CV^2/2)\). For the double-Blumlein circuit, the overall maximum conversion efficiency obtained was 0.51 \( \% \) at a charging voltage of 6.2 kV, which is remarkably high for an \( \text{N}_2 \) laser as compared to the earlier reports. The high power and better conversion efficiency obtained using the present design is attributed to the low inductance of the system. It
may be noted that the highest value (1%) reported so far for laser action in nitrogen is by Godard [2].

3.3. Experimental observations

3.3.1. Dependence of laser pulse energy on the spark gap pressure

The pressure in the spark gap affects the inductance of the discharge circuit. It is observed that the higher the pressure in the spark gap, the lower will be the inductance. The optimum output power obtained is at around 2 atmospheres of pressure. The variation of pulse energy with the spark gap pressure at a plasma tube pressure of 80 torr (10.6 kPa) for different voltages is shown in Fig.3.6.

3.3.2. Variation of pulse width with spark gap distance

As shown in Fig.3.7; the variation of pulse width with spark gap distance is not appreciable. Ishikawa et al.[8] have reported that changing the electrode spacing may
Fig. 3.6 Variation of pulse energy with spark gap pressure for different voltages (in kV). The plasma tube pressure is 80 torr.

Fig. 3.7 Variation of pulse width with spark gap distance.
Fig. 3.8 Variation of pulse width with cavity pressure.

Fig. 3.9. Variation of laser power with spark gap distance.
influence the readings as it affects the discharge inductance of the spark gap. No experimental data have been reported on the power increase and reduction of the pulse width of $N_2$ lasers with decreasing the gap of the spark gap switches, although the behaviour has been predicted [9,10].

3.3.3. Variation of pulse width with cavity pressure

As described earlier in Table 3.3, pulse width (FWHM) for various pressures is shown in Fig.3.8. The result shows that the pulse width slightly decreases as the pressure is increased.

3.3.4. Variation of laser power with spark gap distance

As seen in Fig. 3.9, laser output power decreases with increasing the spark gap distance. This may be due to the reduction of the residual inductance of the gap switch.

3.3.5. Variation of output peak power with the pressure

The dependence of the output peak power with
Fig. 3.10 Variation of output peak power with pressure for single-Blumlein circuit (free-running spark gap).
Fig. 3.11 Variation of the output peak power with pressure for double-Blumlein circuit (free-running spark gap).
Fig. 3.12 Variation of output peak power with pressure for double-Blumlein circuit (triggered spark gap).
nitrogen pressure for different charging voltages is shown in Fig. 3.10 for single Blumlein circuit (free running spark gap) and for the double-Blumlein circuit (free-running spark gap) (Fig.3.11). The readings were taken in the pressure range of 10 to 200 torr when the transmission lines were charged to 3.9-10.5 kV. With the free-running spark gap, lasing is obtained for a wide range of plasma tube pressures from 10 torr to 180 torr. The firing voltage of the spark gap is adjusted by changing the electrode spacing.

In the case of double-Blumlein circuit (triggered-spark gap), lasing is obtained when the plasma tube pressure in the range 40-180 torr (Fig.3.12). Above 180 torr, streaming and arcing in the discharge region ultimately stops the lasing. The typical curves for 6kV, 9kV, 12 kV and 14kV are given in Fig.3.12. By using a triggered spark gap switch, the experimental conditions could be set more accurately.

As seen from the three figures, for a fixed voltage, the energy per pulse and hence the output power increases with pressure, reaches a maximum and then decreases.
with further increase in pressure. The present results are in good agreement with the previous observations by many authors. It was observed that the optimum laser output was obtained when the E/P values are in the range 60-135 V/cm.torr. The initial increase in the laser power with increasing pressure is due to the fact that the number of molecules available for inversion keeps on increasing as the pressure is increased, with electron temperature of the plasma remaining fairly high. At high N\textsubscript{2} pressures, the electron temp. T\textsubscript{e} is low, hence both the rate of ionization and excitation fall reducing the output power due to onset of arcing, while at low pressures though the electron temp. is high, the number of molecules available for laser action is small and hence the output power decreases.

3.3.6. Variation of output power with voltage

Fig.3.13 and Fig.3.14 shows the change in output peak power with voltage at different N\textsubscript{2} pressures for the single and double-Blumlein circuits (free-running) and Fig.3.15 for the double-Blumlein circuit (triggered spark gap) respectively. It is seen that the variation in output power
Fig. 3.13 Variation of output peak power with voltage for single-Blumlein circuit (free-running spark gap switch).
Fig. 3.14 Variation of output peak power with voltage for double-Blumlein circuit (free-running spark gap).
Fig. 3.15 Variation of output peak power with voltage for double-Blumlein circuit (triggered spark gap).
is not linear with voltage. The rate of increase of power with charging voltage is rapid at higher pressures.

The variation of output peak power with the applied voltage at corresponding optimum pressure shows a non-linearity in the graph, unlike the results reported by many workers \(1,4,7,11-13\) except Ritcher et al.\[14\]. Following Ritcher and co-workers, the non-linearity can be explained on the basis of the voltage dependence of electron temperature.

The absolute value of output power is proportional to \(N_o\):

\[
W_p \propto \phi_+ (I,t) N_o \quad \ldots \ldots (3.6)
\]

where, \(N_o \propto \sigma (T_e) N_e \quad \ldots \ldots (3.7)\)

Here \(N_e\) is the electron density, \(\sigma\) is the sum of the electron excitation cross section to the upper and lower laser levels, and \(\phi_+ (I,t)\) is the value of the output peak photon density. The above equation shows that \(W_p\) increases linearly with \(N_e\). It means that the output power increases as
the voltage applied to the storage capacitor increases. The dependence of $T_e$ with voltage shows a saturation at higher discharge voltage. The deviation from non-linearity originates from the voltage dependence of $T_e$ and therefore also $\sigma(T_e)$ which in turn depends on the charging voltage.

3.3.7 Variation of power with repetition rate

The dependence of output power with the pulse repetition frequency for the three different conditions are shown in Fig. 3.16, Fig. 3.17 and Fig. 3.18. The variation of average power with repetition rate for the two configurations are shown in Fig. 3.19 and Fig. 3.20 respectively.

In all the cases, the pulse energy is drastically reduced with an increase in the pulse repetition frequency. It may be due to the change in the initial pre-ionization conditions prevailing in the plasma tube before each pulse.[15]. After the gas pressure in the plasma tube is adjusted in the range of tens of torrs, a high voltage applied across the electrodes of the plasma tube by the firing
Variation of output power with repetition rate:

Fig. 3.16. Single-Blumlein circuit (freerunning spark gap).

Fig. 3.17. Double-Blumlein circuit (freerunning spark gap).

Fig. 3.18. Double-Blumlein circuit (triggered spark gap).
Fig. 3.19 Variation of average power with repetition rate for single-Blumlein circuit (free-running spark gap).

Fig. 3.20 Variation of average power with repetition rate for double-Blumlein circuit (free-running spark gap).
of the spark gap. The voltage increases till a discharge develops in the plasma tube producing a highly conducting plasma. The actual firing voltage depends upon the pressure and the initial ion density in the plasma tube [16,17]. For a constant pressure, the higher the actual firing voltage, the higher the optical output. It can be shown that there is a reduction in the firing voltage as the repetition rate increases. The ions remaining in the plasma tube after a pulse play the pre-ionization role for the next pulse. Thus by increasing the time interval between two successive pulses, that is, by decreasing the pulse repetition rate, the initial ion density (pre-ionization) for each pulse is reduced. The lower the initial ion density, the higher the actual starting voltage and consequently the higher the power of the laser beam. An increase in the gas flow rate enhances the rate of removal of the remaining ions from the discharge area resulting into increase in the power output. Therefore inorder to obtain high repetition rates, one may increase the gas flow rate.

3.3.8. Variation of overall efficiency with the voltage and E/P ratios

The net electrical to optical efficiency is one
Fig. 3.21 Variation of maximum efficiency with voltage (free-running spark gap).

Fig. 3.22 Variation of maximum efficiency with voltage (triggered spark gap).
**Fig. 3.23** Variation of optimum E/P with voltage (free-running spark gap).

**Fig. 3.24** Variation of optimum E/P with voltage (triggered spark gap).
of the most important parameters in a laser. It determines the optimum operating conditions for the maximum life of the system. The overall efficiency obtained under different plasma tube pressure conditions but with the same voltage is calculated. The values are plotted against the corresponding voltages as shown in Fig. 3.21. and 3.22.

The E/P ratio is plotted against the voltage (Fig. 3.23 and 3.24). It is found that the overall efficiency is higher when a free-running spark gap is used instead of a triggered spark gap. It is also observed that the optimum E/P value increases with voltage.

The maximum efficiency obtained is 0.51% at a charging voltage of 6.18 kV. To the author's knowledge, this value appears to be the second highest one reported so far for the transverse electric nitrogen lasers. It may be noted that the highest efficiency (1%) reported so far for laser action in nitrogen is by Godard [2]. Other typical values reported are 0.039 % by Bergmann [18], 0.05 % by Mehendale and Bhawalkar [4], 0.065% by Sam [19], 0.025% by Fitzsimmons et al. [5] and
3.3.9 Variation of the power density over the cross section of the laser electrodes

The interelectrode separation in a transversely excited (TE) $N_2$ laser is much smaller in comparison with that in an axially excited laser, and very little studies of the non-uniform population inversion in the laser channel have been made. In the case of nitrogen laser applications, the distribution of the output power over the cross section of the beam is very important [21]. Many authors have reported that the intensity distribution in the $N_2$ laser beam along the interelectrode gap was found to be asymmetric [22,23]. This asymmetry in the intensity distribution has been interpreted in terms of strips parallel to the electrode length in the interelectrode region with different degrees of population inversion. The population inversion in each strip has been assumed to be the same. This nonuniformity of population inversion can be discussed with the help of ionizing wave fronts propagating between the two electrodes. This was
Fig. 3.25 Variation of the power density distribution over the cross section of the laser electrodes.
Fig. 3.27. ISO-intensity contour of the laser beam cross section.
first suggested by Loeb [24] to account for the formation of luminous pulses in electrical breakdown.

The laser operated using the double-Blumlein circuit was charged by 9.3 kV (pressure: 90 torr) and triggered by the spark gap switch. The intensity distribution along the horizontal and vertical direction in the laser beam cross section was measured by an HP-2-4207 Hewlett Packard photodiode and a 466 DM44 Tektronix storage oscilloscope. The photodiode was fixed in a travelling microscope, at one metre away from the laser output window and could be moved horizontally as well as vertically. The laser beam was attenuated by inserting a 1 cm thick transparent perspex plate before falling on the photodiode. As seen in Fig.3.25, the position of the intensity maximum is shifted towards the edges of the electrodes.

The peak intensity is at the centre of discharge cavity at midway between the cathode-anode separation. The position of the peak shifts from above the middle line of the cross section near the cathode to lower side near the anode, thus gives rise to a helical type pattern for peak position.
This non uniformity is due to the off centering of the peak intensity of the emission cross section of the beam profile. This is clear from the intensity contour as given in Fig.3.26 and 3.27 respectively.
REFERENCES


7, 2232 (1968).


15, 756 (1976).


QE-12, 183 (1976).


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