Since the invention of nitrogen laser operating at 337.1 nm (0,0) band of second positive ($\text{C}^3\Pi_u - \text{B}^3\Pi_g$) system by Heard in 1963, many researchers have built different models of $\text{N}_2$ lasers with a view to achieve high peak power, high repetition rate and short or long pulse widths. Studies of power output and pulse width; and their relation to power input, channel dimensions, pressure, voltage and flow patterns have been reported. Simple theories based on direct electron impact excitation of $\text{C}^3\Pi_u$ and $\text{B}^3\Pi_g$ states have been developed and applied to gain an understanding of mechanism of these lasers.

$\text{N}_2$ laser radiation has been spectrally examined and gain curves have been determined at different pressures and temperatures. A simple model that is qualitatively satisfactory has been used to interpret these gain curves. There are two reports about the relation between spontaneous and laser radiation in $\text{N}_2$ lasers but they are not extensive enough to include emission from levels other than $v' = 0$. Also the correlation between spontaneous and laser radiation has not been examined critically.

$\text{N}_2$ is an important molecule possessing a large number of electronic transitions and these have been subjected to many spectroscopic investigations: wavelength determinations, measurement of molecular parameters through high
resolution studies, intensity measurements, lifetimes studies, theoretical calculations of Franck-Condon factors etc. Some of these data are used to understand laser mechanisms and gain curves. An important data required in this respect are the intensities of bands and lines. We do find from literature an abundance of data on intensity measurements of $N_2 (C \rightarrow B)$ bands but they do not appear to agree well with one another indicating the dependence of intensity distribution on experimental conditions. In addition, a consistent set of intensity measurements are necessary to have an unambiguous determination of electronic transition moment variation for the $N_2 (C \rightarrow B)$ transition. In this connection, we are not aware of any intensity measurements from the laser discharge for the entire band system which would provide a set of data that would help in understanding the changes in populations of $v' = 0, 1, 2, 3$ levels of the C-state as a function of pressure and flow as the discharge is taken from the stage of non-lasing to that of lasing and beyond in steps. This is expected to provide a comparison of the populations of $v' = 1, 2, 3$ amongst themselves and their comparison with that of the $v' = 0$ level. These populations are significant in the lasing process. This is expected to provide correlation between the spontaneous emission from level $v' = 1-3$ and the lasing emission from level $v' = 0$. In order to understand the relation of
spontaneous emission to laser emission which is directional along the length of the discharge, it was also thought necessary to determine these intensities in a direction perpendicular to the discharge.

In order to appreciate the proliferation and the finer points of N$_2$ laser and its studies, a critical review of the literature since its discovery is presented in Chapter II. It contains a general introduction, and a comparative description of design and output characteristics of low and high pressure N$_2$ lasers in the longitudinal and transverse mode along with mechanism of lasing and its theory. Electron beam and proton beam excited N$_2$ lasers have also been included since they are high efficiency lasers with energy transfer mechanism as a predominant mechanism. Spectral studies and effect of added gases have been included so that a complete picture is obtained.

In Chapter III, the details of the fabrication of N$_2$ lasers and measurements of various parameters have been described. We have fabricated a simple and inexpensive N$_2$ laser employing Blumlein circuit which gave enough power to pump dye lasers. The first model was in perspex. An adjustable and demountable spark-plug was fabricated so that the role of position of spark-plug could be examined. This unit gave average power of about 380 $\mu$W and also did not show any
dependence on the position of spark-plug.

With this experience six other models were built, all in glass but with different volumes of laser box and different channel lengths. In one of these, quartz windows were provided perpendicular to the discharge to facilitate simultaneous study of laser (superradiant) emission and spontaneous emission. Volume, channel length and capacitance were changed.

Power measurements were done using Scientech Power-Energy Meter (Model 362) with 1" Disc Calorimeter Type 36-0001. This had a facility for measurement of average power and energy. Pulse widths (FWHM) were measured using Tektronix Oscilloscope Model 7904 (500 MHz) with Scientech Fast Photodetector Type 301-020 or ITT Biplanar Fast Phototube Type F 4018 (S-5). The traces were photographed on Polaroid - films.

The optimum pressure for maximum laser output power was about 90 torr, and operating voltage range was 5-10 kV. Laser power was about the same in both directions. It was found that the power improves considerably for glass surfaces and for smaller volumes of laser box. The effect of the addition of gases such as oxygen, hydrogen, argon, acetylene and nitrous oxide on the laser power was examined. Except \( \text{O}_2 \) others were found to reduce the laser power,
whereas, $O_2$ increased the laser power until its partial partial pressure was about 3 torr and further addition reduced the laser output. Effect of variation of pressure, voltage and spark gap on output power was examined. A rear mirror increased the power more than double and in some cases the power was as high as 20 times that without the mirror. The amplification factor (laser output power with mirror/laser output power without mirror) being high for large volumes and also small channel length. The amplification factor as a function of reflectivity (20% to 90%) has been examined. It was found that the powers were saturated at about 70-80% reflectivity and the amplification factors were high at low reflectivity. At this point it should be emphasized that whenever the output is low, the amplification factor is high. Both these points suggest that when power saturation has not taken place, the gain factor is high leading to high amplification. Effect of volume of the laser box and channel length on the output power was examined. The fabricated $N_2$ lasers were found to operate with non-flowing $N_2$ gas but with low power. These units lase with air in place of nitrogen but with lower power.

The maximum average power was 10 mW. The measured laser pulse width (FWHM) of various lasers varied from 2.5 to 3.5 ns without mirror and 3.5 to 6 ns with mirror. The pulse width (FWHM) was about 100 μs for spontaneous
emission, with a sharp rise and a slow decay. Using high voltage probe P-6015 the breakdown voltage pulse and laser emission have been photographed. The pulse repetition rate found to vary up to 100 Hz when A.C. voltage was used. The details of the fabrication of various lasers and the measured output characteristics with different parameters are presented.

In Chapter IV, the details of intensity measurements of the nitrogen second positive (II P) bands are described. The \( \text{N}_2 \) II P bands were photographed along the length of the laser discharge and perpendicular to the laser discharge using Hilger Medium Quartz Spectrograph. The relative intensities of the bands were measured employing the techniques of photographic photometry. Relative intensities of these bands emitted from a condensed (longitudinal) discharge and also from an arrangement similar to laser without the parallel plate condenser were measured in the same way. Both these experimental arrangements were built in the laboratory. Using these relative intensities, vibrational populations \( (N_{v'}) \) of the \( \text{C}^3 \Pi_u \) state of different vibrational levels \( v' = 0, 1, 2, 3 \) were measured. The relative intensities and vibrational populations in end-on direction are compared with similar data in the direction perpendicular to the laser discharge and also with those obtained from condensed discharge (longitudinal) and transverse discharge. These are significantly different and are used in Chapter V to
understand the excitation mechanism of the laser. Vibrational temperatures are determined for these discharges. All the measurements and the derived results are tabulated.

In Chapter V, the data obtained have been critically analysed in relation to other reports. The results can be summarised and assessed in the following way:

(i) Effect of pressure on the intensities of bands, and the consequential derived values of vibrational populations and the vibrational temperature.

(ii) Comparison of populations with the reported cross-sections for electronic excitations of $C^{3}\pi_u$ state of $N_2$ and their evaluation.

(iii) Comparison of fluorescence ('spontaneous emission as viewed in the direction perpendicular to laser discharge) with the emission along the laser direction.

The following six conclusions have been drawn:

(a) We have shown that a simple and inexpensive $N_2$ laser that is adequate to pump dye laser can be built with practically no workshop facility.

(b) The laser has been systematically investigated and it is found that the power improves considerably for
glass surfaces and for smaller volumes of discharge tube (box).

(c) Amplification on using a rear mirror could be very high (upto 20) and thus help in reducing the size.

(d) Fluorescence measurements from the side can be fruitfully employed for low pressure lasers to determine population changes in the lasing and non-lasing levels.

(e) Cross-section for electronic excitation are not precisely known and hence are not adequate to explain all the details of the observed population distribution.

(f) The population of $v' = 0$ as observed in the perpendicular direction appears lower when the band at 337.1 nm is lasing at its best (i.e., at 90 torr).

The totality of the data is hoped to add to the body of the knowledge on $N_2$ lasers and lead to a fuller understanding of the relation between spontaneous and laser emission in this molecular source.