kV DC have already been developed and work on sealed off nitrogen laser tubes is in an advanced stage of completion. An electron gun for linac using LaB_6 emitter has been made and is under test. The cathode assemblies for 20 MeV microtron have also been made. The emission current from these was found to be about 75% of that of imported single crystal cathodes. A fixed anode X-ray tube has been sealed off and is awaiting tests. Development and production of various types of flash lamps and arc lamps is also planned in this section.

COMPUTER FACILITY

A supermini computer system MAGNUM MULTI-RISC-2 with 32 MB main memory and 15 Wheatstone MIPS in double precision and a twin CPU based minicomputer system MAGNUM have been installed to augment capabilities for scientific computations. The centre now has a 2D-graphics workstation (NEXUS-3500) which is used as a dedicated system for scientific graphics and as a TEKTRONIX terminal for other computers. A one day course for familiarization with this system was also organised. Besides, an Electronic Design and Analysis (EDA) work station has been commissioned for PCB layout design.

The Computer Centre organised several other courses of both introductory and advanced levels to keep the users informed and developed several general utility softwares. It has also developed a package for the analysis of accelerator beam. The PC based package has the capability of displaying two images simultaneously with 256 gray levels and has provision for back ground subtraction, noise reduction, beam profile plotting, computation of mean standard deviation and other parameters.

CONSTRUCTION PROGRAMME

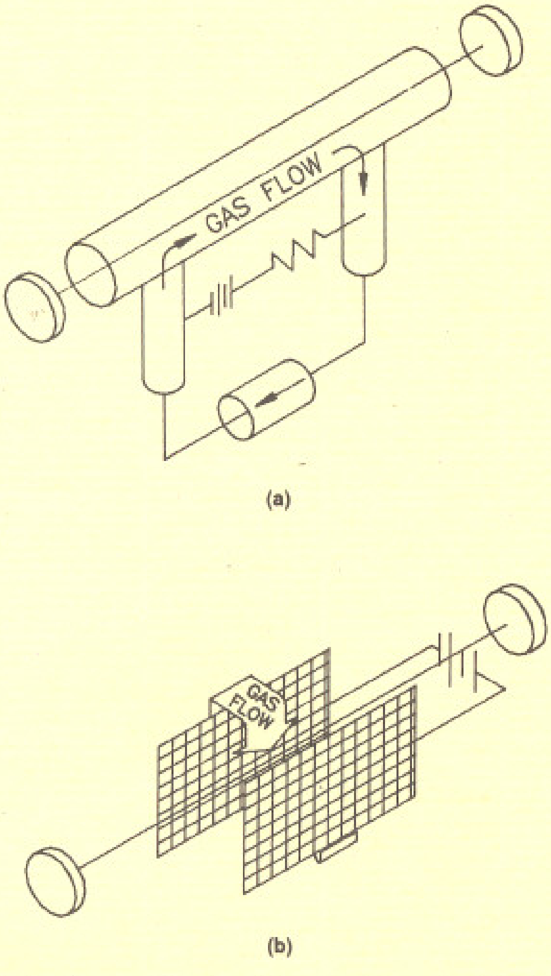
The construction of Laser Fusion Laboratory has been completed and the laboratory is now in use. Work on the Indus-I laboratory, erection of a 132 kV substation, a fire station and construction of 131 residential quarters is progressing well. Work has also been started for the construction of Laser Research and Development Laboratories and Accelerator Development Laboratory.

HIGH POWER TRANSVERSE FLOW CW CO_2 LASER

High power CW CO_2 lasers with powers ranging from 1 to 10 kW are finding increasing use worldwide for several industrial applications such as welding, cutting, surface hardening, cladding and alloying. Even in India these lasers are being used though mainly for cutting metal sheets. Perhaps a major obstacle in a wider use of such systems in our country is their high cost (~Rs. 20 Lakhs/kW laser power). Realising that th*e availability of a cheaper indigenous laser system should help in fuller utilisation of the potential of this promising technology, a programme on the development of high power transverse flow CW CO_2 laser was initiated in 1986. The first indigenous laser system is now operational. Though optimization of the system is still in progress, laser output power of more than 2.5 kW has already been achieved.

In this article we first provide a brief introduction to CW CO_2 lasers and then describe the design and operational characteristics of the high power transverse flow CW CO_2 laser developed at CAT.

CO_2 Lasers are one of the efficient laser systems. About 15-30% of the excitation electrical power can be converted into laser radiation. Rest of the electrical power gets dissipated as heat in the laser gas. If not removed, this results in an increase of gas temperature, which increases the thermal population of the lower laser level and the collisional decay of the upper laser level population. Both of these effects reduce the available population inversion and hence limits laser operation. The heat dissipated in the gas has therefore to be quickly removed before the temperature of the laser gas rises too high for an efficient laser action. In conventional CW CO_2 lasers, heat is removed via diffusion through the wall of the laser tube which is cooled by water flowing continuously through a jacket put around the tube. Diffusion cooling limits the laser output power from this type of system to about 50 W/m active length. The laser power from such diffusively cooled systems can be increased by increasing the active length achieved by placing several discharge tubes in series and/or parallel. Diffusion cooled laser systems upto 10 kW maximum power have been reported. However, for output powers beyond 1-2 kW such systems become rather cumbersome and therefore an alternative cooling technique, *viz.* the convective cooling is usually employed for high power CW CO_2 lasers. In convective cooling, the laser gas is circulated through the discharge zone and then through heat exchangers at a high speed with the help of a suitable gas circulating system. The laser output power scales up with the gas flow velocity. Two different gas flow configurations shown in fig.1 have been utilized for convective cooled CO_2 lasers; axial flow (fig.1a) in which the gas is flown through the discharge tube along the optical axis and transverse flow (fig.1b) in which the direction of gas flow is perpendicular to the optical axis. Though axial flow CO_2 - lasers provide better beam quality, they require specially designed roots blower or turbo blower of high volumetric flow and large pressure head capacity for circulating the gas through long and narrow discharge tube. These blowers need to be imported and are very expensive. In transverse flow configuration, fast gas flow can be established through large discharge aperture with suitably modified indigenously available centrifugal or axial blowers. In transverse flow lasers the discharge excitation field is applied across two large area electrodes (fig.1b). Unlike the axial flow lasers in which discharge uniformity in the radial direction is maintained by diffusion process and highly turbulent gas flow, the transverse flow lasers require some additional means to establish uniform and stable discharge between the electrodes. Various techniques have been tried out for this purpose. These include discharge assisted by electron beam, corona discharge, RF discharge, high frequency impulses, and auxiliary DC discharge. In the system developed at CAT uniform and stable discharge is maintained by simultaneous application of a DC voltage and a high repetition rate, short duration high voltage pulses on the electrodes. The DC voltage is by itself not sufficient to maintain electrical discharge and the high voltage pulses provide the necessary ionisation to sustain it. The duration of these pulses (~500 nsec) is such that arc formation does not occur within this period. The repetition rate of the pulses is selected to be significantly higher than the characteristic plasma relaxation time. This makes the laser discharge to operate in a true CW mode though the ionization source is pulsed. Another advantage of this scheme is that, discharge being externally controlled, the E/P (Discharge electric field/gas pressure) ratio can be adjusted to optimise vibrational excitation of CO_2 molecules and thus obtain efficient laser operation.



(a)

(b)

Fig. 1. Gas flow configurations for convective cooled CO_2 lasers: (a) axial flow, in which the gas is flown through the discharge tube along the optical axis and (b) transverse flow in which the direction of gas flow is transverse to the optical axis.

Fig. 2 shows a schematic diagram of the laser head of CW CO_2 laser system. This has been constructed with a cylindrical vacuum chamber of 2m diameter and 1.5m length having dished end doors. The chamber is made of mild steel and houses discharge electrodes, a gas circulating system and heat exchangers. Two discharge zones each of 1m length are created between a common cathode and a pair of anodes. Each anode consists of one hundred Stainless Steel (SS) tubes of 4mm diameter spread equidistantly on a line of one meter length. To distribute current evenly through all the tubes these have been individually ballasted with resistances. About 30-40% of the total electrical power may be dissipated in these resistances,

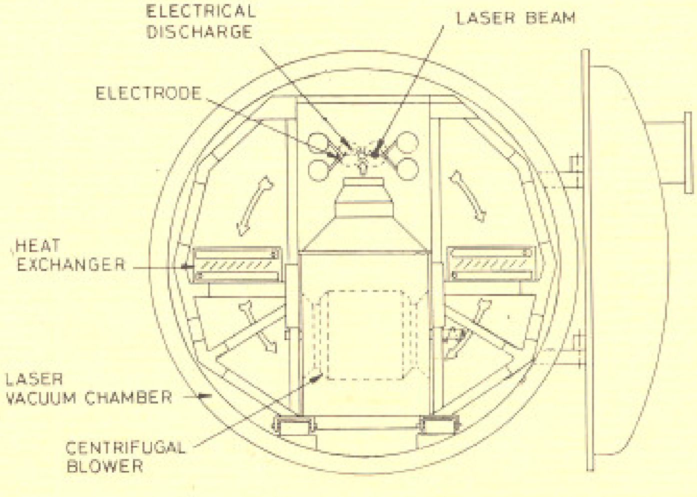


Fig. 2. A schematic diagram of the laser head of CW CO_2 laser system. Arrows indicate the direction of gas flow.

and this waste heat has to be removed. For this a column of aqueous solution of potassium carbonate is used as ballast resistance with each SS tube. This solution is flown through each tube to keep them cool and then circulated through heat exchanger in a closed loop to remove heat. The common cathode placed between anodes is made of a water cooled copper tube. The resistance ballasted multiple tube anodes help in distributing current uniformly over the entire discharge length. Uniformity and stability of the discharge are further ensured by the high voltage high repetition rate, short duration pulses on which the main DC discharge current is superimposed. High voltage impulses are generated by a solid state pulser system incorporated with magnetic compression circuit developed for this laser. This can provide 15 kV peak voltage pulses of 250 ns duration at 1-5 kHz repetition rate. A commercially available double entry centrifugal blower was modified for circulating the laser gas through the discharge zones and the heat exchangers. A uniform gas flow through discharge zones at a maximum speed of 45 ±3 m/s in a direction perpendicular to both optic axis and discharge electric field was obtained. A U-folded stable optical resonator has been utilized to extract laser power from both discharge zones in a single beam.

One important feature of this laser is that it has positive impedance discharge characteristics unlike the normal self sustained DC discharge. This is because the discharge in this laser is sustained by high voltage impulses. This ensures better stability of the discharge and hence of the laser output power. Another interesting feature of the laser is that the maximum input power that can be dissipated in the discharge without deterioration of the discharge quality remains unchanged over a large variation in pulser power. This can be seen from fig 3a and 3 b where the pulser power has been changed by varying the repetition rate (fig.3a) or by changing the peak voltage of the pulses (fig.3b). This is so because while increase in pulser power increases the discharge current that could be flown before the onset of discharge instability it also reduces discharge impedance and hence the DC voltage across the discharge. This observation also implies that the discharge instability is influenced more by the product of the discharge current and the voltage rather then their individual values. Further since gas temperature is directly proportional to the input electrical power the main reason responsible for deterioration in discharge quality at large input powers appears to be thermal instability.

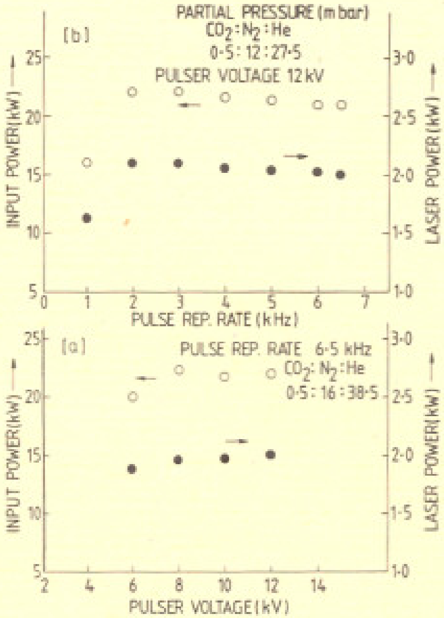


Fig. 3. Effect of pulser parameters on electrical input power and laser output power.

While system optimization with respect to gas flow and optical resonator design is still in progress, continuous laser output power upto 2.7 kW has been obtained so far in a gas mixture containing 0.5 mbar CO_2, 16 mbar N_2 and 38.5 mbar He. It is interesting to note that the ratio of CO_2 and N_2 partial pressures in the optimum laser gas mixture is very different from that for diffusion cooled lasers where this ratio is in the range of 1:1 to 1:2. Important parameters of the laser are summarized in the table below.

Laser Specifications

Laser Power	:	**2.5 kW (CW)**
Electro-optic Efficiency	:	**11%**
Active Length	:	**2 X 1 m**
Inter electrode gap	:	**35 mm**
Gas mixture	:	**CO_2 - 0.5 mbar** **N_2 - 16 mbar** **He - 38.5 mbar**
Gas flow velocity	:	**45 ±3 m/s**
Laser beam mode	:	**Multimode**
Laser beam diameter	:	**30 mm**
Laser beam divergence	:	**~2 mrad**

The laser developed at CAT has been used for a preliminary metal sheet cutting experiment. Mild steel sheets upto 5 mm thickness could be cut at 2 kW power level. Apart from cutting metal and non-metal sheets this laser will find many other material processing applications such as laser welding, surface hardening, cladding and alloying. A Prototype model of this laser for industrial use is being developed. It is also planned to develop laser systems of continuous output power upto 10 kW.

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