High Repetition Rate TEA CO_2 Laser

Many scientific as well as industrial applications such as photochemical processes, laser isotope separation, range finding, remote sensing, marking, surface glazing and cutting of glass and ceramic etc., require high pulse energy, high average power CO_2 lasers. For these purposes we have developed a high repetition rate transversely excited atmospheric pressure (TEA) CO_2 laser which gives a maximum average power of 500 watts at 500 Hz pulse repetition rate. Uniform excitation of laser gas at high pressures by electrical discharge at high input power densities poses problem in its development. High pressure electrical discharge has a tendency to degenerate into an arc. In order to create an uniform glow discharge, it is necessary to preionize the gas volume at an electron density of the order of 10^4 -10^6 electrons/cc. A fast rising electric voltage pulse is then applied to the discharge volume, causing electron density to increase via avalanche process, leading to uniform self-sustained discharge. In laser system developed at CAT, we preionize the laser gas by UV photoionization process. UV radiation is produced by two rows of multiple sparks placed along the discharge length near anode. To ensure uniformity, it is essential to equalize the discharge current through each sparks. Resistance, capacitance or inductance are normally used as ballast elements to distribute energy uniformly through all sparks. Each has some drawbacks in terms of power dissipation and peak current which determines the intensity of UV radiation and operating life. Inductive ballasting is one of the best method for this purpose from efficiency, cost and life point of view. However, it limits the peak current through the sparks. Recently, we have developed a new method which is virtually ballast - free and the discharge current is equalized by connecting mutually coupled inductors 'M' in series with each spark-source as shown in fig. (2). When the current is equal in all sparks, the mutual inductance gets canceled; allowing a high peak current to flow through sparks. If the current through a spark tends to rise, it induces additive emfs in other coupled inductors which cause the current to increase in other sparks too. This way the current is uniformly distributed over all sparks.

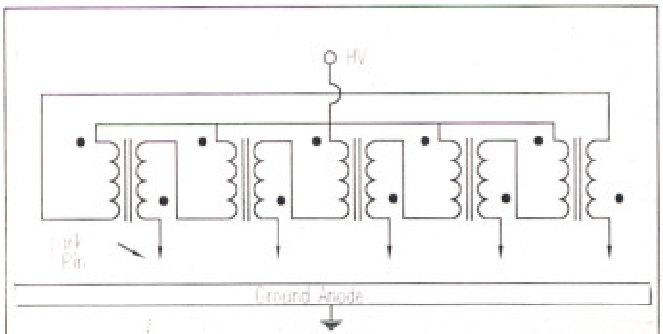


Fig. 1:Equivalent circuit of ballastless spark preionization scheme

The laser head consists of a discharge chamber, a centrifugal blower for gas circulation and a pair of heat exchangers. They are interconnected by vacuum tight flow ducts. The discharge chamber encompasses discharge electrodes, UV spark sources and the optical resonator. We have used a Chang profiled electrode and a semi-infinite flat electrode to create uniform discharge in a volume of 2.0x2.0x50.0 cms (200 cc). Two rows of pins, 25 numbers in each row spaced equidistant, are placed along the either side of the flat electrode, at 5.0 cm distance from the central line of the electrode. The gap between tips of the pins and the flat electrode is 3 mm. Sparks are produced between these gaps by flowing high peak pulsed current through them. As mentioned earlier, current through each spark has been equalized by connecting coupled inductors in series with each pin. The laser is excited by discharging the electrical energy stored in capacitor C_e of 25 nF with the help of a thyratron T_h. The storage capacitor C_e is charged to a maximum voltage of 33 kV through an IGBT 'Q', high voltage transformer 'T' and a shunt inductor L_{SH}. This scheme isolates the thyratron from dc power source, thus avoids possibility of thyratron latching in case of fault conditions like arcing in laser cavity and load impedance mismatching etc. Fig. 2 shows the schematic circuit of TEA-CO_2 laser power supply. When C_1 has charged to the peak, the thyratron is triggered. Capacitor C_{P1} (4nF) limits the energy in the sparks, and C_{P2} isolates the preionization circuit from the thyratron. In case of arc formation in laser cavity, a negative voltage reflection generated from the load travels towards IGBT. This is sensed by an optically isolated protection circuit which blocks the trigger pulse to IGBT , saving the later. The performance of this new preionization scheme has been compared with the conventional using ballast inductors in a test electrode set up. In the later scheme, inductors of ~30μH were connected in series with each spark pin for ballasting purpose. The ultraviolet light signal of the spark was detected by a photo diode. In the new scheme, a photo signal of ~2.5-2.7 times that of the conventional preionization scheme was measured.

The optical resonator is formed with a nearly 100% reflecting gold-coated copper mirror of 4 m radius of curvature and 70% reflecting ZnSe plane output

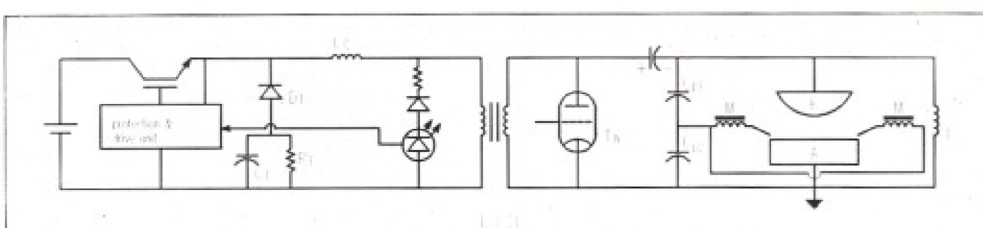
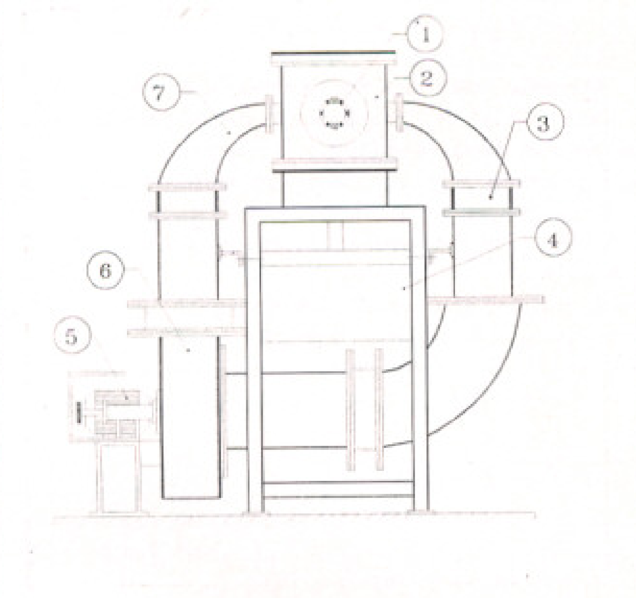


Fig. 2: Schematic circuit of TEA - CO_2 laser power supply.

Specifications of high repetition rate TEA CO_2 laser	
Laser power	500 watts (average)
Laser rep. rate	500 Hz
Laser active volume	2.0 x 2.0 x 50.0 cms
Gas mixture	$CO_2 : N_2 : He = 1:1.5:6$
Gas pressure	1000 mbar
Operating voltage	33 kV
Gas flow velocity	40 m/s
Laser beam size	1.8 x 1.6 cms
Laser beam mode	Multimode

coupler, separated by a distance of 1.2 m. The centrifugal blower recirculates laser gas through discharge zone and then through heat exchangers at a high speed so as to avoid the thermal bottleneck at high repetition rates. Blower runs at 3000 rpm and provides about 40 m/s flow velocity through discharge zone. Laser has been operated at high repetition rates up to 500 Hz at atmospheric pressure in an optimum gas mixture of $CO_2 : N_2 : He = 1 : 1.5 : 6$. With 13 J per pulse input energy the maximum average laser output power



Schematic of the laser system.
1. Output coupler, 2. Laser head, 3. Heat exchanger, 4. Power supply , 5. Motor, 6. Centrifugal fan, 7. Flow duct.

obtained was about 500 watts. The maximum repetition rate and output power are limited by the onset of discharge instability which causes non-uniform streamer discharge. One of the important reasons for onset of discharge instability and limitation on pulse repetition frequency is the shock waves generated by the electrical discharge. This can be improved by either increasing the gas flow velocity or damping the shock wave using some suitable acoustic absorber inside laser chamber and flow duct. Further improvements in the laser are being carried out. At present, the laser is operated on P(20) line of 10.6 micron band. This will be made line tunable on different P and R lines of 9.6 and 10.6 micron bands by incorporating a reflective grating in optical resonator. Technical specifications and laser operating characteristics are summarized in the table below.

High rep rate TEA CO_2 laser developed at CAT

This laser is being planned for use in isotope separation of carbon-13 which has a wide range of applications as a trace element in medicine, chemistry, biochemistry and environmental sciences. Other applications which will be tried out with this laser are hole drilling, surface glazing, marking and cutting of highly reflecting materials along with a CW CO_2 laser.

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