to recycle the gas, then a fresh mixture must be supplied continuously (i.e., there are recycled and opened designs). Vacuum pumps are used for recycling purposes in the recycled design and water or oil cooling is needed. Since in the opened design , however, gas pressures are relatively low, the gas demands are not excessive and vacuum pumps are used to remove the waste gases from the tube to discharge them into the atmosphere (since it is non poisonous). The main limitation in these lasers is that the gas temperature inside the electrical discharge tube must be lower than500C.Power output of these lasers increases linearly with tube length at a rate of some 60 W per meter. Hundreds of watts can be achieved at the output of these lasers. For power outputs of greater than a few kilowatts, however, the tube lengths required become impractically large. In the fast axial-flow CO_2 lasers, the gas velocity along the tube axis is equal or greater than 100 m/s (the gases are convectively cooled), so these lasers operate at higher pressures than the slow axial-flow lasers. The high pressures allow high specific inputs (about 600 J/g) that leads to produce multi-kilo Watt outputs.

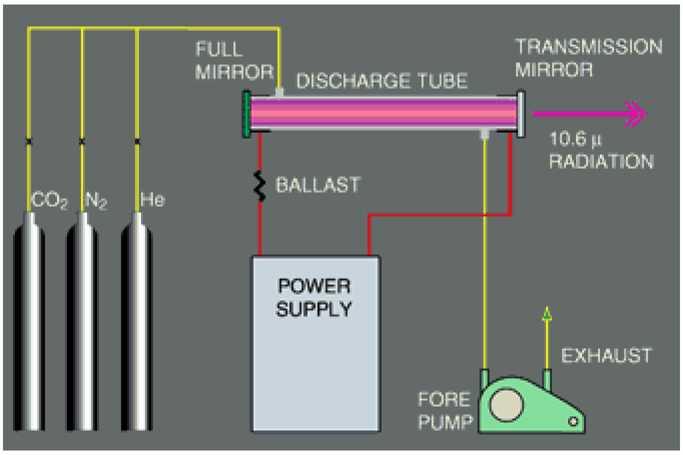

Fig. 2.16: Construction of a slow flow CO_2 laser.

-- Transverse-Flow CO_2 lasers

A much larger gas flow and a corresponding increase in maximum power output is possible if the flow takes place transversely to the lasing axis. The electrical discharge can also be usefully applied transversely (and normally to the gas flow), as illustrated in Fig. 2.17.The small electrode separation (3-5 cm) makes use of lower discharge voltages and high currents. The gas flow velocities are in the range 40-100 m/s. Since cooling by gas flow is very efficient in these designs, it is possible to get very high CW power levels of some tens of kilowatts. Larger outputs are possible but the sheer size and power requirements begin to preclude common industrial use.

-- Transversely Excited Atmospheric (TEA) CO_2 lasers

So far in our discussion raising the power output in CO_2 laser has involved increasing the length (as in slow flow lasers) and/or the gas flow rate (as in fast axial and fast transverse flow). There is, however, another option, namely that of raising the gas pressure. Unfortunately this carries with it the penalty of an increase in the voltage needed to excite the discharge, and at relatively high pressures the requirements may become embarrassingly large. For example at atmospheric pressure the breakdown voltage is 1.2 kV/mm. Obviously at this pressure it would be difficult to contemplate a longitudinal discharge in a tube several meters long. On the other hand a transverse discharge over a length of some 10 mm or so would be much more acceptable. CW operation also causes problems because of discharge instabilities which occur at pressures

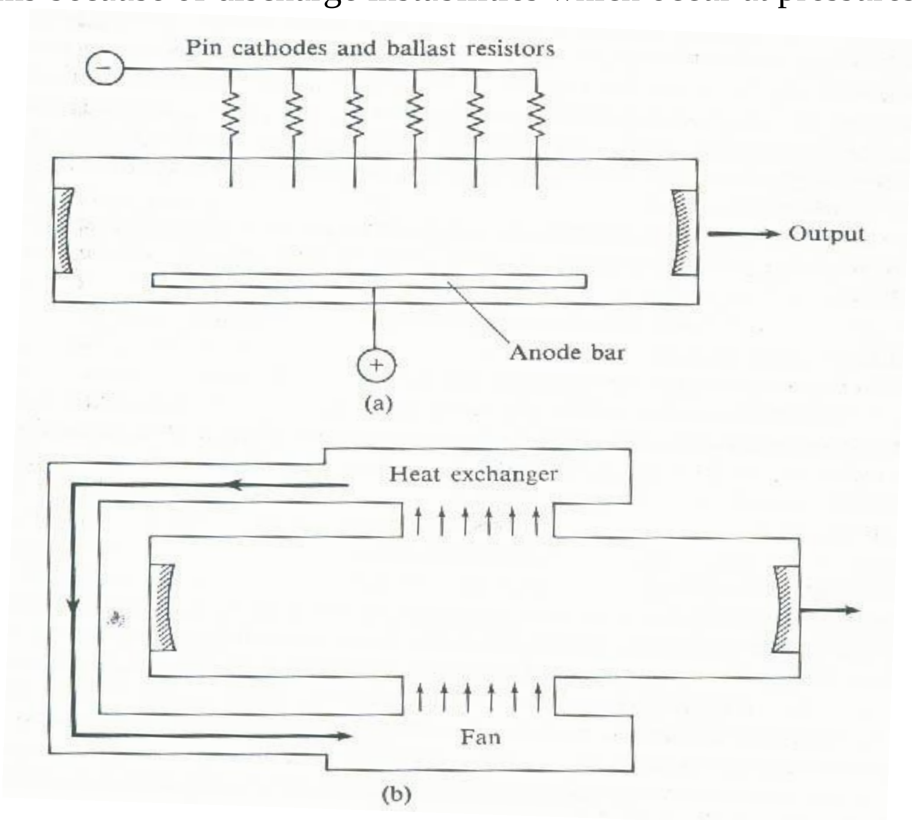

Fig.2.17. Schematic diagram of a TEA CO_2 laser; side view (a), and top view(b).

above l00 torr. Thus high–pressure lasers are of necessity pulsed and are pumped using a transverse discharge. Such lasers are termed transversely excited atmospheric (TEA) even though the gas pressures may cover quite a wide range about atmospheric. Very high–power pulses may be achieved having durations down to 50 ns and with energies of up to 100J.Both the gas flow and the electric discharge in TEA CO_2 lasers are along the width of the laser (as it can be seen Fig.2.17). Thus, the distance between the electrodes is short, so electric discharge can be achieved even for gas at very high pressure (up to a few atmospheres).

At very high pressures (above 10 atmospheres) molecular collisions cause the individual lines to broaden into a continuum and a more or less continuous tuning of the laser output becomes possible. Line broadening is also useful when the technique of mode locking is used to generate nanosecond duration pulses.

-- Gas Dynamic CO_2 lasers

With gas dynamic lasers we reach, from a laser point of view, the possibility of the quite staggering power levels of some hundreds of kilowatts. Population inversion is created through thermodynamic means rather than in a gas discharge. A nitrogen-carbon dioxide mixture is heated and compressed and then allowed to expand rapidly through a nozzle into a low-pressure chamber. In the high-temperature regime most of the energy is stored in the vibrational modes of the nitrogen molecule. After expansion and cooling most of the rotational and translational energy of the nitrogen molecule is rapidly lost by collisions with other molecules whilst the vibrational energy is stored for rather longer. Resonant collision processes can then populate the (001) levels of the carbon dioxide molecule and hence create a population inversion between these and the (100) levels. Gas dynamic lasers, however, are not commercially available and in any case there are few, if any, real uses for such high powers especially in view of the huge size and complexity of the laser structure

CO_2 laser Design Constraints

There are two major constraints that influenced the design of CO_2 lasers:

1. The removal of heat from the discharge tube, and

2. Operation of discharge at high electrical input powers.

Optics

One of the difficulties with having an output at around 10 μm is that 'normal' optical materials, such as glass or quartz, are quite useless for components such as Brewster windows, since they exhibit very high absorption at this wavelength. There are a number of materials which are transparent but many of them suffer from having rather poor mechanical properties. Germanium, gallium arsenide, zinc sulfide, zinc selenide and various alkali halides have all been used. The latter show the lowest absorption of all but are fairly soft and hygroscopic (that is they absorb water from the atmosphere). Metal mirrors can be used for the 100% reflecting mirror. In high–power designs even a small amount of absorption can lead to appreciable heating up of the optical component, and then some form of forced cooling may be necessary.

Properties of CO_2 Laser

- High output power. Commercial CO_2 Lasers produce more than 10,000 Watts continuously.
- Output spectrum is in the Infra-Red (IR) spectrum: 9-11 μm (10.6 μm is the strongest)
- Very high efficiency (up to 30%).
- Can operate both continuously or pulsed.
- Average output power is 75 W/m for slow flow of gas, and up to few hundreds W/m for fast gas flow.
- Very simple to operate, and the gasses are non-toxic.

QUESTIONS

1.Why does the CO_2 laser regarded one of the most important lasers?

2. On what parameters does the gas mixing ratio in CO_2 lasers depend?

3. How could the performance of CO_2 lasers be optimized?

4. How do CO_2 lasers operate? How are they pumped? What transitions in them that lead to lasing?

5. Explain that the excitation process in CO_2 lasers is similar to that in He-Ne lasers?

6. What are the factors that make the $N_2(V_1)$---- $CO_2(001)$ excitation process very efficient?

7. What are the roles of He in CO_2 laser?

8. What are the different types of CO_2 lasers?

9. Describe three types of CO_2 lasers, and draw one type only.

10. Give the problems associated with three types of CO_2 lasers.

11. On what factors does the output power depend in three types of CO_2 lasers?

12. Explain the statement: High power CO_2 lasers are high pressure systems.

13. Why does high pressure CO_2 laser operated in pulsed mode and pumped by transverse discharge?

14. What is the penalty on raising the gas pressure in CO_2 lasers?

15. What is the advantage of gas-flow CO_2 laser?

16. What are the options of raising the power output from CO_2 lasers?

17. What is the problem with CW operation in TEA laser?

18. What are the characteristics of TEA CO_2 lasers?

19. How does the population inversion created in gas dynamic lasers?

20. What are the major constraints that influenced the design of CO_2 laser?

21. What are the difficulties with having an output around 10μm ?

22. What are the coating materials of the coupler mirror of CO_2 laser?

23. Compare the characteristics of the following materials when they are used as CO_2 laser mirror substrates:

a. Germanium (Ge).

b. Gallium Arsenide (GaAs).

c. Zinc Selenide (ZnSe).