CHAPTER 5

CONCLUSIONS

5.1 SUMMARY OF OPERATIONAL CHARACTERISTICS

We have characterized a home-made HRR TEA CO_2 laser with a two-stage spark gap and high-voltage command charging technique. The main parameters for reliable operation of this HRR TEA CO_2 laser are summarized as follow:

(a) Time delays for stable laser output energy
  (i) For C_{Ms} = 20 nF, time delay ≥ 125 ns
  (ii) For C_{Ms} = 40 nF, time delay ≥ 300 ns

(b) $C_{Ps} \geq 4$ nF with $C_{Pp} / C_{Ps} > 2/3$

(c) C_{Ms} = 12 to 65 nF, may depend on V_C

(d) $C_{Mp} = 4 \times 0.44$ nF or 9×0.44 nF

(e) V_C = 12 to 24 kV

(f) highest output energy = 800 mJ per pulse at 40nF/23.3kV or 49nF/21.2kV

(g) highest efficiency = 10.5% at 65nF/11.7kV

(h) maximum frequency = 300 Hz, V_C = 15 kV and $C_{Ms} \leq 40$ nF

(i) maximum output power = 70 W at conditions (h) with C_{Ms} = 40 nF.

(j) flow velocity = 22 m/s

(k) clearing ratio ~ 4

Although the maximum arc-free operation frequency was around 300 Hz, irrespective of the input energy density if it is <60 J/*l*-atm, we did observe that this could be limited mainly by the gradual arc damages on the laser electrode surfaces. Thus, we may expect a higher frequency of up to 500 Hz if these electrodes are polished.

5.2 SOME COMPARISONS WITH OTHER REPORTED SYSTEMS

(a) The Clearing Ratio

The clearing ratio is an important factor which determines the discharge gas removal ability. This value also depends on the preionization level, or photoelectron density and the excitation circuit configuration. The higher the preionization level and the more oxygen-tolerant of the discharge circuit, the lower will be the clearing ratio. Figure 5.1 shows the distribution of our recorded clearing ratios.

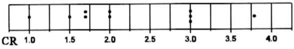

Fig. 5.1 The clearing ratio distribution.

The clearing ratios of the present system are in between 3 to 4.6, which are slightly out of the distribution. Therefore, improvement on the gas flow conditions and excitation circuit may be required for higher output power operation.

(b) The Spark Gap

There are a number of reported HRR TEA CO_2 laser systems using the spark gap as the HRR switch. In Table 5.1, the spark gap performance for different discharge conditions are compared. The maximum power delivered by the present spark gap is 1350 W and the maximum frequency is around 2000 Hz. It is noted that the present spark gap performance is limited by the maximum operational voltage, i.e., at about 15 kV. Further improvement on this spark gap is needed in order to raise this maximum operational voltage. It is expected that by using other insulation materials instead of perspex for the spark-gap chamber and a large spark-electrode diameter, it may allow the HRR TEA CO_2 laser to be operated at voltage > 15 kV.

Fig. 5.1: Reported spark gap performance for HRR TEA CO_2 laser.

Descriptions	frequency (Hz)	C_{Ms} (nF)	V_C (kV)	power (W)	Ref.
-	250	2	31	240	[43]
trigatron	160	8	38	924	[48]
N_2 pressurized, resistive charging	100	6.3	28	247	[45]
fast flow 30-psi N_2 blown trigatron	200	50	30	4500	[41]
resistive charging	100	10	36	648	[65]
Present system, air-blown spark gap command charging	2000	20	5.5	605	
	480	20	15	1080	
	300	40	15	1350	

5.3 SUGGESTIONS FOR FUTURE WORK

In the present system, some parts need to be improved in order that the system can be operated reliably. A further study on this system is needed before the system can be used for certain applications. The following are some of the suggestions for future works:

(a) The preionizer

A more lasting preionizer is needed for HRR operation. The preionizer must be made for easy maintenance and the adjustable gap distance, such as by using screw heads [92].

(b) The transverse gas flow

A larger range of transverse gas flow is needed in order to investigate the laser performance more thoroughly. Therefore, a higher flow capacity fan or blower is needed for this purpose. Improvement on the clearing ratio may require further study on the gas flow behaviour across the laser channel.

(c) Gas mixture lifetime study

A sealed-off long operational lifetime HRR system is advantageous for certain applications such as for remote sensing, tracking, and monitoring. Gas mixture lifetime needs to be studied for long lifetime operation and this may require catalysis of the dissociated CO_2 components.

(d) The air-blown spark gap

The operating voltage range, electrode erosion, and trigger-breakdown reliability of the spark gap can be improved by improving the electrode design, electrode material, triggering mode, and insulation material.

5.4 CONCLUSIONS

The single-pulse operation of a TEA CO_2 laser has been characterized prior to its HRR operation. This project found that the laser output energy and efficiency depend on some factors such as the preionizer-to-main time delay, the optical alignment, main storage capacitance, and the storage capacitor voltage. The preionizer storage capacitance and main peaking capacitance can affect the laser operation at discharge conditions near to the unstable regions.

In HRR operation, the gas flow velocity across the laser channel is the main factor affecting the maximum frequency for arc-free discharges. This maximum frequency is unaffected by the low input energy density.

The air-blown command charging spark gap circuit and the two-stage spark gap have been operated successfully on the HRR TEA CO_2 laser. Further improvements on these two spark gaps and their circuits may allow the laser to be operated more reliably. Such spark gaps can become an economical way to operate the HRR lasers.