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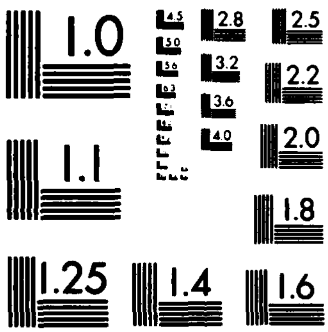
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FOREIGN TECHNOLOGY DIVISION

A LONG LIFE CO_2 LASER

by

Cai Lijuan, Yu Linxiu and Zhang Kenian

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A LONG LIFE CO_2 LASER

by Cai Lijuan, Yu Linxiu and Zhang Kenian
(Institute of Laser Technology, Shanghai)

Abstract

It is shown experimentally that three major factors must be considered to obtain a CO_2 laser with long life. They are: 1) elimination of slow gas leakage; 2) selection and oxidation of electrode material; 3) decreasing the decomposition of CO_2 molecules. Our method was: the laser tube is not dried but filled with water vapor, the electrode material must be degassed in a vacuum and oxidized by filling oxygen gas. When pure silver electrodes are employed, the gas mixture constitutions are separately 1) CO_2-N_2-He-Xe-H_2O; 2) CO_2-CO-He-Xe-H_2O; 3) CO_2-N_2-CO-He-Xe-H_2O, the operating lives reach 1) 10,476 hours; 2) 9,185 hours (still in operation); 3) 9,207 hours (still in operation). When pure nickel electrodes are used, the gas composition is CO_2-N_2-He-Xe-H_2O and the operating life reaches 1,644 hours.

The operating life of a sealed CO_2 laser is a problem in need of fast solution. In the last ten or more years a great deal of domestic and foreign testing has been done on sealed CO_2 lasers and there have been noticeable achievements. Foreign nations have reported that when a silver-copper (internal oxidation) alloy is used as the electrode material in a CO_2-CO-He-Xe gas mixture, the CO_2 laser output power is 1 watt and its life reaches 12,000 hours.

We drew from foreign tests and at the same time based on the actual circumstances of existing laboratory conditions and operating CO_2 lasers, tests were carried out on lasers with 25-30 watt output power and an 800 millimeter discharge length whereupon an operating life of 10,000 hours was able to be obtained.

I. Test Conditions

The serial numbers were A, B, C, D, E, F and G. The effective discharge length was 800 millimeters, the inner diameter of the discharge tube was 8 millimeters, the cavity structure was a plane-spherical cavity, the total reflector curvature radius was 3 meters, the output window plate was a germanium wafer, and there was non-coated uniform output. Fig. 1 shows the structure of the CO_2 laser. The material used was GG17 hard glass.

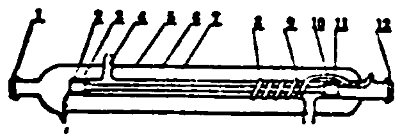


Fig. 1 Structure of the CO_2 Laser

Key:
1. Output window (germanium wafer)
2. Cathode
3. Cathode cover
4. Outfall
5. Receiver
6. Water-cooled tube
7. Discharge tube (8 millimeter inner diameter)
8. Gas return tube
9. Water intake
10. Anode cover
11. Anode
12. Reflector plate (R is 3 meters, gold plated)

There are two types of electrode material, nickel and silver hollow cylinders, and both must be degassed in a vacuum and oxidized by filling oxygen gas. All of the manufacturing techniques for the lasers are the same. The laser tube is not dried but filled twice with He gas for discharge degassing and adding H_2O. Vacuity is 5×10^{-5} torr. The gas compositions of these seven lasers are listed separately in table 1.

1 编号	电极材料 2	气体比例 10						总气压 13 (托)
		CO_2 :	N_2 :	CO :	He	11 Xe (托)	12 H_2O (托)	
A	镍 3	1	2		7	0.5	0.2	25
B	银 4	1		1.5	7	0.5		24
C	银 5	1	2		7	0.5	0.2	25
D	银 6	1		1.5	7	0.3	0.2	27
E	银 7	1	1	1	7	0.5	0.2	28
F	银 8	1		1.5	7	0.5		24
G	镍 9	1		1.5	7	0.5		24

Table 1

Key: 1. Serial number
2. Electrode material
3. Nickel
4. Silver
5. Silver
6. Silver
7. Silver
8. Silver
9. Nickel
10. Gas ratio
11. (Torr)
12. (Torr)
13. Total gas pressure (torr)

The discharge is: when the direct current discharge (whole wave integral flow) operates in a discharge current with N_2 in the mixed gas it is 18 to 20 milliamperes and when it is in a CO (when there is no N_2) discharge current it is about 16 milliamperes. The operating mode is: it operates continually 24 hours each day, the water coooling temperature is a constant temperature (room temperature), the reflector plate and output window both use water cooling, and when the laser is operating it has a water and electric breaking controller. So-called laser life is the output power of the component which changes with the operating time. When the laser's output power declines to 70% of the initial power, the operating life is terminated.

II. Test Results

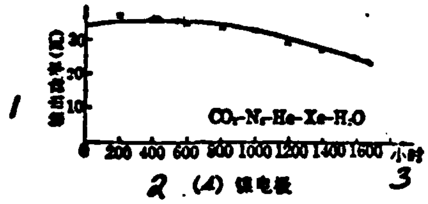
See table 2 for the long-life test results of various materials used for the sealed CO_2 laser. Fig. 2 shows that the output power changes with the time.

1 编号	2 电极材料	工作寿命 10 (小时)	11 备注
A	3 镍	1,644	寿命终止(1978.3.18→5.31) 12
B	4 银	1,514	因断水控制器失灵而炸裂 13 (1977.12.9→1978.8.8)
C	5 银	10,476	寿命终止 14 (1978.3.22→1979.6.23)
D	6 银	9,185	仍在运转 (1978.8.31→现在) 15
E	7 银	9,207	仍在运转 (1978.8.29→现在) 16
F	8 银	1,200	银电极与钨棒的连线为镍丝 17 (1977.5.26→1977.9.21)
G	9 镍	43	因CO与Ni起化学反应的结果 18

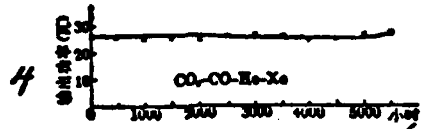
Table 2

Key: 1. Serial number
2. Electrode material
3. Nickel
4. Silver
5. Silver
6. Silver
7. Silver
8. Silver
9. Nickel
10. Operating life (hours)
11. Remarks
12. Life terminated (1978.3.18 to 5.31)

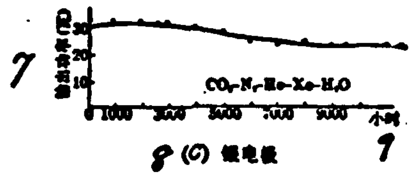
13. Blew up because water breaking controller was
 not working (1977.12.9 to 1978.8.8)
14. Life terminated (1978.3.22 to 1978.6.23)
15. Still in operation (1978.8.31 to present)
16. Still in operation (1978.8.29 to present)
17. Connector wire of silver electrode and tungsten
 rod is nickel wire (1977.5.26 to 1977.9.21)
18. Result of chemical reaction caused by CO and Ni



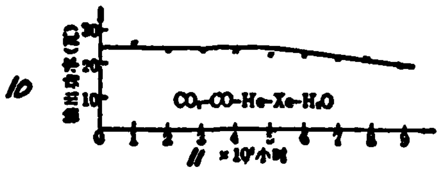
2 (A) 镍电极



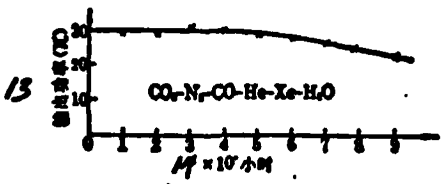
5 (B) 镍电极



8 (C) 镍电极



12 (D) 镍电极



15 (E) 镍电极

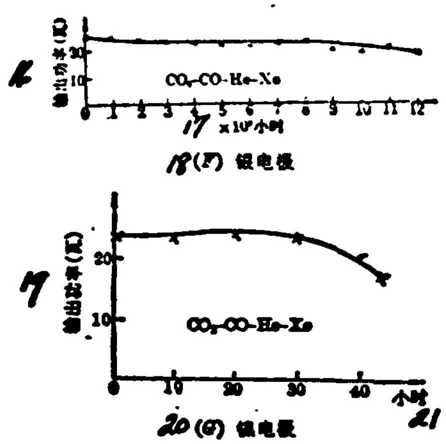


Fig. 2 Output Power Changes With Time

Key: 1. Output power (watts)
2. (A) Nickel electrode
3. Hours
4. Output power (watts)
5. (B) Silver electrode
6. Hours
7. Output power (watts)
8. (C) Silver electrode
9. Hours
10. Output power (watts)
11. x 10^3 hours
12. (D) Silver electrode
13. Output power (watts)
14. x 10^3 hours
15. (E) Silver electrode
16. Output power (watts)
17. x 10^2 hours
18. (F) Silver electrode
19. Output power (watts)
20. (G) Nickel electrode
21. Hours

III. Discussion

It can be seen from fig. 2 which shows ouput power changes with the time that the operating life varies with different electrode materials and different gas compositions. Based on test results, we think that there are three main factors which must be considered to obtain a sealed CO_2 laser with long-life.

1. Elimination of Slow Gas Leakage

Manufacturing technology for sealed CO_2 lasers must be strict. This includes the conditions that the manufacture of glass semi-finished products cannot have weak links and tungsten sintering. To guarantee all technological aspects when gluing the wafer we can eliminate slow gas leakage.

2. Selection and Oxidation of Electrode Material

As regards the cold cathode of the CO_2 laser, we select a material with very low sputtering rate for the cathode. This type of material does not separate the gas because of the sputtering and avoids undergoing a chemical reaction and consuming any gas compounds. This is very important.

Nickel is a widely used electrode material in sealed CO_2 lasers. Although its sputtering is less than other metals yet when it reactes with the CO_2 and is decomposed into CO the formed carbonyl nickel ($Ni(CO)_5$) can spoil the electrode. Moreover, because of the decomposed O which continually consumes CO_2 molecules the CO cannot again form CO_2. Therefore, when a nickel electrode is used this makes it more difficult for the sealed CO_2 laser to obtain long-life.

When we change to use pure silver as the electrode material, because the silver and CO do not cause a reaction and the compound of O and silver is very reactive, when in 200-300°C, the oxide of silver can be reduced to form pure silver. Therefore, the use of a silver electrode can cause the sealed CO_2 laser to reach long-life. Because the sputtering of silver is relatively strong it can be suitable for lengthening the distance from the window to the electrode. In this way, we can decrease or eliminate the sputtering substances on the window plate.

Furthermore, the oxidation of the electrode is very important. If the nickel electrode does not undergo oxidation, its operating life will only be 500-600 hrs but if it undergoes oxidation its operating life will be 1644 hrs.

oxygen gas so that a uniform oxidation layer will first form on the surface of the electrode. The aim is that during the discharge process as little oxygen as possible will be consumed and at the same time this can cause the decomposed product to again synthesize CO_2. Besides this, after oxidizing the electrode there is little escaped energy of the electrons and there is also a decrease in sputtering. Because there is less absorbed gas caused by sputtering, operation life increases.

3. Decreasing the Decomposition of CO_2 Molecules

During the discharge process, a portion of the CO_2 molecules decompose:

uddenly go out. Therefore, when
CO is used to replace N_2 and the
Xe-H_2O.
er replacing N_2 with CO, its
the current voltage of adding a
ectron temperature is also
se of the decomposition of the
o extending long-life. After CO
erating life exceeds 5,514 hours
already reached 9,185 hours and
The output power which changes
and (D) of fig. 2.
ng-life and not cause output power
ver electrode. There is CO in the
that is, CO_2-N_2-CO-He-Xe-H_2O. The
1. Operating life has reached
perating normally.
ng pure silver electrodes with a
N_2-He-Xe-H_2O we can also obtain
to 10,476 hours. The output power
s shown in (B) of fig. 2. The
$_2$ laser with added N_2 is 30 watts
6 hours the output power is still

21 watts. By using CO to re
operating life close to 10,0
after using N_2 the operating
10,000 hours. This explains
oxide of the nitrogen is sti
using silver electrodes.

When manufacturing CO_2
H_2O is added. The effect of
catalytic effect in the disc
noticeable effects on output
is advantageous to the rever
the CO_2 laser's energy level
quickens the composite of th
the quantity of CO_2 decompos
long-life of the sealed CO_2

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