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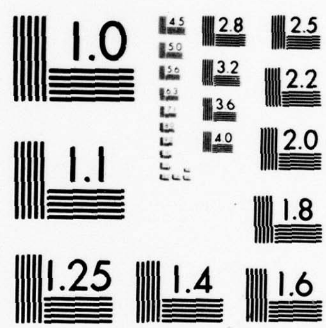

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

DELNV-TR-76-0830-F

TEN POINT SIX MICRON LASER TARGET DESIGNATOR

R. I. Rudko
RAYTHEON COMPANY
Advanced Development Laboratory
Equipment Division
Wayland, Massachusetts

November 1978

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A research version of a 10.6 micron laser designator was constructed. The device weighs 26 lbs without power supply. Output energy of 100 mJ in 30 nsec pulses at 2 - 20 pulses per second with a 1.5 percent overall efficiency were achieved.

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TEN-POINT-SIX MICRON LASER TARGET DESIGNATOR

I. INTRODUCTION

The virtue of laser systems to provide narrow beamwidth and large energy densities has been utilized by the military to provide target designation and range-finding capabilities to weapon delivery systems. Laser wavelengths from the visible through the near-IR have been or are under development at the present time. This report describes the design, development, and preliminary testing of a research version of a 10.6 micron laser designator performed under Contract No. DAAB07-76-C-0830 with the U. S. Army Electronics Command. This device will allow testing to determine the capability of designation at this wavelength for a variety of targets in a variety of atmospheric conditions, including rain, fog, smoke, and haze. Additionally, the potential of combining this development with a passive IR system might allow an IR target acquisition, rangefinding, designation system that could have high utility and adverse weather capabilities.

A. Program Goals

The characteristics of this designator were chosen to be similar to those of designators developed for operation at other wavelengths so that performance could easily be compared. The design goals for the 10.6 μm designator are given in Table 1.

The object of this program was not necessarily to meet all of these goals, but to come as close as possible and to show where they could not be met. In addition, the laser which was constructed was to be delivered to ECOM for field testing.

B. Summary of Program Results

Under this program, a research version of a 10.6 μm laser designator was constructed. In order to do this, several research

TABLE 1

10.6 MICRON DESIGNATOR DESIGN GOALS

Output energy	200 mJoules per pulse
Pulsewidth	100 nsec or less
Repetition rate	20 pulses per second
Beam divergence	0.5 mradian
Operating time	15 - 20 min. on battery charge
Efficiency	1.5 percent overall
Weight	15 lbs.

were performed to provide the basis for the system design and to determine the optimum configuration. These tasks included optical resonator studies, capacitor studies, beam divergence studies, spark gap studies, electrode studies, power supply studies, and gas mix studies.

The designator which was constructed is shown in Figure 1. The device is 18 inches long by 7.5 inches high by 7.5 inches wide. Total weight without primary 28V DC power supply is 26 lbs. The unit was built with an internal high-voltage supply. However, due to reliability problems experienced with the power supply during the program, an external high-voltage supply was purchased and delivered with the designator as backup for testing. However, we believe we have now increased the reliability of the internal supply enough so that the external supply is not really needed.

The characteristics of the 10.6 micron laser designator as delivered are given in Table 2. By comparing this performance with the design goals in Table 1, we see that the research effort produced reasonably good results. Two problems, however, still remain. First, that a reasonable amount of engineering is going to have to be done to meet the 15 lb. weight goal. The second problem is the lifetime problem.

In the design of this designator, no special effort was made to design in features which would provide long sealed-off lifetimes. However, the laser was fabricated of clean Pyrex and is leak-tight and made to operate in either a flowing gas mode or sealed off. At low repetition rates (2 - 5 pps), the laser operates sealed-off for reasonably long times (10^4 pulses). However, at higher repetition rates the lifetime drops off considerably.

Since designing and building this laser designator, we have made considerable progress on our Raytheon internal research program

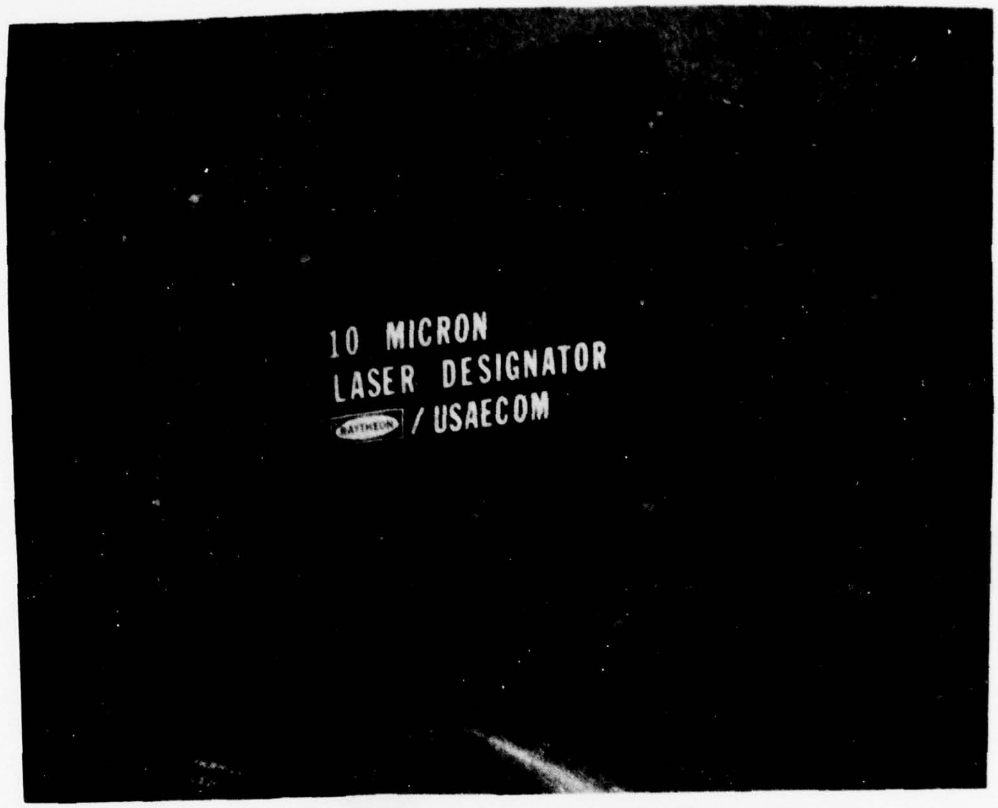

Figure 1 10.6μm Laser Designator

TABLE 2

10.6 MICRON DESIGNATOR OPERATING CHARACTERISTICS

Output energy	100 - 125 mJoules per pulse
Pulsewidth	80 nsec FWHM
Repetition rate	2 - 20 pps
Beam divergence	0.8 mradian
Efficiency	1.5 percent overall
Weight	26 lbs.

to obtaining long-life, sealed operation of CO_2 TEA lasers. We have proposed that the Army support a study of this problem.

C. Report Format

Section 2 of this report describes the research tasks performed to determine the optimum design parameters for the designator and also discusses the construction of the designator. Section 3 explains how to operate the designator and gives some of its operating characteristics.

II. DESIGNATOR DESIGN AND CONSTRUCTION

A. Introduction

This section discusses various technical aspects of the laser designator transmitter. The design of the designator is summarized, along with the experiments and studies which are the basis of the design.

The first step in the design of the 10.6 μm laser designator was to determine the optimum type of CO_2 laser for this application. Since small size and high pulse energies are both required, a high-pressure pulsed system must be used. After examining the options, we determined that a conventional double-discharge TEA laser appears to be the best device available. This type of laser is relatively efficient, simple to design, and the scaling criteria are well known. In addition, it can provide the required energy in a small, lightweight package. The rest of the designator system can be designed around the CO_2 TEA laser.

B. TEA Laser Considerations

Having decided on the TEA laser as the basis of the designator transmitter, the next step was to investigate the details of the transmitter design. Before describing this study, we will briefly trace the evolution of the present TEA laser to better explain its operating characteristics.

1. TEA laser development

The pulsed atmospheric-pressure laser is a significant outgrowth of the extensive research on CO_2 lasers. The multimegawatt output pulses generated by these relatively simple devices provide a clear improvement over the performance of earlier low pressure gas lasers.

High pressure pulsed CO_2 lasers are now capable of peak powers comparable with those of solid state lasers; furthermore, they operate with greater electrical efficiency.

The first high pressure pulsed CO_2 laser was demonstrated by Hill[1] in 1968. Since this system was axially pulsed, it required ultrahigh voltage. In addition, this excitation technique was not conducive to simple scaling in size, operating pressure, or gas mixtures.[2,3] Transverse excitation had also been demonstrated for the CO_2 laser[4,5] but these devices operated at low pressure. These two techniques were first combined in the powerful transversely excited atmospheric-pressure (TEA) CO_2 gas laser reported late in 1969 and early in 1970 by French[6] and Canadian[7] scientists. These two groups independently devised techniques which allowed reasonably large volume glow discharges to be maintained in high-pressure CO_2-N_2-He mixtures.

Most of the early TEA lasers used an excitation technique developed by Beaulieu, involving the use of very short high voltage pulses applied to a transverse discharge electrode structure.[7] This structure consisted of a long tubular anode, spaced a few centimeters from an array of 1000 carbon resistors. One end of each resistor acted as a separate cathode, while the remaining leads of all the resistors were joined together for a common negative connection. When this structure was highly overvoltaged with a short electrical pulse, a shower or brush discharge was formed from each resistor cathode resulting in an excited volume which was an array of overlapping discharges. This simple method prevents atmospheric-pressure glow discharges from becoming narrow, localized, arc discharges by having the discharge pulse short compared to the arc formation time. In addition the array of cathode resistors limits the discharge current and spreads it uniformly over the discharge area.

Soon after Beaulieu's technique was presented, a number of other techniques were developed to obtain multiple transverse discharges distributed along the length of the laser cavity; several of these techniques improved the spatial uniformity and efficiency. Eliminating the resistors gave improved efficiency by reducing I^2R losses; electrode arrays were also used to enlarge the discharge volume and improve its uniformity.

Parallel to the advancements of discrete-electrode transverse discharges, several investigators, including Dumanchen et al.,[8] La Flamme,[9] and Lambertson and Pearson,[10] introduced the idea of preionization and the use of specially shaped electrodes in order to enlarge the area of the atmospheric pressure uniform discharge. Preionization refers to the presence of charged particles in the gas volume prior to the initiation of the discharge. These charges aid in the production of a large volume glow discharge of high spatial uniformity. A high-pressure pulsed molecular laser based on a discharge scheme involving preionization of the discharge volume with the aid of an auxiliary discharge from a separate electrode is designated a "double-discharge" TEA laser. The main discharge electrodes are usually solid or a mesh which are shaped to an approximate Rogowski[11,12] profile to avoid field concentration. Several different electrode configurations can be used to produce the preionization.

The development of the TEA CO_2 laser not only produced a laser which operated better than previous gas lasers but also led to an advancement in the understanding of gas lasers, laser excitation techniques, and even discharge physics.

2. Laser scaling

The output pulse energy from a given laser volume depends upon the number of excited molecules present and therefore on the gas pressure. It has been observed from work on TEA lasers that operation up to tens of atmospheres does not alter the fundamental excitation processes. If the ratio of E/p (electric field to pressure) is held constant, the fraction of energy delivered to the various vibrational modes is constant and the output energy per unit volume increases linearly with pressure.

We can write two simple equations which describe the TEA laser operation. The first is

$$\frac{E_{out}}{w \times h \times \ell} = K_1 p \quad , \qquad (1)$$

where E_{out} is the energy output per pulse, w, h and ℓ are the width, height and length of the discharge volume, p is the gas pressure and K_1 a constant. This equation simply states that the energy output per unit volume is proportional to pressure. The second equation is

$$\frac{V/h}{p} = K_2 \quad , \qquad (2)$$

where V is the discharge voltage, h is the electrode spacing, p is the gas pressure and K_2 is a constant. This equation states that E/p is to be kept constant. From our past experimental work we can determine the two constants K_1 and K_2. In the short-pulse mode of operation (≈50 nsec) we have measured TEA laser output of 2 - 5 joules/liter atm. For design purposes we will use 4 joules/liter atm. We have also found that the discharge voltage stabilizes at values of E/p of about 20 kV/cm atm. Using these numbers we can rewrite Eq. (1) and (2) as

$$E_{out} = 2 \times 10^{-3} \; w \times h \times \ell \times p \text{ (joules)} \qquad (3)$$

and

$$V = 20 \times p \times h \text{ (kV)} \qquad (4)$$

where w, h, and are in centimeters and p is in atmospheres.

As an example of how these two equations are used, we will look at the particular case of the laser designator. In this laser, optical considerations dictate that the discharge width should be twice the electrode spacing, or w = 2h. For an output energy of 0.2 joules, the two equations become

$$\ell = \frac{25}{h^2 p} \tag{5}$$

and $$V = 20\ ph \quad . \tag{6}$$

These two equations are plotted in Fig. 2 for several different gas pressures. From these curves it is easy to pick a point which is suitable for operation based on any external restraints. For example, it is advantageous to operate at atmospheric pressure to avoid having to construct the equipment to handle pressure differences. In addition, keeping the discharge voltage as low as possible reduces the insulation necessary in the power supply. Of course, in almost all applications it is also good to keep the laser as small as possible. Looking at Fig. 2 we find that operating at atmospheric pressure with an electrode spacing of 1 cm, the discharge length should be 25 cm. These are the dimensions we used in the designator, as summarized in Table 3:

TABLE 3

DESIGNATOR DISCHARGE DIMENSIONS

Discharge height:	1 cm
Discharge width:	2 cm
Discharge length:	25 cm

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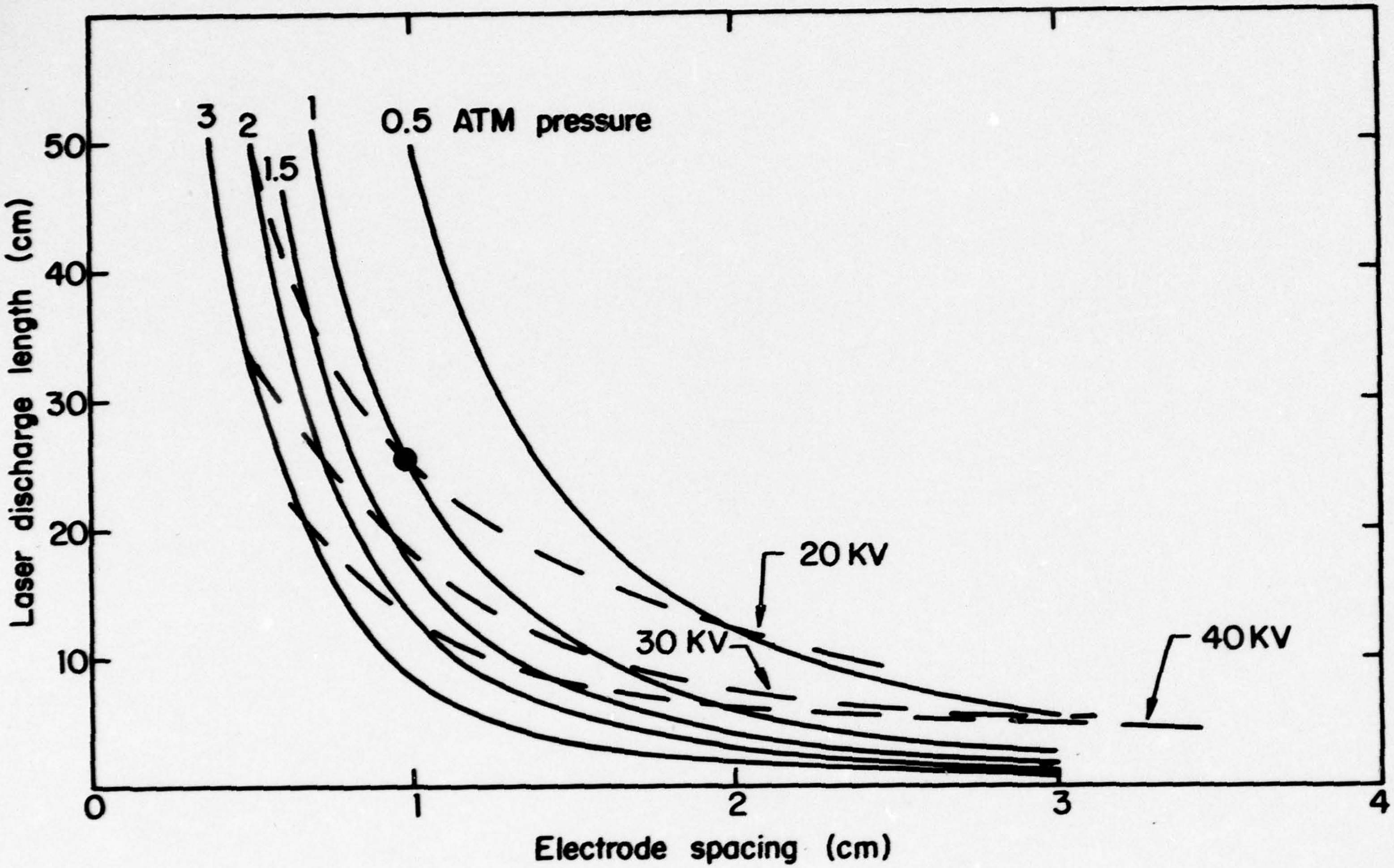

Figure 2 TEA Laser Design Curves

3. Output pulsewidth

In order to be effective as a laser designator, the duration of the pulses obtained from the CO_2 TEA laser must be less than 100 nsec. Under normal operation, a CO_2 TEA laser produces an output pulse which has an initial gain switched spike followed by a tail which lasts up to a few microseconds and can contain a large percentage of the laser energy. In a designator we would like all the energy in the initial spike with little or no energy in the tail.

The tail which normally occurs on a CO_2 laser pulse arises from nitrogen transferring energy to the upper laser level for a time which depends on the operating pressure. At atmospheric pressure the time is of the order of one microsecond.

To eliminate the tail and obtain the desired pulse shape we varied the percentage of nitrogen in the gas mixture and the output coupling until a suitable pulse was obtained. Figure 3 shows a photograph of the output pulse. Note that the full width at half maximum power is about 80 nsec and there is almost no tail.

4. Pulse-to-pulse repeatability

While it is not especially important to have extremely good pulse-to-pulse repeatability in the actual operation of the laser designator, it is important to have good pulse-to-pulse repeatability for many of the experiments which will be performed with this device such as reflectance measurements. For this reason every effort was made to construct a device with good pulse-to-pulse repeatability.

Figure 4 shows examples of output repeatability for various repetition rates. For these measurements a "Gen-TEC" energy meter was used so the height of the pulse is proportional to the laser output energy. As the data show, the pulse-to-pulse energy variation for 1.5, 5, and 10 pulses per second is less than about ten percent.

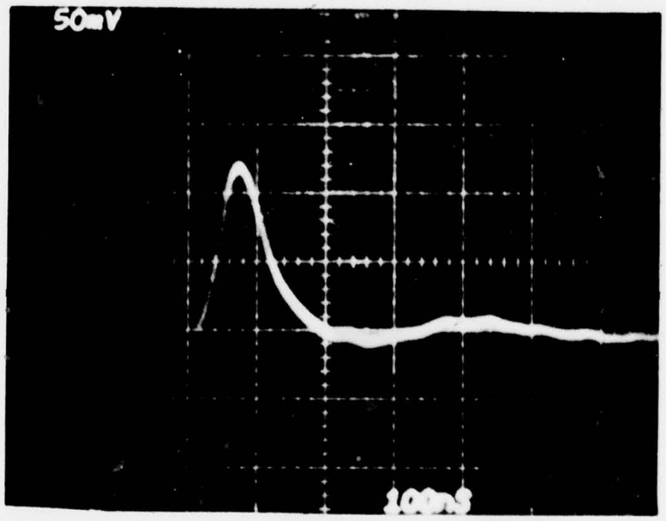

Figure 3 Designator Output Pulse

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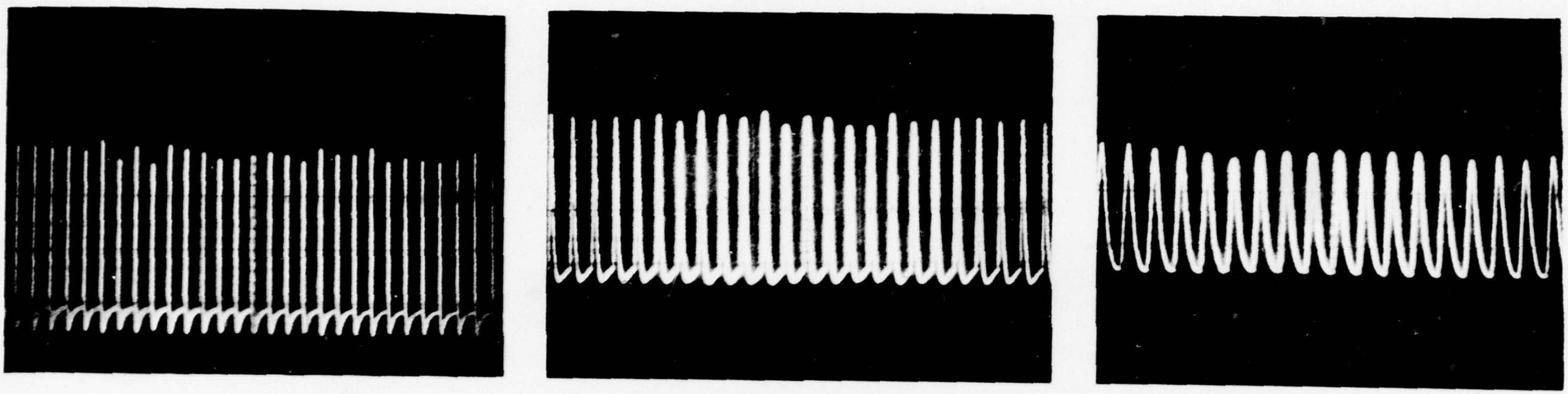

2 sec/cm
1.5 PPS

0.5 sec/cm
5 PPS

0.2 sec/cm
10 PPS

Figure 4 Pulse-to-Pulse Repeatability

C. Optics

The optical designs used in the 10.6 μm designator are important to its operation for several reasons. First of all, the laser resonator optics must produce a beam which is near diffraction-limited; in addition, the beam must have "high brightness" in order to put as much energy as possible into a small spot. Secondly, the beam-expanding optics must be able to produce the required divergence without affecting the beam quality and without adding much size and weight to the system. Finally, a sighting scope must be mounted to the designator and bore sighted to the laser beam so that the beam can be put onto the desired target.

This section discusses these various aspects of the designator optics design and presents our solutions to the problems and the rationale behind them.

1. Resonator optics

The high Fresnel number CO_2 TEA laser used in the 10.6 μm laser designator does not usually lend itself to simple single-mode resonator design. In most cases a high Fresnel number usually leads to the choice of a conventional "unstable" resonator. However, in the case of the designator laser, the relatively low gain would require low output coupling and the conventional "unstable" resonator would therefore produce a thin, annular-shaped beam. This type of beam is not really high brightness (an appreciable fraction of the energy is not in the center lobe in the far field.)

Since the conventional unstable resonator is not suitable for the designator, we investigated and tested several other types of unstable resonators. One type of resonator tested was the hybrid unstable resonator. This configuration is similar to the conventional unstable resonator except that the center of the output coupler, instead of being 100 percent reflective, is partially transmissive.

This means that the output beam is an annulus with the center partially filled in. The more energy which appears in the center portion of the beam, the higher its brightness.

The problem with this type of resonator is that it is sensitive to alignment. Tilting one of the mirrors moves the beam off the center of the output coupler and produces an asymmetric beam. Also, the portion of the beam which goes through the central, partially transmitting portion of the mirror may be phase shifted from the annular portion which goes around the outside of the mirror. This would produce unusual far-field patterns.

The laser resonator we eventually decided to use for the designator was the two-pass stable resonator. Figure 5 shows a cross-section of the far-field beam shape obtained with this resonator. This picture was made by focusing the beam and shining a pinhole and detector across the focused spot. As the picture shows, the beam is Gaussian in shape, which is confirmed by measuring the beam size at the output aperture and the beam divergence.

2. Beam-expanding optics

The raw divergence of the beam exiting the designator laser is 2.4 mrad. To reduce this to a more usable value, a beam-expanding telescope is used.

The measured beam divergence from the designator using the beam expander is 0.8 mradians.

3. Sighting optics

In order to easily point the designator beam to a given target, a sighting scope is mounted to the designator and bore sighted to the laser beam. The sighting scope consists of a standard 6X rifle

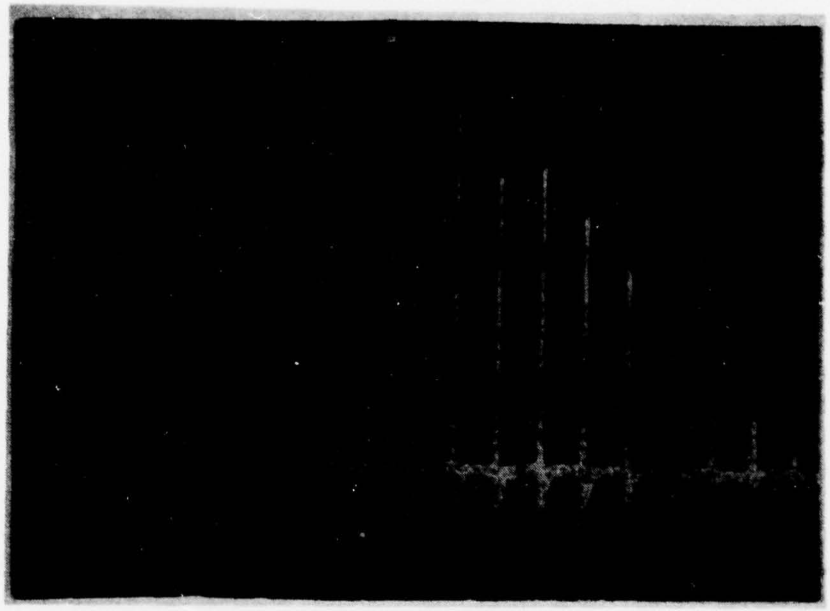

Figure 5 Far Field Beam Pattern

scope as supplied by the Army.

D. Gas Handling

The active medium in the CO_2 laser designator is an atmospheric pressure mixture of carbon dioxide, nitrogen, and helium. When a high-current pulsed discharge is formed in this gas, its temperature rises due to the energy dumped into it; in addition, some of the components of the mixture can be dissociated. If the same gas were allowed to remain in the discharge volume for any length of time, its temperature could rise enough to reduce the laser gain below threshold, or a gas such as oxygen could be formed which would cause the discharge to go into an arcing mode and prevent the laser from operating. For this reason, CO_2 TEA lasers are usually operated under flowing-gas conditions where a fresh mixture of gas moves into the discharge region after a pulse occurs. The gas which is removed can either be discarded or processed for reuse.

Completely discarding the gas after use is very wasteful and requires carrying a large supply of fresh gas, which is impossible for field-portable applications. The best design would be one where the laser is completely sealed off and requires no external gas supply. For the higher repetition rates, this type of system would have to have a gas recirculator.

The CO_2 laser designator is designed to be able to operate sealed-off and has a built-in gas recirculator. In addition, the system can be operated as a flowing-gas laser but with the recirculator also operating, which reduces the amount of fresh gas required. At low repetition rates, up to 3 pps, the laser will operate sealed for about 10^5 pulses. Operating sealed-off at higher repetition rates, the total number of pulses drops considerably, and it is better to operate the designator with some fresh gas bleeding into the system. Typical bleed rates are 2 - 3 liters per minute.

Most recirculating gas TEA lasers use transverse-flow gas systems. That is, the gas flow is orthogonal to both the optical axis and the electric field. This is reasonable for high-power, high-repetition-rate lasers where large gas flow volumes are required. However, small, relatively low-power low-repetition-rate TEA lasers such as the designator transmitter, where the gas flow rate is relatively low, can use a system where the gas flow is along the optical axis (longitudinal flow). This type of system takes up much less space and is lighter in weight.

The recirculation path in the laser designator uses 2 in. square pyrex tubing. The gas is removed from one end of the laser, goes around the recirculation path and is forced back into the laser at the other end. The fan used to force the gas through the square tubing is a "Rotron" Aximax 1 with a 623YS motor operating at 400 Hz.

The volume of the laser discharge is 2 cm x 1 cm x 25 cm or 50 cu cm (1.77×10^{-3} cu ft). To remove one complete gas volume from the discharge at 20 pps would require a gas flow of 2.1 cubic feet per minute. The Aximax 1 fan chosen for the gas flow will provide about 10 cfm, which is more than enough.

The gas is cooled by another Rotron Aximax 1 fan which forces cooling air over the outside of the recirculation path and the discharge volume itself. This appears to be suitable for maintaining the operating temperature, even at 20 pps.

E. Laser Electronics

A major portion of the CO_2 laser designator is made up of electronics. Because of this, we have tried to optimize the efficiency and minimize the size of each of the required circuits and components to keep the entire system as small and lightweight as possible.

Figure 6 is a block diagram of the 10.6 μm laser transmitter showing the various electrical parts. The primary power is shown on a battery; however, in most of our tests a 28 v DC power supply was used. The primary power source supplies power directly to the timing and trigger generation circuitry and to the high voltage power supply. In addition, it supplies power to a 400 Hz inverter which runs the gas recirculator and the cooling fans. The energy storage capacitors are charged by the high voltage power supply and discharged with the spark gap.

The following section discusses the various circuits and components used in the CO_2 laser designator and the reasons for their use.

1. <u>TEA laser pulsing</u>

There are several available techniques for pulsing a TEA laser discharge. Basically, a TEA laser is pulsed in the following way: A capacitor or series of capacitors is charged up to the required laser operating voltage or higher. Then, a high-voltage high-current switch such as a spark gap or thyratron is used to apply the capacitor voltage across the laser electrodes and discharges the energy stored in the capacitors into the laser discharge.

Several variations of this simple technique are possible and are usually used for voltage boosting. The pulsing technique used in the designator laser is one of these voltage boosting techniques.

In this circuit the capacitors are charged up in parallel with the negative side of each capacitor at its respective electrode. When the spark gap fires, the energy storage capacitor C_1 discharges rapidly through it.

This type of circuit has many advantages. First of all, it is easy to construct a compact unit using this circuit and the storage

CO_2 LASER DESIGNATOR

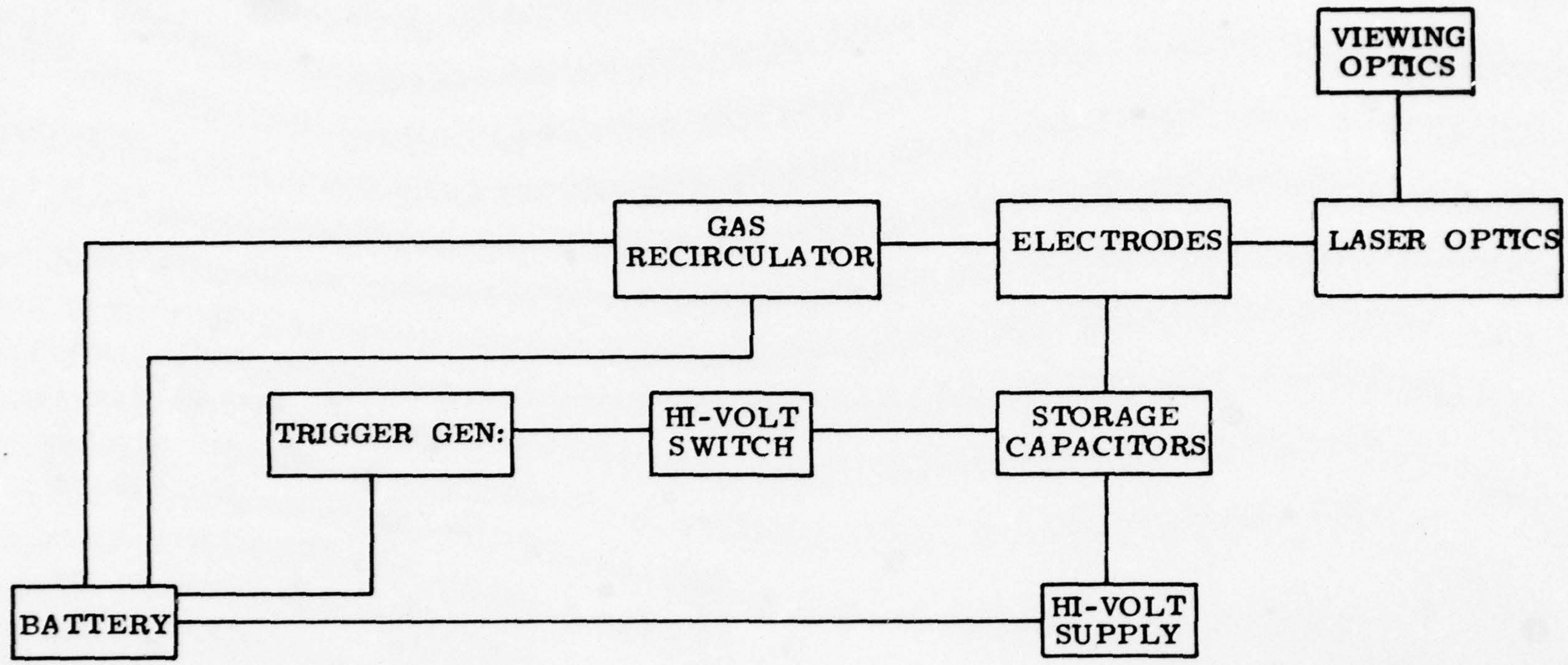

Figure 6 Designator Block Diagram

capacitors can be mounted directly to the back of the electrodes. In addition, since it can be made compact, the circuit inductance is low, and very fast electrical pulses occur. This relaxes the shape requirement on the electrodes and, in addition, provides high gain and therefore short laser output pulses. Also, it does provide voltage multiplying and therefore allows the power supply to operate at a lower voltage. Because of these properties, we decided to use this circuit for the 10.6 μm laser designator.

2. Discharge capacitor

The capacitors used in this type of application must be low inductance to provide short pulses and must be able to handle the 20 pps repetition rate and the voltage reversal which occurs in the L-C inversion generator. In addition, they must be constructed from a high dielectric constant material to be as small and lightweight as possible.

To obtain 0.2 joules per pulse from the designator transmitter in pulses of less than 100 nsec duration, we have found it necessary to put about 6.5 joules into the discharge. Since some energy is lost between the capacitor and the discharge, we have to store about 8 joules in the capacitor. To do this, we use two 0.02 μf capacitors charged up to 20 kV.

The capacitors we used in the laser designator are 0.02 μf, 25 kV fabricated mica capacitors of the extended foil design.

3. High voltage power supply

The high voltage power supply must be able to produce in excess of 20 kV and be able to supply about 180 watts to charge the capacitors at full repetition rate. In addition, the supply must be as small and lightweight as possible. The technique we have chosen to do this is the rf high voltage technique.

The transformer is capable of producing slightly more than 10 kV from a 28 V DC source. A voltage-doubler circuit is used to obtain the required voltage. Since the transformer has an air core and is loosely coupled, the power supply has a built-in high impedance, which is ideal for charging the discharge capacitors.

A regulator circuit must be used with the power supply, since the supply sees an open circuit when the capacitors are fully charged and the output voltage can get excessively high.

To prevent this, a portion of the capacitor voltage is monitored and compared to a reference voltage. When the voltage on the capacitors is at the required value, the feedback circuit in the power supply is shorted, thereby turning it off. When the capacitor voltage drops below the required value, the power supply turns back on and recharges the capacitors.

4. High voltage switch

A high-voltage switch is required to dump the energy stored in the capacitors into the laser discharge. For the designator application, the best choice for this switch is a triggered spark gap.

These devices are small, lightweight, rugged, and can handle the required voltage and current. After consulting with various manufacturers, we have chosen the EG and G GP-70 spark gap for use in the laser designator. This device performs well except that its operating life is limited to about 10^6 shots.

5. Triggering circuitry

A 10 kV open circuit pulse is required to trigger the spark gap to discharge the energy stored in the capacitor. This pulse must be delivered at the 20 pps repetition rate.

To do this, we use a unijunction oscillator as the clock, with its repetition rate adjustable with a variable resistor. The unijunction oscillator triggers a silicon-controlled rectifier which then discharges the 1.0 μf capacitor through the primary of the TR-180B trigger transformer. The output from the transformer consists of the required 10 kV trigger pulses. The 1.0 μf capacitor is charged up by using the voltage produced by the fan power supply and rectifying it.

6. Fan supply

The recirculation fan and the cooling fan require 110 V AC at 400 Hz and draw 0.16 ampere each. To provide this voltage, a 28 v DC to 110 V, 400 Hz transistor inverter is used.

This inverter is also used to provide the DC voltage necessary to charge the spark gap trigger capacitor.

III. DESIGNATOR OPERATION

This section describes the procedures for operating the 10.6 μm laser designator, as well as the technique for aligning the optical resonator. There are several configurations in which the laser can be operated, such as using its internal high voltage power supply or an external high voltage supply, or using its internal trigger clock or an external trigger source. Operation using the internal power supply and trigger will be described first and the differences in operation using the external power supply and trigger will be discussed afterwards.

A section on trouble-shooting is included at the end of this discussion.

A. Operating Procedures Using Internal Power Supply & Trigger

Figure 7 is a photograph of the rear panel of the designator, showing the operating controls and connectors. The only external connections required for operation of the designator are to the 28 V dc primary power and to the laser gas tanks. Before making any connections, all switches should be in the "off" position and the trigger switch set for internal trigger.

Connect the 28 V dc primary source to the connector marked "28 volts" located near the center of the rear panel. An Acopian Model A 28 HT 1400 power supply capable of providing 14 amperes at 28 volts dc was supplied to the Army for use as the primary power source; 28 volt batteries may be used for field applications.

The tube from the laser gas tanks and flowmeters is connected to the fitting marked "gas in". For flowing-gas operation, the toggle valve just below the gas input connector must be opened.

For normal operation, the gas flow rates are: 2 ℓ/min. He, 0.57 ℓ/min. CO_2 and 0.4 ℓ/min. nitrogen.

After the gas and primary power are connected, turn the repetition rate control fully counterclockwise and turn the fan switch to "on." This switch controls both the gas recirculating fan and the cooling fan. When the fans have come up to speed, turn the trigger switch to the "on" position. This supplies power to the internal trigger generator. The repetition rate is adjustable from 2 to 18 pps and is controlled by the knob marked "rep rate" and located at the lower middle section of the rear panel. When the "int trig/ext trig" switch is in the "int trig" position, the repetition rate of the designator is controlled by the internal generator and a sync pulse is available at the "sync in/out" connector.

Switching the "HV on/off" switch located at the upper left corner of the rear panel to the "on" position activates the internal high voltage supply and starts the designator.

To turn the designator off, the above procedure is reversed; first the high voltage is turned off, then the trigger, and then the fans.

B. Operation With External High Voltage Power Supply

When using the external high voltage power supply, the high voltage cable is connected to the designator using the high voltage connector located at the lower left of the rear panel between the gas value and the repetition rate control. It is also important to connect a good ground between the high voltage supply and the designator.

The power supply provided to the Army for use as the external high voltage supply is a Universal Voltronics BAP 22-10, which is capable of providing 10 MA at 22 kV. It has been modified in two ways. First, a 100 kohm ballast resistor has been inserted in series with the output to limit the peak charging current to the designator. In addition, a capacitor has been attached across the coil of the current overload relay to slow its response to the peak capacitor charging currents and to prevent the overload from tripping on these short high-current pulses.

Operation with the external supply is not very different from operation with the internal supply. Instead of turning on the internal supply, the "HV on/off" switch is left in the "off" position and the external supply is turned on and set at 22 kV.

C. Operation With External Trigger

The 10.6 μm laser designator can operate either with its internal trigger circuit, which is variable from about 2 to 18 pps, or it can be triggered externally. The external trigger must be capable of providing a 20 volt positive pulse into 50 ohms.

To operate with the external trigger the "int trig/ext trig" switch is set at "ext trig" and the "trig on/off" switch is kept in the "off" position. The external trigger signal is then connected to the BNC connector marked "sync in/out".

D. Cavity Alignment Procedure

If the laser cavity becomes misaligned for one reason or another, it is a simple procedure to realign it. The laser cavity consists of four mirrors. The two flat turnaround mirrors are fixed and do not require any adjustment. The 5 meter radius of curvature 100 percent reflector and the flat output coupler are turned by adjusting the four nuts against each of the glass mounting plates. The four adjustment nuts for the curved mirror are accessed by removing the four rubber stoppers in the glass plate which holds the output coupler.

Either a HeNe laser or an autocollimator can be used to align the laser. First the HeNe laser or the autocollimator is aligned with the apertures in the laser, then the curved mirror is aligned. After that, the output coupler can be aligned by observing the reflection off the front surface of the ZnSe mirror. The laser can then be fine tuned by observing the output with the laser operating. If tuning is performed with the laser operating, it is important to use the specially insulated tool provided.

If the laser becomes misaligned in the field and a HeNe laser or autocollimator is not available, it is possible to align the laser by looking down the laser cavity and superimposing the reflections of your eye from the curved rear mirror and the output coupler. Important note: <u>Do not align the laser with your eye while it is operating</u>.

E. <u>Trouble-Shooting</u>

If for some reason the laser designator fails to operate, it may be something relatively easy to repair. If nothing happens when any of the switches are turned on, make sure there is 28 volts at the input and that both fuses are OK. Before working on any of the electronics inside the laser designator, make sure to discharge the high voltage capacitor.

If the fans just hum when they are turned on and do not come up to speed, check the .22 μf phasing capacitor or the IN4007 diodes in the bridge circuit.

If the laser operates on external trigger but not internal trigger, check the unijunction transistor.

If neither trigger can fire the laser, check the SCR.

If the fans and trigger circuit operate and there is no high voltage, the following items should be checked:

- The LM1488 integrated circuit.

- The diode between the HV transformer feedback coil and the 10 μf 50V capacitor.

- The high voltage diodes.

If the laser multiple fires or tends to miss pulses, the spark gap may be going bad.

The above items are the most likely to be the cause of trouble if any occurs. Electrical component failures are caused by the high voltage pulses getting back into the semiconductor devices. In order to prevent this from occurring, most of these devices are protected by varactors or diodes.

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