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NASA LIDAR SYSTEM SUPPORT AND MOPA TECHNOLOGY DEMONSTRATION

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INTRODUCTION

Since 1982 NASA Langley Research Center has contracted with CLS Laser Systems, Inc. to perform a series of lidar design and technology demonstration tasks in support of the CO_2 lidar program as NASA LARC. The first of the these tasks is discussed in Section VI of this report under the heading of "NASA Optical Lidar Design" and it consists of detailed recommendations for the layout of a CO_2 Doppler lidar incorporating then existing NASA optical components and mounts. The second phase of this work consisted of the design, development, and delivery to NASA of a novel acousto-optic laser frequency stabilization system for use with the existing NASA ring laser transmitter.

The second major task in this program encompasses the design and experimental demonstration of a master oscillator-power amplifier (MOPA) laser transmitter utilizing a commercially available Lumonics Model 820 TEA laser as the amplifier. It was recognized at the outset of this effort that the limited gain length of the Lumonics was less than optimum for use as an amplifier, but it was felt that the time and cost savings afforded by use of a commercial gain module could greatly facilitate future lidar system design. In addition the amplifier performance characteristics evolved within this program would provide a credible basis for future MOPA system design whether commercial or custom amplifier technology was employed.

MOPA System Design

1. Amplifier Design Formalism

The amplification of energy in a CO_2 amplifier is fully described only by detailed numerical analysis which takes into account the molecular kinetics and the spatial and temporal pulse characteristics. Fortunately, the two level model of Frantz and Nodvik (J. Appl. Phys. 34, 2346 (1963)) can be extended to provide a useful description of the CO_2 amplifier by incorporating a pulse-width dependent saturation energy. In the two level amplifier the saturation fluence is $E_s = h\nu/2\sigma$ where σ is the stimulated emission cross section. In the multilevel CO_2 gain medium E_s increases with pulse width as a result of repumping of the upper level and depopulation of the lower laser level. The basic amplifier equation is as follows:

$$E_{out} = E_s \, A \, \ell n \, \{1 + \exp(g_o \ell) \left[\exp(E_{in}/E_s) - 1 \right] \} \qquad (1)$$

where

E_o = energy density at amplifier output (J/cm^2)
E_s = saturation energy density (J/cm^2)
g_o = unsaturated gain
ℓ = gain length
E_i = input energy (optical) density (J/cm^2)

While not explicitly presented in the original paper of Frantz and Nodvik, equation (1) follows from a slight modification of their model to incorporate the readily measured quantities g_o and E_s. Equation (1) also is implied by the following equation for the increase in pulse energy as it propagates through an amplifier:

$$\frac{dE}{dx} = g_o E_s \left(1 - e^{-E/E_s}\right) \qquad (2)$$

(See for example Lachambre et. al. JQE 9, p. 459, 1973) Integration of (2) along the length of the amplifier yields equation (1). In the limit of long gain lengths (3) reduces to

$$E_o = g_o \ell E_s \quad (J/cm^2) \tag{3}$$

This equation provides a convenient means of estimating the maximum output energy from a gain medium and sets an upper bound for both amplifier and oscillator configurations. For an electrical pumping energy E_e the maximum efficiency with which optical energy can be extracted is

$$\text{Efficiency} \leq g_o \ell E_s A/E_e \tag{4}$$

where A is the cross sectional area of the discharge. In the low energy limit, $E \ll E_s$, (2) reduces to the expected expression for small signal gain

$$\frac{dE}{dx} = g_o E \qquad (E \ll E_s) \tag{5}$$

The "correct" values of g_o and E_s to use for designing a MOPA system are dependent on the pulse shape and on our confidence in our ability to configure a high quality gain medium. There are a number of measurements of saturation energy which place the saturation energy for a 1us pulse at ≈450 mJ/cm^2 for gas mixtures of $He:N_2:CO_2$::7:1:1 or 8:1:1. The Lachambre reference given above and measurements by Lumonics Inc. give this magnitude of E_s. There are however some oscillator measurements which strongly imply a much greater value for E_s in lasers which have been tuned for maximum output energy. Ernst and Boer (Opt. Commun. 34, p. 221, 1980) obtained a multimode output of 49 J/liter at 19% efficiency from a 5 x 5 x 40 cm^3 gain volume. If we assume a value of g_o =.05 cm^{-1}, equation (3) implies a saturation energy of 1 J/cm^2. Possible explanations for this high value of E_s could be the gas mixture, $He:N_2:CO_2$::3:1:1 which was relatively rich in CO_2 and N_2, and the high specific input energy 250 J/liter atm. Since their measurements involved only such easily measured parameters as total output energy and discharge volume it seems unlikely that they are in error by a factor of two or more. There is also little doubt that the corona preionization and the resulting discharge uniformity were essential to achieving this level of performance. In a paper on injection locking (JQE. vol. 12, p. 756, 1976) Lachambre presents performance parameters for a UV preionized TEA ring oscillator. The gas mixture $He:N_2:CO_2::70:15:15$ is pumped at 200 J/liter atm. and a small signal gain of .04 cm^{-1} is achieved. The active volume is 6mm diameter x 100 cm long and a single mode energy of 0.75J was measured, which when inserted in equation (3) yields a saturation energy of 663mJ/cm^2. Note that both of the oscillator results put a lower limit on the saturation energy since diffraction and other loss mechanisms tend to reduce the laser efficiency from the theoretical maximum. The relatively high diffraction loss of Lachambre's TEMoo laser and its lower N_2, CO_2 concentrations possibly account for the reduced lower limit for E_s compared to the results of Ernst and Boer. The uncertainty in realistically achievable value for E_s will probably only be resolved by doing long pulse amplification experiments on a high quality TEA gain medium. In the interest of proceeding with a reasonably conservative design we shall assume E_s = 500 mJ/cm^2.

The Lumonics TEA laser exhibits a gain area of at least 1.8 x 2.8 cm as demonstrated by the higher order mode cross-section specified by the manufacturer. The gain length is given as 48 cm while the physical length of each amplifier pass will be approximately 120 cm minimum. The geometry we have chosen to model utilizes 3 passes through the amplifier: the first pass involves a diverging beam which is collimated for the second and final third pass. The first pass overlaps the second pass while the second and third pass are parallel to one another. This arrangement is shown schematically in Figure 1.

AMPLIFIER OPTICAL SCHEMATIC

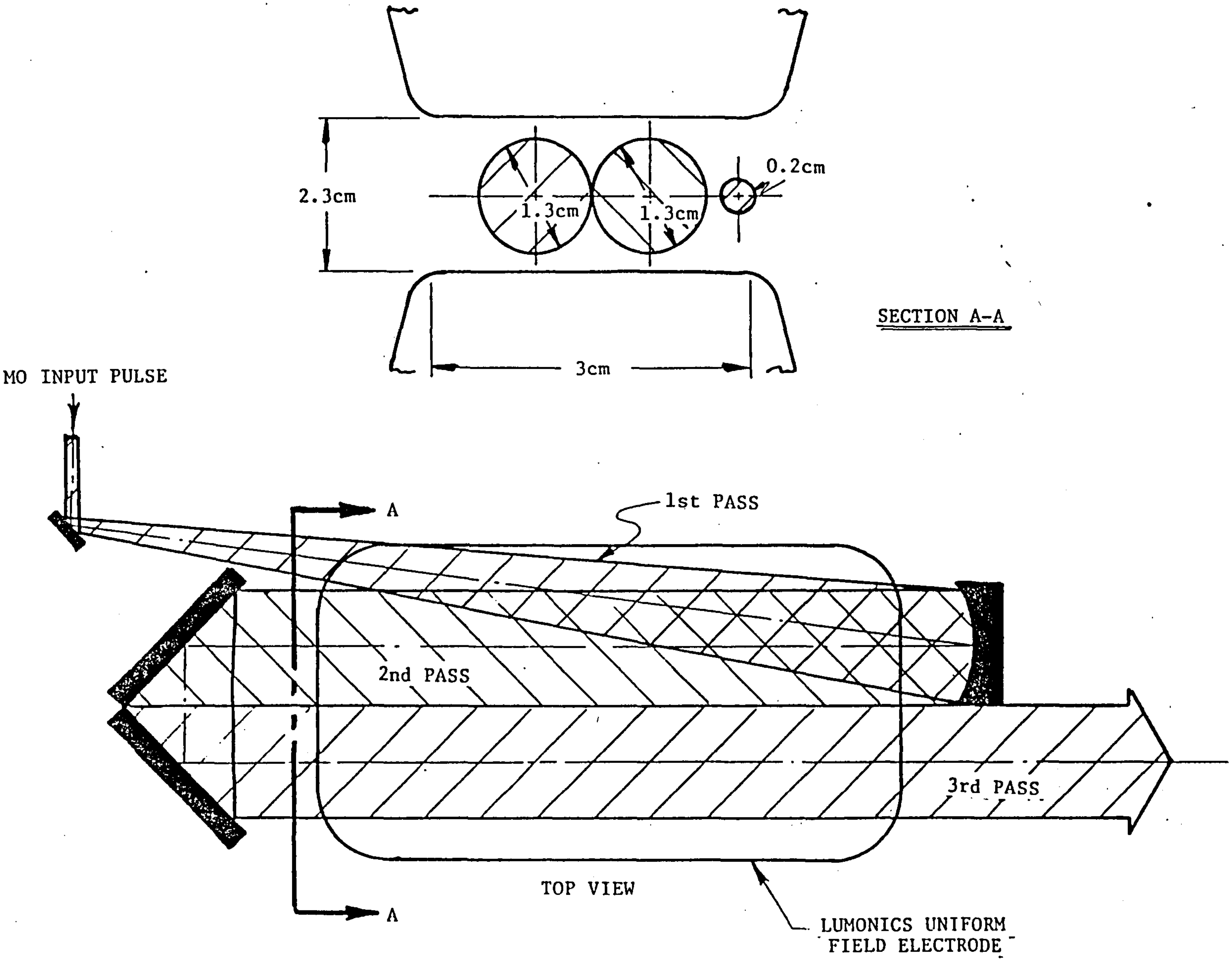


Fig. 1

The protocol we have evolved for accurately estimating the amplified energy available from a multipass amplifier when the first pass is strongly diverging and overlaps the second pass, and the second and third passes are collimated, is as follows: the amplified first pass output energy E_{01}, is calculated by using the average cross-sectional area of the beam to determine the available saturation energy. The output energy of the first pass is used to calculate the amplified energy from the sum of the second and third passes. Finally, the output energy of the amplifier is calculated by subtracting from the amplified output energy the energy extracted for the medium in the first pass.

The Master Oscillator beam enters the amplifier with a beam waist of approximately 0.8mm and diverges to approximately a 5.1mm beam waist after the first complete pass. The beam will be collimated after this pass. Because the first pass beam is diverging strongly, the saturation energy in Joules, Es x A, will vary as the input pulse propagates along the first pass of the amplifier. To allow for this, the average of the integrated area over the gain path of the first pass was calculated. This average area is 0.52 cm^2.

The pertinent amplifier parameters at atmospheric pressure are:

$E_s = 500\ mJ/cm^2$

$g_o = 0.03\ cm^{-1}$

$\ell = 48\ cm$

The first pass output energy for various input energy levels can now be calculated using equation (1). If we begin with an input energy level of E_{in} = 20 mJ, the amplified first pass energy is:

$$E_{01} = 500\ mJ/cm^2 \times 0.52cm^2 \ln \{ 1+ \exp (0.03 \times 48) [\exp (20 / (500x\ .52)) - 1] \} \qquad (6)$$

E_{01} = 76 mJ

If the input energy is increased to 30, 40, and 50 mJ respectively, the amplified first pass energies that result become 108 mJ, 138 mJ and 166 mJ.

We can calculate the resultant combined second and third pass output energies using 76, 108, 138, and 166 mJ as the input energies to the combined second and third passes. The calculation for the amplified output energy with 76 mJ as the input, for example, is as follows:

$$E_{03} = 500 \text{ mJ/cm}^2 \times 1.33 \text{ cm}^2 \ln \{ 1 + \exp(0.03 \times 48 \times 2) [\exp(.076/(500 \times 1.33)) - 1] \} \quad (7)$$

$$E_{03} = 764 \text{ mJ}$$

$$E_{03} - E_{01} = 764 - 76 = 688 \text{ mJ}.$$

For 108, 138, and 166 mJ input pulse energies to the second and third passes, the resultant net output energies calculate to be 836 mJ, 945 mJ and 1.03 Joules.

2. Master Oscillator Design

The pulsed Master Oscillator source developed by CLS Laser Systems under this program is a hybrid-TEA configuration, employing a low pressure intracavity gain cell operating above oscillation threshold to assure single longitudinal mode (SLM) operation. The pulsed gain medium employs a thyratron switched, ultraviolet preionized discharge between uniform field electrodes. A transverse gas flow is provided to permit operation to 20 Hz and beyond while a slow flow of fresh gas mix provides the partial gas replenishment required for continuous arc-free operation. The hybrid gain cell is also of the slow flow variety to allow optimization of tube pressure and current for above and below threshold operation. The optical cavity is a stable resonator design with a design Fresnel number of approximately 1.2 to ensure TEM_{oo} operation. Selection of the cavity Fresnel number allows further specification of the Master Oscillator hybrid-TEA laser as follows:

The Fresnel number is given by $N = a^2/\lambda L$ where "a" is the radius of the cavity limiting aperture, L is the separation of the end reflectors of the cavity and λ is the wavelength of oscillation. If we select N = 1.2 based on previous experience and choose a cavity length of L = 1.5 meters as a compromise between cavity filling factor (and hence lower chirp) and a stable resonator structure, we can solve for the aperture size "a" as follows:

$$N = a^2/\lambda L \quad (8)$$

$$a^2 = N\lambda L \quad (9)$$

$$a = (N\lambda L)^{\frac{1}{2}} \quad (10)$$

With N = 1.2, $\lambda = 10.6 \times 10^{-6}$μm, and L = 1.5 m, the required cavity limiting aperture and the surface of the uniform field electrodes. This translates into a discharge gap of 11 mm. The active gain length of the Master Oscillator pulsed section has been chosen to be ℓ = 20 cm (based principally on achieving 50 mJ pulsed output energy). The active discharge volume will be approximately 11 mm x 11 mm x 20 cm or 24.2 cubic centimeters. The active mode volume is less than this by quite a bit, and is given by:

$$V_{mode} = a^2\ell = 12.2 \text{ cubic centimeters} \quad (11)$$

Based on previous work[1], a specific input energy density of E = 85 Joules/liter-atmosphere at an operating pressure of 500 Torr (0.66 atmosphere) results in a quite uniform discharge with satisfactory output power when operated as an oscillator. Specifically, utilizing a measured oscillator efficiency of 7.2% (based on the ratio of measured output energy to the energy deposited within the active mode volume), the proposed Master Oscillator should yield an output energy of:

$$E_{out} = \eta \times E \times V_{mode} \times \text{Pressure} \quad (12)$$

$$E_{out} = 0.072 \times 85\text{J/liter-atms.} \times 12.2 \times 10^{-3} \text{ liter} \times 0.66 \text{ atms}$$

$$E_{out} = 0.05 \text{ Joules}$$

The total input energy per pulse can be calculated since the discharge dimensions are specified (the discharge gap is 11 mm and the discharge length is 20 cm). When pumped at 85J/liter-atmosphere at 500 Torr, this results in an input discharge energy of:

$$E_{in} = 85 \text{ J/liter-atms} \times 24.2 \times 10^{-3} \text{ liter} \times 0.66 \text{ atms} \quad (14)$$

$$E_{in} = 1.36 \text{ J} \quad (15)$$

1. L.M. Laughman, et.al., CO_2 Coherent Doppler Laser Radar System, Final Technical Report No. R81-924366-25, Contract No. 03-78-B01-87, NOAA, Environmental Research Laboratories, Boulder, CO., March 1981.

A conservative estimate of total input pulse energy required (including the preionizer circuit) would be $E_{in} \leq 2$ J maximum. At 20 Hz pulse rate, this is 40 watts maximum power.

3. Chirp Estimate

A TEA oscillator optical pulse will undergo a frequency shift because of discharge induced gas heating and thermalization of the lower laser level. The total frequency sweep Δf is related to the change Δn in the gain medium refractive index by the simple formula

$$\Delta f = -\alpha f \Delta n \qquad (16)$$

where α is the cavity filling factor, i.e. the fraction of the total optical cavity length occupied by the gain medium, and f is the (infrared) optical radiation frequency.

A quantitative estimate of master oscillator chirp may be made by using as a reference the chirp measured in a previously developed hybrid-TEA laser oscillator (Ref. 1) and scaling from the analysis provided recently by Willetts and Harris (Ref. 2). Theory predicts that the chirp scales as:

$$\text{Chirp} \;\; \alpha \;\; E_{out} \,/\, L\, \sigma^4 \qquad (17)$$

2. P.V. Willetts and M.R Harris, An Investigation into the origin of frequency sweeping in a hybrid TEA CO_2 laser, J. Phys. D: Appl. Physics., 15 (1982) pp. 51-67.

where E_{out} is the output pulse energy of the oscillator, L is the total cavity length and σ is the Gaussian beam radius. Previous experimental measurements Ref. 1 in a hybrid TEA laser have shown a measured frequency chirp of ±125 kHz in a 100 mJ output pulse from a gain length of 22cm in a 2.5 meter long cavity whose Gaussian mode size was determined by a 12mm diameter internal aperture (2a). For the same pulse shape (3 μsec), and specific input energy density (85 J/liter-atms), we would expect the proposed Master Oscillator to have a chirp of K x ±125 kHz where K is given by:

$$K = \frac{E_{MO}\, L_{REF}\, \sigma_{REF}^4}{E_{REF}\, L_{MO}\, \sigma_{MO}^4} \tag{18}$$

$$K = \frac{\left(E_{REF} \dfrac{a^2_{MO}\, \ell_{MO}}{a^2_{REF}\, \ell_{REF}}\right) L_{REF}\, \sigma_{REF}^4}{E_{REF}\, L_{MO}\, \sigma_{MO}^4} \tag{19}$$

The master oscillator output energy is 50 mJ, its gain length is 20 cm, the cavity length is 1.5 meters and the limiting aperture diameter will be 8.8 mm. At 50 mJ output energy, K becomes 2.8. Thus the maximum expected chirp will be ±350 kHz. If the output pulse energy is reduced to 20 mJ by reducing the specific input energy density, for instance, the predicted chirp from the master oscillator should be as low as ±130 kHz for the same pulse shape and duration.

In the oscillator the chirp is a result of the change of the Fabry-Perot resonance frequency as refractive index n changes. As the index changes at a rate dn/dt the Fabry-Perot resonance slews at rate given by equation (16). In an amplifier this dn/dt effectively impresses a Doppler shift on the beam as it traverses the gain medium. The resulting frequency shift is given by:

$$\Delta f_A = \frac{L}{\lambda} \frac{dn}{dt} \qquad (20)$$

where L is the length of the gain medium and λ is the nominal wavelength of the amplified beam. Even in an oscillator the flux within the resonator undergoes a Doppler shift in accord with equation (20). For a fractional output coupling of, for example 20%, the effective length to be used in equation (20) would be roughly 5 x (i.e. 1/.20) the actual oscillator gain length. As we shall see this contribution to chirp will still usually be much smaller than the chirp due to the shifting Fabry-Perot resonance. It is interesting to note however, that the Doppler-shifting of the existing flux is the mechanism which allows the optical frequency to continuously follow the Fabry-Perot resonance. Using the measured oscillator chirp data discussed earlier, we can compute $dn/dt = \frac{1.9 \times 10^{-7}}{3 \times 10^{-6} S} = .063 S^{-1}$ where the value of dn was determined on the basis of a 500kHz frequency shift. For a three-pass, 48 cm gain medium equation (20) yields a frequency shift Δf_A = 9kHz. A medium loading of 200 J/liter atm. might double this to 18kHz, but this is still a major improvement over the chirp rate of an oscillator. It should also be noted that to the extent dn/dt is constant, the amplifier does not produce a frequency chirp, but merely a frequency offset which is of minor significance if, as we expect, it is constant from pulse to pulse.

We conclude therefore that even with several meters of gain length and a high specific energy input the amplifier induced frequency chirp is negligible in comparison with the frequency chirp arising in an oscillator.

EXPERIMENTAL MOPA SYSTEM

As discussed previously the MOPA system utilized a hybrid TEA master oscillator built by CLS and a Lumonics 820 gain module was used as the amplifier. Both the master oscillator TEA gain section and the hybrid gain cell are normally operated with an open cycle gas system to permit maximum versatility with respect to gas mixture and pressure. Likewise the MO TEA discharge circuit is a simple direct switched type to permit broad variation in system parameters such as gas mixture, gas pressure, discharge voltage and energy loading.

Figure 2 presents a plan view of the general system layout. The amplifier Brewster windows are perpendicular to the plane of the table and the optical path in the amplifier is also folded perpendicular to the plane of the table. Figure 3 gives beam sizes at various locations in the optical train and Figure 4 gives nominal dimensions of the various components of the optical layout. Reflector 9 is a corner reflector consisting of two mirrors and is described in greater detail in Section V of this report. In the preferred optical configuration, shown in Figure 2, the first and second amplifier passes form a "V" while the second and third passes form a "U". A simpler configuration replaces the corner reflector 9 with a single mirror so that the beam path through the amplifier forms a "Z". In this arrangement, however, mirrors 8 and 9 are forced to be nearly parallel as a result of the limited amplifier aperture, with the result that parasitic lasing between mirrors 8 and 9 occurs in the amplifier. This lasing is of such intensity that over a Joule has been observed leaking past mirror 8 and the circulating flux can destroy a NaCl amplifier window in a single shot. No such problem is encountered with the corner reflector at position 9.

A word must be said about the Brewster windows used on the Lumonics amplifier since the repeated failure of these windows resulted in the substantial unplanned expenditure of dollars and

MOPA DESIGN

Schematic Component Layout

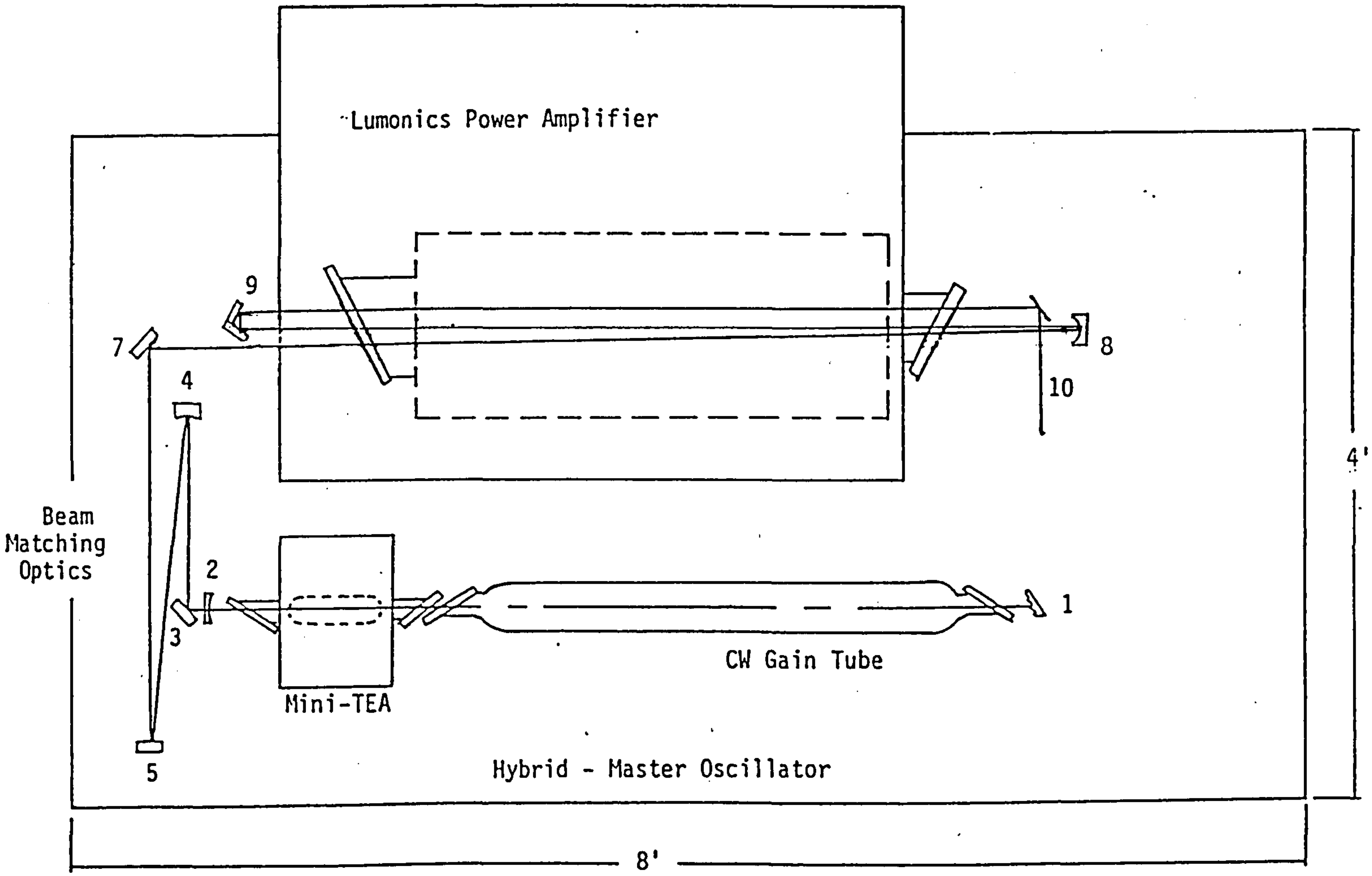
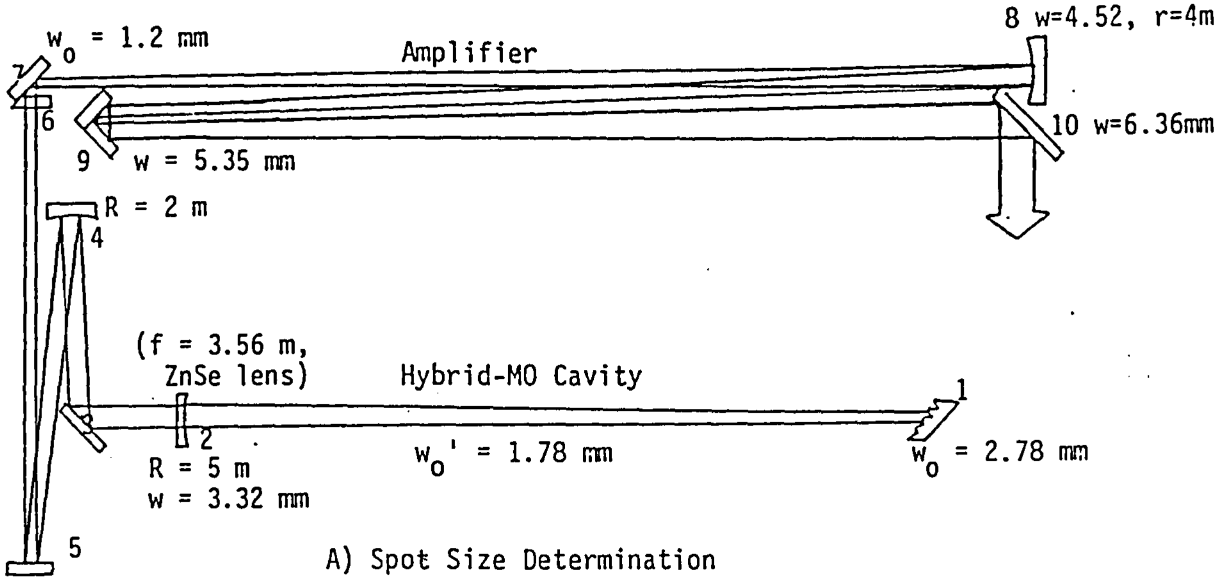
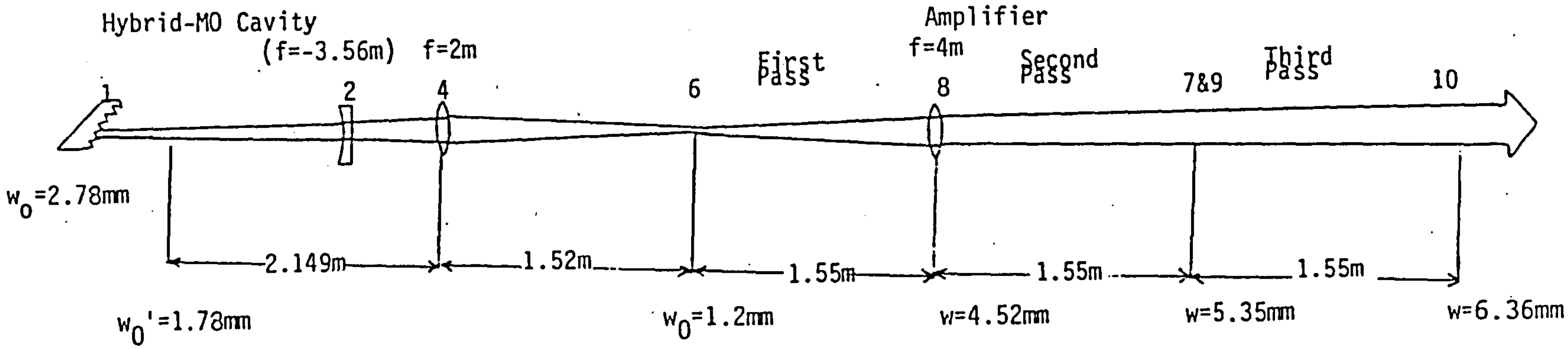


FIG. 2

MOPA OPTICAL DESIGN



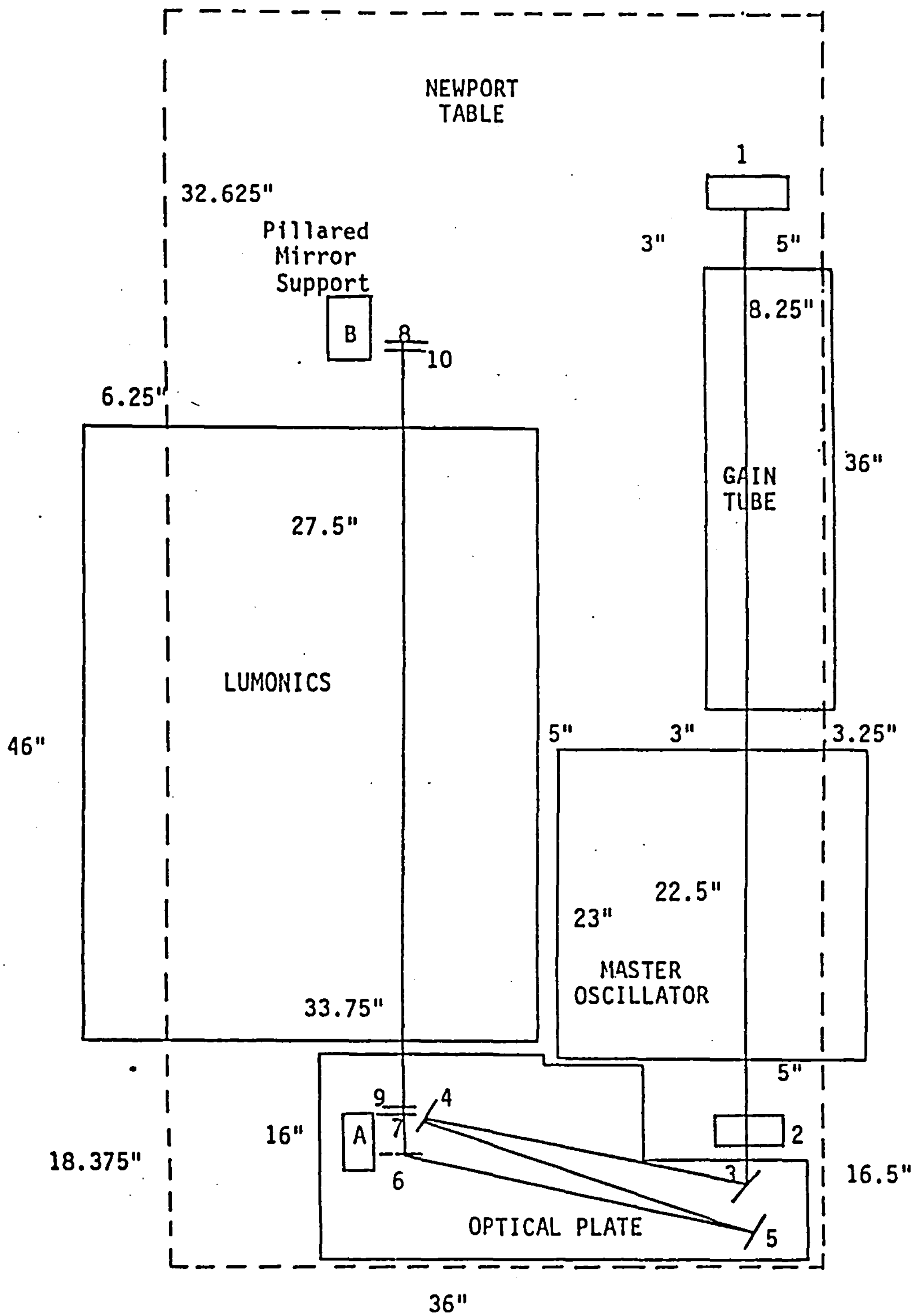
A) Spot Size Determination



B) Unfolded Beam Paths

FIG. 3

FIG. 4



COMPONENT LAYOUT

manhours. The Lumonics 820 was provided with 0.4 inch thick KCl Brewster windows and the factory recommended procedure for mounting the windows and filling the chamber with gas involved requiring the windows to bear the full load of atmospheric pressure. After many trials utilizing NaCl and KCl windows up to ½" thick provided by several manufacturers, it was concluded that this type of window always develops slip planes and eventually fractures as a result of the atmospheric pressure loading. Alternative approaches to the window mounting/chamber filling procedure designed to eliminate the pressure stress on the windows reduced the severity of the window destortion but could not really solve the overall system problem. In particular, if the window was mounted at atmospheric pressure and the chamber was purged with laser gas to drive out the air, it was found that the residual air contamination always lead to discharge arcing problems. The problem was ultimately solved by using ½" thick ZnSe windows in place of the alkali halide windows. The higher strength of the ZnSe allows it to repeatedly bear full atmospheric pressure without showing any permanent optical strain. It was only after the ZnSe windows were used that credible 3-pass amplifier performance was obtained. Prior to this the strained alkali halide windows so distorted the beam that 25-50% loss was incurred in the amplifier.

Figures 5 and 6 are photographs of the MOPA system and Figure 7 shows instrument control panels.

IV MOPA System Performance and Evaluation

MOPA power extraction measurements were made in one, two and three pass optical configurations. The general amplifier design formalism used in Section II.I can be refined to account for two effects neglected in that discussion. The first of these is absorption of the beam power by unexcited gas in the amplifier. Based upon single pass and three pass transmission measurements of the Lumonics, with and without laser mixture, we find that the

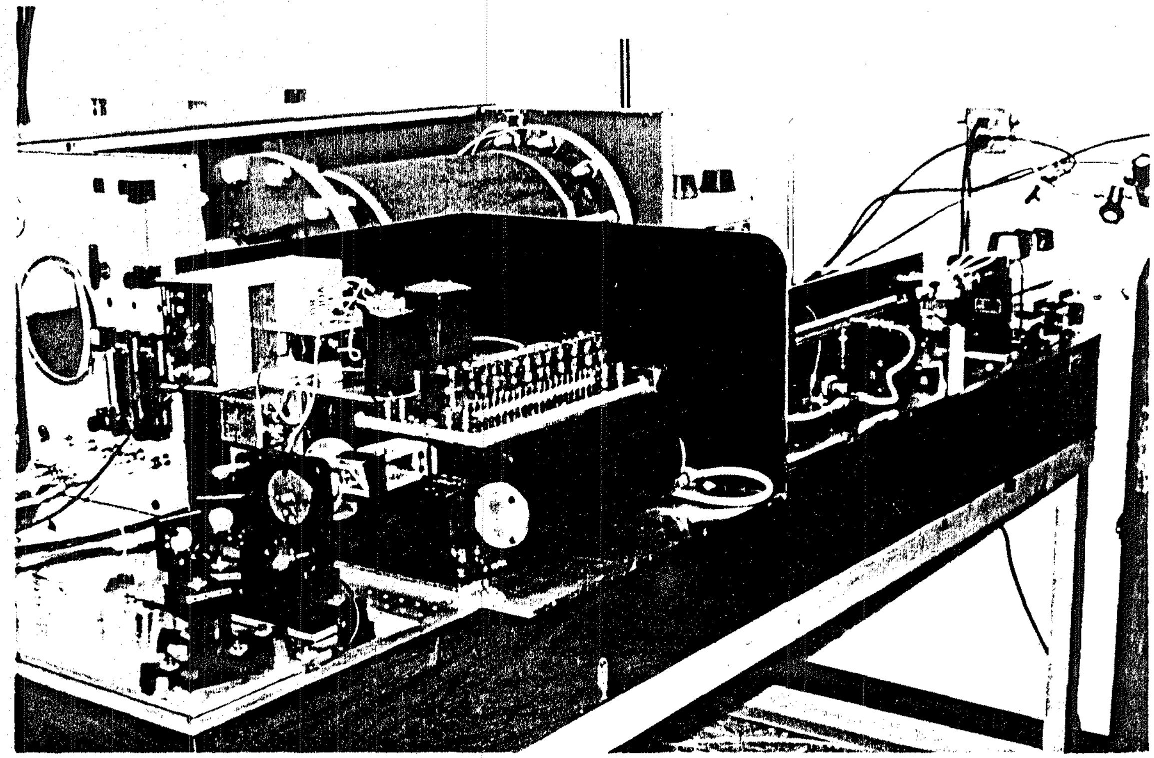


Figure 5a - Master Oscillator Laser

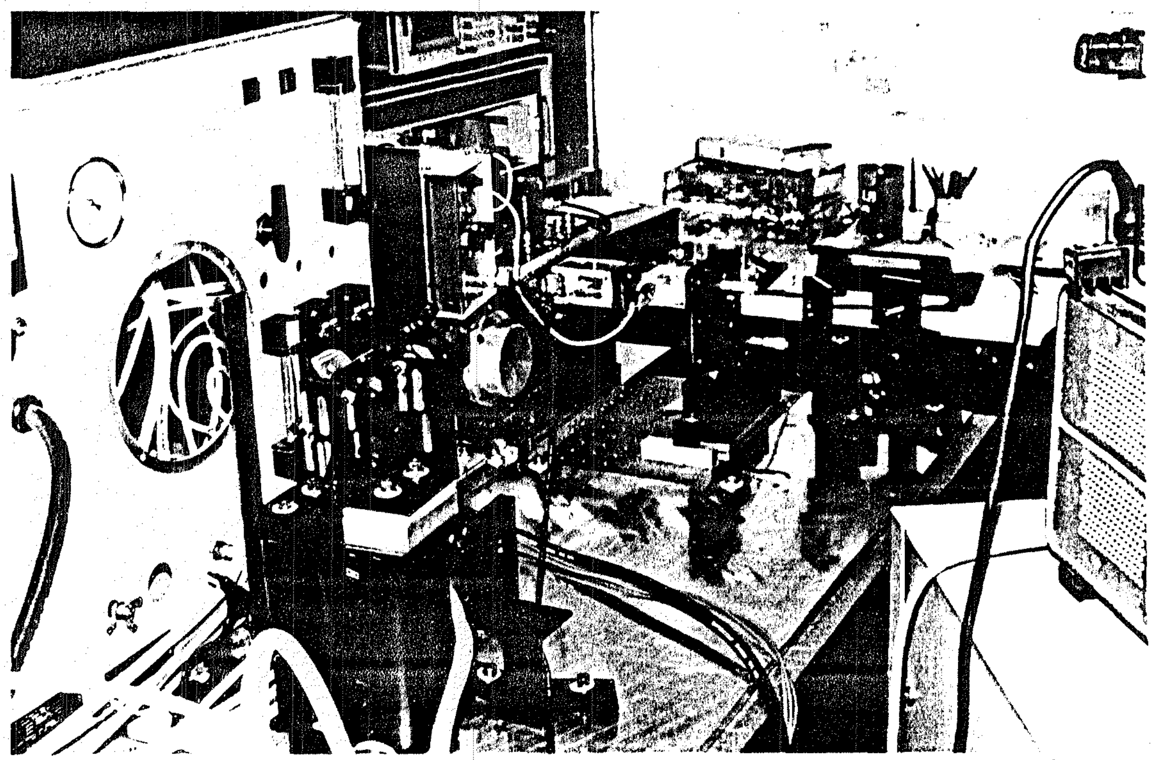


Figure 5b - Transfer Optics between Master Oscillator and Power Amplifier

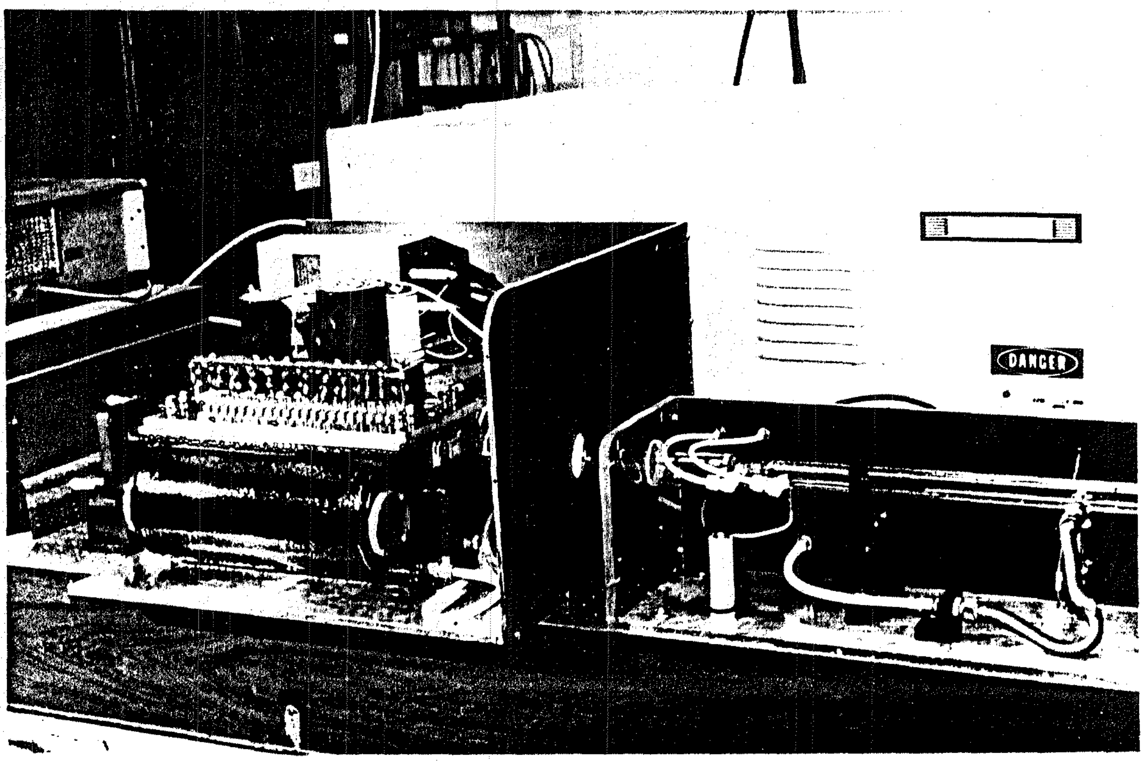


Figure 6a - Hybrid Cell and TEA Gain Module of Master Oscillator

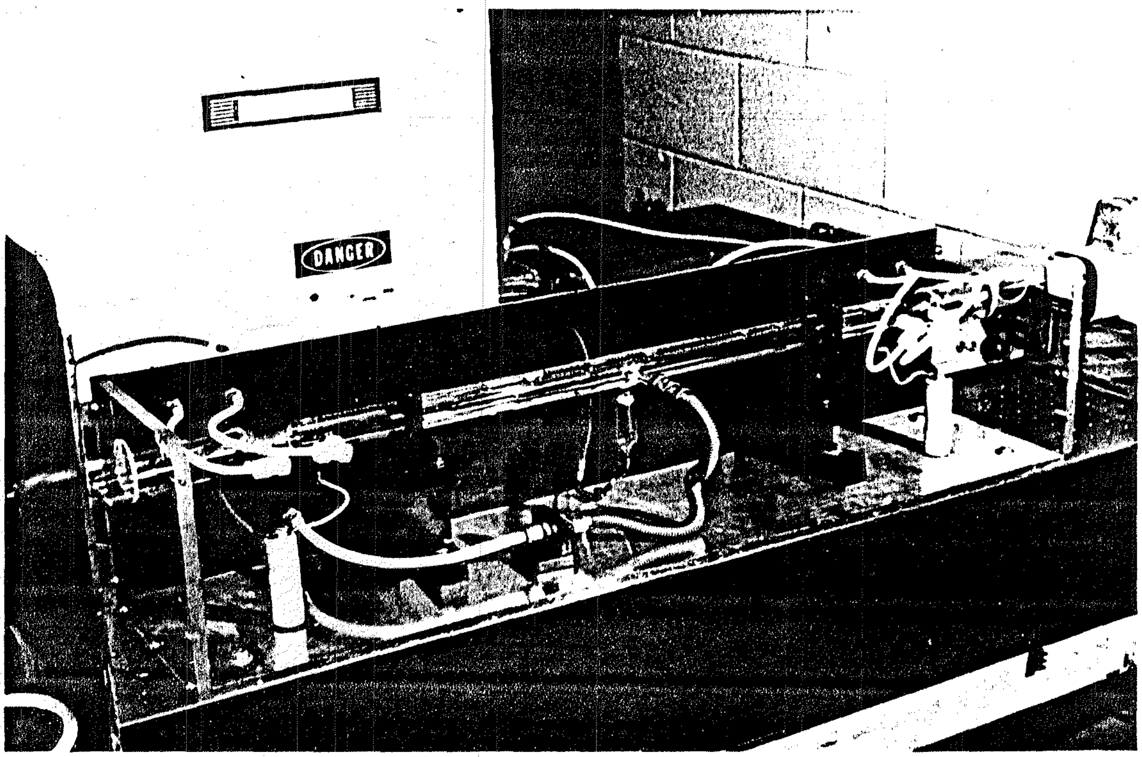


Figure 6b - Master Oscillator Hybrid Cell

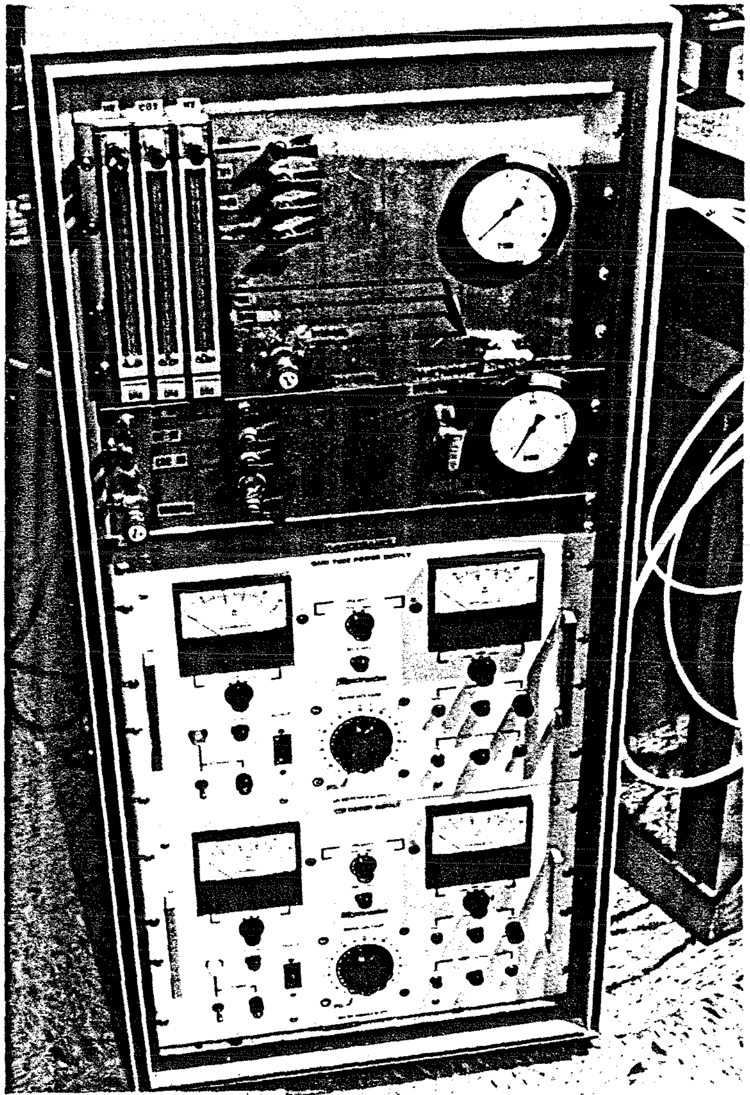


Figure 7a
Master Oscillator Power Supplies
and Gas Controls Cabinet

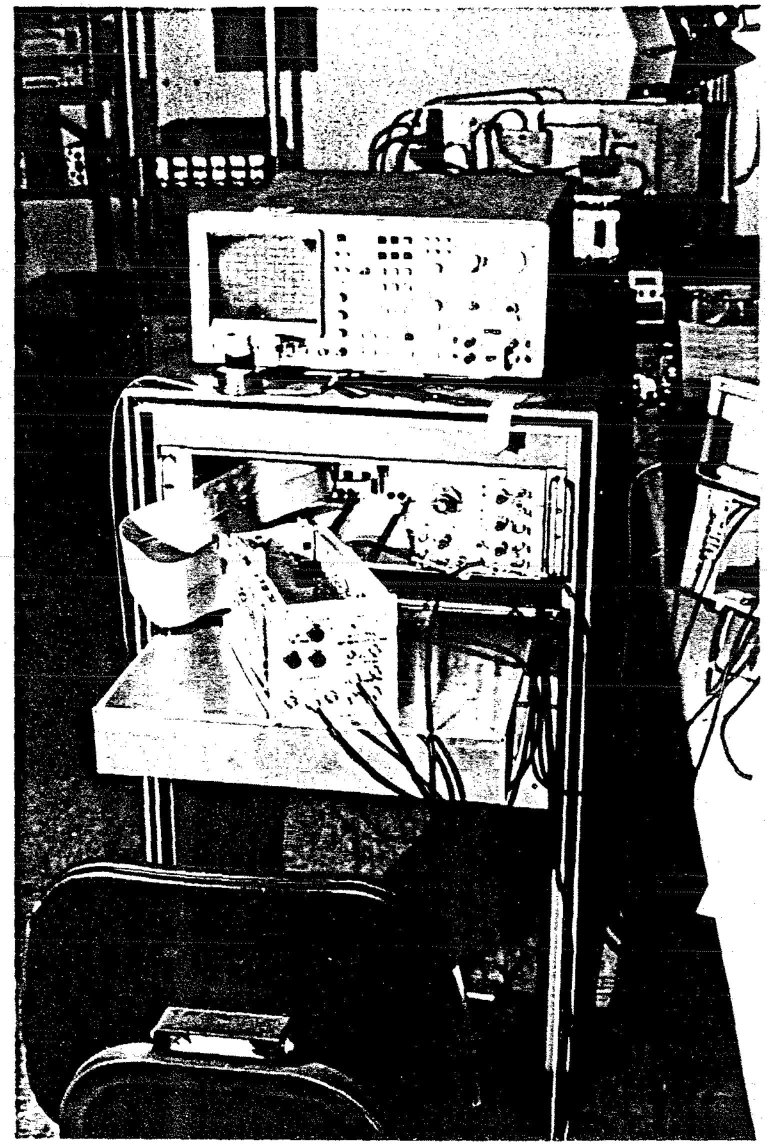


Figure 7b
Frequency Control Electronics Cabinet

$He:N_2:CO::3:1:1$ mix at 760 torr has an absorption coefficient of 4.9×10^{-4}/cm. This implies a single pass transmission of 0.97 with the absorption occuring in the 56 cm of unexcited gas in the Lumonics. This absorption is assumed to reduce the first and second pass amplified energies by 3%.

The second factor neglected in the earlier discussion is the gaussian beam profile of the master oscillator beam. A gaussian beam with total energy E_i may be written

$$E(r) = \frac{2E_i}{\pi W^2} \exp\left(\frac{-2r^2}{W^2}\right) \tag{21}$$

where E(r) is the fluence (Joules/cm^2) at a distance r from the beam axis, and w is the standard gaussian spot size. The basic Frantz-Nodvik equation is

$$E_o = E_s \ln(1 + e^{g_o \ell} (e^{E_i/E_s} - 1))$$

where E_o, E_s and E_i are all in Joules/cm^2. In the interest of defining a solvable problem we now choose to ignore diffraction of the beam during the amplification process. This should not be too unreasonable an assumption if the beam is not expanding too rapidly or if the fluence is well below E_s. Under these conditions, the output fluence in an annular region $2\pi r dr$ is given by

$$E_o = E_s \ln\left[1 + e^{g_o \ell}\left(\exp\left\{\frac{2E_i e^{-2r^2/w^2}}{\pi w^2 E_s}\right\} - 1\right)\right] \tag{22}$$

Integrating across the beam (to a maximum radius of 2w) we find the total output energy,

$$E_{total} = E_s \int_0^{2w} \ln\left[1 + e^{g_o \ell}\left(\exp\left\{\frac{2E_i e^{-2r^2/w^2}}{\pi w^2 E_s}\right\} - 1\right)\right] 2\pi r dr \tag{23}$$

In a system of the type we are here considering, inclusion of the gaussian profile in the described fashion reduces our estimate of the three pass amplified energy by typically 6%.

Experimental and theoretical energy extraction measurements are summarized in the following table. Theoretical values assume an unsaturated gain of $.03cm^{-1}$ and a saturation fluence of $500mJ/cm^2$.

	MASTER OSCILLATOR ENERGY (mJ)	AVERAGE SPOT SIZE (cm)	OUTPUT ENERGY THEORY (mJ)	OUTPUT ENERGY EXPERIMENTAL (mJ)
1st Pass	42	.286	125	130
2-Pass	42	.465	374	420
3-Pass	50	.554	990	900

Data were taken at 10 pulses per second and the spot sizes listed are the average spot sizes in the gain medium on the final pass. The small excess of experimental over theoretical energies for one and two pass amplification probably indicates that the assumed value (supported by manufacturer's data) for saturation fluence or gain is slightly pessimistic. The deficit between experiment and theory in the three-pass amplification is principally a result of beam clipping at the final turning mirror and aperturing by the power meter. In the three pass geometry the unamplified MO beam needed to be aligned very precisely within the clear aperture defined by amplifier electrodes and steering mirrors. With a proper alignment the unamplified MO beam emerged after three passes with an excellent gaussian profile. When the amplifier was pulsed however, the effective beam diameter increased substantially because the low power, larger diameter portion of the MO beam is amplified exponentially while the higher intensity near axis portion saturates and approaches a linear amplification. With a nonideal MO beam of

80mJ (more nearly TEM_{01} than TEM_{oo}) the measured amplified energy was 1100mJ. Not surprisingly, energy loss by vignetting was even greater for the higher order mode input beam. In the limit of fully saturated amplification the output beam will assume a profile that is limited by the shape of the gain medium or by apertures in the beam path. For the experimental system under consideration it seems clear that if the amplified beam is to have good transverse mode characteristics, either smaller beam sizes or fewer amplifier passes must be used. Both the large beam/two pass and small beam/three pass approaches have advantages and disadvantages, however the amplifier model presented above appears to be fully adequate for evaluating the different concepts.

The amplifier data presented above were all obtained without hybrid cell control of the master oscillator. This was a consequence of some contamination and distortion problems with the hybrid cell Brewster windows. Wihtout the hybrid cell the MO necessarily oscillated on several longitudinal modes and the output pulse was a partially modelocked waveform. The sharp pulse structure in the modelocked pulse reduces the effective saturation energy but the magnitide of this effect in the present case is difficult to estimate. The MO was operated in a single longitudinal mode during development and testing of the MO frequency control loop. This loop derives an error signal from impedance variations of the hybrid cell discharge as the MO cavity length is dithered by a PZT. The hybrid cell operates at about 25 torr and the narrow gain curve provides a strong locking discriminant for the hill-climbing servo. This approach also has the advantage of obviating the normal requirement for an optical detector in the control loop.

V MOPA System Operating Procedures

This section is constructed as a self-contained unit the purpose of which is to guide the user in the setup and operation of the MOPA system. The system was constructed as a research testbed to test and develop certain MOPA system concepts and is intended to sit on a 4' x 8' optical table, typically 12" thick. Because the system incorporates roughly fifteen general purpose optical components and mounts, alignment of the system constitutes a significant fraction of the effort required to bring the system into operation. This section discusses the alignment procedures in detail, and some discussion is also given to troubleshooting.

Materials

All materials will be listed in two sections. The first section will list parts supplied by the contractor and the second list includes items that must be provided by the user.

CLS Supplied Items

1. Lumonics

    a. Assorted poly-flo tubing
    b. Two ZnSe windows with Brewster mounts
    c. Two sets of mounting flanges
    d. Two O-rings
    e. Two aluminum centering apertures for alignment
    f. Two plexiglass windows for alignment

2. Master Oscillator

    a. Two electro-static shields
    b. Two ZnSe windows with Brewster mounts
    c. Assorted poly-flo tubing, wiring and fittings
    d. Triggering system with support structure
    e. Two O-rings
    f. Two centering apertures for alignment

3. Gain Tube

    a. Assorted poly-flo tubing, wiring and fittings
    b. Two ZnSe windows with Brewster mounts
    c. Two electro-static shields
    d. One bellows
    e. Electrical stand-offs
    f. Two O-rings
    g. Two centering apertures for alignment

4. Aluminum optical plate with four Newport MM 2A-B2 mirror mounts with stand-offs

5. Two cabinets

   a. Loop locking cabinet
   b. Power and gas control cabinet

6. Two pillared mirror supports

   a. One for mirrors 8 and 10
   b. One for mirrors 7 and 9

7. One double pulse signal generator

8. Two Newport 600A-2 mirror mounts with bases

9. Intracavity iris aperture with mount

10. 22 mechanical dogs

11. Miscellaneous screws, washers and lock washers

12. 12 teflon washers

13. Silver enhanced mirrors

   a. 6 - 1", R = ∞, 100% reflective at 10.6 μm
   b. 1 - 1", R = 4 m, 100% reflective at 10.6 μm
   c. 1 - 1", R = 2 m, 100% reflective at 10.6 μm
   d. 2 - 1.5" R = ∞, 100% reflective at 10.6 μm

14. One ZnSe mirror, R = 5 m, 90% reflective at 10.6 μm

15. Two positioning cards

16. One electrical shield (cover) for the Master Oscillator

17. One electrical shield (cover) for the Gain Tube

NASA Supplied Items

1. Two HeNe lasers

2. Four lab jacks

3. Four tanks with regulators

   a. He
   b. CO_2
   c. N_2
   d. Extra dry Air

4. Two, 2 stage low pressure, $\geq$ 5.6 CFM vacuum pumps

5. One DC power supply, 0 - 30 VDC, 0 - 2 A

MECHANICAL ASSEMBLY

The Master Oscillator, the Gain Tube and the Lumonics operate as independent discharge modules within the MOPA system. Each module has its own electrical, gas, vacuum, and cooling systems. These systems are connected externally to sources and regulators that are designed to fit the individual needs of each laser. How these connections are made is the topic of this section.

Master Oscillator

The Master Oscillator, shown in figures 1 - 4, consists of five distinct subassemblies: the discharge head, the blower assembly, the triggering system, the cooling, gas and vacuum lines, and the power supply.

1. Laser Head

The laser head is mounted securely to the bottom of the shielded enclosure with ¼ - 20 screws. The head's two parts that need assembling are the Brewster windows and the electro-static shields. The Brewster windows are held in a face down position by dowel pins and they are fastened by 8 - 32 screws to the housing. The outside of the windows are protected by electro-static dust shields that slide over the Brewster mounts.

2. Blower Assembly

The blower must be externally powered with a D.C. power supply. There are two feedthroughs located at the blower housing's G10 back plate. The feed-through that is mounted highest on the G10 is the high voltage side of the motor. The locking nuts on the feed throughs can be turned with the cover off by a 3/8" wrench or with the cover on by a 3/8" nut driver. The blower runs between 7.5 and 15 volts DC. Any lower than 7.5 volts will cause the Master Oscillator to arc, any higher than

15 volts causes unwanted noise on the closed loop locking system and possible motor burn-out. If the blower's power supply has EMI, it can be eliminated by either grounding the Newport table or isolating the power supply from the table.

3. Triggering System

The triggering circuit is composed of two main loops. The driver and thyratron loop and the reservoir and cathode loop (see figure 5). The thyratron driving circuit is connected externally by a 115v ac line. To trigger the circuit, a double pulse generator is connected to the external trigger input of the driver. For convenience the driver can also be internally triggered.

The reservoir and cathode must be heated before any triggering can take place. The heating circuit is connected externally by the same 115v ac wiring that supports the driver. The reservoir and cathode must be preheated for 1/2 hour at the 70 mark on the Variac dial. The 70 mark corresponds to 6.3v or 80^3C across the cathode and reservoir. When the cover is on adjustments may be made with a long common screwdriver.

4. Main Power Supply

The main power supply is stored in the cabinet (see figure 5). It is connected to the ionizing circuit by a RG-8 cable. The same RG-8 cable grounds the ionizing circuit back to the power supply through its shielding. The external connection for the power supply is a 115v ac line. The 115v ac line is also connected to the cabinet's fan, so any time the power supply is on, the fan is on.

5. Cooling, Gas and Vacuum Lines

All gas and vacuum lines are connected to the cabinet before they reach the MO (see figure 6). The water lines, however, are connected directly to the MO.

The 1/4" gas lines originate at the tanks where the pressure is regulated at 40 PSI. From the tanks the lines are run to the cabinet and enter at the poly-flo bulk head unions that are marked MO-He, CO_2, N_2. Within the cabinet the gases flow through 3 Matheson flow meters. The flow meters are regulated at the stainless steel ball height of 70 for N_2, 68 for CO_2 and 35 for He. This ratio constitutes a 5-1-1 mix (see charts A,B,C). The gases continue to three snap valves where the gases can be turned off or on without disturbing the flow meter settings or the contents of the laser. The gases then combine and enter a 3-way switch where the outlet pressure or inlet pressure can be measured on the Busch torr gauge. The gases then leave the cabinet through the 1/4" bulk head union labeled "MO Gas" and are fed into the side of the MO cover by the bulk head labeled "Gas".

The gases are pumped from the MO through the 3/8" poly-flo line labeled "Vacuum". The vacuum line runs to the cabinet's side and enters through a 3/8" bulk head Union labeled "MO to laser". Within the cabinet the line is connected to the same three way switch as the inlet gases were. This connection will allow you to read the outlet pressure. The vacuum line then passes a snap valve for "on and off" switching, before it leaves the cabinet at the 3/8" bulk head Union labeled "Vacuum MO". The line is then connected to a two stage low pressure, 5.6 CFM pump.

The water lines are connected to a water supply outlet where they are regulated by an "on and off" lever. The lines are then connected to the side of the MO shield by a 3/8" bulk head Union labeled "In". The water is exited through the 3/8" bulk head Union labeled "Out", where it is drained.

Gain Tube

The Gain Tube consists of three parts: the plasma tube, the power supply, and the cooling, gas and vacuum system.

1. Plasma Head

The plasma tube shown in Figure 7 is double-walled pyrex and provides for water cooling. It is supported between the center and the ends by two aluminum dutch clamp mounts. Each clamp can be adjusted for height requirements by loosening the 1/4 - 20 screws on its side and then sliding the mount up or down as needed. The tube, electrodes, gas inlet, gas outlet, water inlet and water outlet are permanently assembled and the laser mounts are dogged to the base of the aluminum cover. The Brewster windows are mounted face up with 6 - 32 screws and they are protected by plexiglass shields.

2. Cooling, Gas and Vacuum System

The gas system provides flowing gas to the laser head at the proper mixture, pressure, and flow rate (see figure 8). The 1/4" poly-flo lines that carry the three gases to the cabinet are teed from the MO gas lines at the gas cylinders. The lines are teed at that point to eliminate any possible pressure drop when the MO and GT are operating at the same time. The lines are then brought into the cabinet at the point where it is labeled "He, N_2, CO_2, GT". Three needle valves are used to control the gas flow. Their respective settings are He - 5.50, N_2 - 3.25, CO_2 - 3.25. The gases continue to three snap valves where the gases can be turned off or on without disturbing the needle valve settings or the contents of the laser. The gases then combine and enter a 3-way switch where the outlet pressure or inlet pressure can be measured on the Busch torr gauge. The gases then leave the cabinet at the 1/4" bulk head Union labeled "GT Gas" and are then fed into fittings at the back of the Gain Tube's cover. From the fittings they are connected to the brass tubes at the ends of the cavity.

The gases are pumped from the laser through a bellows. The bellows is secured to the bottom plate by a clamp, which also acts as a bulkhead connection for the poly-flow line. The poly-flow line is then run through the back of the GT cover to the side of the cabinet where it enters through a 3/8" bulkhead union labeled "GT to laser". Within the cabinet the line is connected to the same three way switch as before, so that the outlet pressure can be monitored on the 0 - 40 torr Busch gauge. The vacuum line then passes a snap valve for on and off switching, before leaving the cabinet at the 3/8" bulk head union labeled "Vacuum GT". The line is then connected, because of pressure requirements, to another low pressure, 5.6 CFM vacuum pump.

The water line for the GT is teed from the MO line. It is then connected to the back of the GT shield by a 1/4" bulkhead union labeled "H_2O In". The connection from the cover to the pyrex is by 1/4" poly-flow which connects to the pyrex tube on the Gain Cell. A 1/4" bulk head union then transfers the water to the outside of the cover.

3. Power Supply

The main power supply for the hybrid cell is stored in the cabinet above the MO power supply. Two red, unshielded Belden high voltage wires are run to strain reliefs and then white silicon HV leads run to the cathodes. The return is also a white unshielded silicon high voltage wire that is strain relieved at the base of the shield before it returns by red Belden cable to the cabinet.

The external connection for the power supply is the same 115vac line that serves the MO's power supply.

Lumonics

The lumonics is supplied with its own instruction manual.

POSITIONING MOPA

The positioning of MOPA is separated into four parts. The initial positioning consists of arranging the Lumonics, the Gain Tube, the Master Oscillator and the Optical Plate on a 4' x 8' Newport table. The second step involves mechanically aligning the Gain Tube and Master Oscillator along an optical laxis. The third step is the positioning of the mirror array which translates the beam from the MO to the Lumonics. The final positioning consists of arranging mirrors 7 - 10 for a three pass alignment through the Lumonics.

Part I

The MOPA system can only be developed after the four reference points (MO, GT, Lumonics, and Optical Plate) have been positioned. The positioning of these parts will be explained in outline form and shown in Figure 9. All measurements are not to be held stringently. The underlining theme is that all parts must work together to form the system. That means slight adjustments might have to be made in positioning and aligning. Also, right and left side references are taken while looking down the length of the table, from front to back.

1. Remove top covers to the Lumonics, the Gain Tube, and the Master Oscillator

2. Lumonics

Size - 33.75" wide by 46" long

Position the Lumonics so 6.25" extend over the left side of the Newport table and its front is 18.375" from the front of the table. Now secure the plate to the table using 4, 1/4 - 20 screws with lock washers and washers.

3. Optical Plate

Size - 16" wide by 36" long

Position the length 1" from the front of the Newport table and the width 1" from the right of the table. Secure the plate to the table using 6, 1/4 - 20 screws, with each screw use a teflon washer above and below the plate and a steel washer between the screw head and the teflon washer.

4. Master Oscillator

Size - 22.5" wide by 23" long

Position the Master Oscillator 16.5" from the front of the Newport table and extending 3.25" over the right side of the bench. Now secure the MO to the table with 1/4 - 20 screws, washers and lock washers.

5. Gain Tube's isolation cover - without hybrid cell

Size - 8.25" wide by 36" long

Positioning of the Gain Tube isolation box should be relative to the Master Oscillator. The two should be separated by a 3" margin. The bottom plate of the cover should be even with the side of the Newport table. To secure the shield to the table use 4, 1/4-20 screws with washers and lock washers.

Part II

The optical aligning of the Gain Tube and Master Oscillator, with a HeNe laser, is the next step. (See Fig. 10)

1. Mirror support 1 - 600A-2 mirror mount with base

Size - 2.5" wide by 5.5" long

Position the mirror mount (without mirror) 2.125" from the right side of the Newport table and 3" from the far end of the Gain Tube's isolation cover. Then secure it to the table with dogs.

2. Mirror support 2 - 600A-2 mirror mount with PZT and base

Size - 2.5" wide by 5.5" long

Position the mirror mount 2.125" from the right side of the Newport table and 9.375" from the front of the table, facing the Master Oscillator. The PZT should be secured in place without the output coupler (a 90% ZnSe mirror with a radius of 5 meters).

3. Place a HeNe laser on two lab jacks behind mirror one and facing towards the Master Oscillator.

4. To align the laser to the MO cavity, centering apertures (two aluminum caps) and one Brewster window are needed. The aluminum caps fit into both optical openings of the cavity and they determine the center of the MO. A Brewster window is held face down by the two dowel pins at the rear cavity opening. The laser is then adjusted until the laser beam passes through both aluminum apertures and forms a bright center spot with concentric rings on an index card positioned in front of one output coupler. Once the HeNe laser is aligned to the cavity remove the aluminum caps, vacuum grease the sealing O-rings and fasten the Brewster windows with 6 - 32 screws and washers.

5. Now place the Gain Tube (without the brewster windows) on the two support beams that are mounted in the Gain Tube's isolated cover. Secure the Gain Tube loosely in the dutch clamps by gently turning the 1/4 - 20 screws that are on top of the clamp (be careful not to crack the gain tube).

6. Manually adjust the sliding plates on the Gain Tube supports until the HeNe beam travels uninterrupted down the center of the cavity.

7. For the final adjustment use the brass plugs to determine the center of the Gain Tube's cavity. Now follow the aligning procedure that was developed in step 4, only this time adjust the gain tube, not the HeNe.

8. Once the HeNe is aligned to the center of the Gain Tube remove the brass plugs, vacuum grease the sealing O-rings and fasten both Brewster windows with 6 - 32 screws and washers to the cavity flanges. *NOTE: When screwing the windows on to the flanges, rotate the Brewster mounts to their maximum clockwise positions.

*The Gain Tube must not only be coaxil with the MO, but their Brewster windows must be in the same horizontal plane. The MO's Brewster windows are permanently set by the dowel pins. The correct plane of the Gain Tube's Brewster windows must be found. The positioning of the Gain Tube's Brewsters can be determined by hanging a bob (plumb) over the center (width and length) of the cavity and then rotating the cavity until the HeNe reflections off both the brewster windows fall on the string holding the bob (the clockwise rotation of the Brewster mounts in Step 8 should present the correct positioning).

9. Behind mirror 2 place mirror support 3, 5.25" from the right side of the Newport table and 6.5" from the table's front. Mount a 1" plane, totally reflective mirror into the support. Now place mirror 3 so the HeNe beam strikes it and is reflected parallel to the front edge of the table. Secure the mount to the optical plate with dogs.

10. Position another HeNe laser on two lab jacks so the beam is coaxial with the first laser beam

11. A 1" totally reflective plano mirror is placed into mirror mount 1. By adjusting the mirror reflection, the beam is directed back to the optical opening of the HeNe that is in front of mirror 3. Now the 90% ZnSe 5m radius output coupler is screwed on to the PZT. The HeNe's reflection on the back of the output coupler will produce multiple reflections. Align the second reflection on the optical opening of the HeNe by adjusting mirror mount 2's vernier controls.

12. Remove the HeNe that is mounted in front of Mirror 3.

13. Mirror 1 must be removed before the mirror array can be mounted on the optical plate. Before removing mirror one from its mount, notice that the back of the mirror has a glass slide attached to it. The reflection off the glass slide onto the face of the HeNe laser should be marked. This mark represents the proper positioning of mirror 1 in its holder, so it can be remounted to form a proper optical path through the MO and Gain Tube with mirror 2.

Part III

Mirrors 3 through 6 translate the CO_2 beam from the output of the MO to the input of the Lumonics. Their general position is found by placing their centers relative to the Newport table. Their final alignment must be developed by walking the HeNe beam to the center of each mirror. (See Fig. 11)

1. Mirror 3

Size - 1", 100% reflective, R = ∞, silver enhanced

Mirror 3, although positioned in part 2, will have to be redirected towards the left, back corner of the optical plate.

2. Mirror 4

Size - 1", 100% reflective, R = 2 m, silver enhanced

Mirror 4 is 29.75" from the right side of the Newport table and 11.75" from the front of the table. The total distance between mirror 4 and 3 is 25". Face mirror 4 to the right front corner of the Newport table. Once the HeNe beam from mirror 3 is centered on mirror 4, secure the mount with dogs.

3. Mirror 5

Size - 1", 100% reflective, R = ∞, silver enhanced

Mirror 5 is placed behind mirror 3 and facing in the same relative direction as mirror 3. Its actual measured location is 27" from mirror 4, 4.5" from the right side and 3.25" from the front of the Newport table. Once the HeNe beam from mirror 4 is centered on mirror 5, secure the mount with dogs.

4. Mirror 6

Size - 1", 100% reflective, R = ∞, silver enhanced

Mirror 6 translates the beam directly upwards to adjust for the difference in height between the Lumonics and the MO-GT system. The location of the mirror is 31" from the right and 8.5" from the front of the Newport table. Mirror 6 is 28" from mirror 5. Once the HeNe beam from mirror 5 is aligned to the center of mirror 6, secure the mount with dogs.

Part IV

The final step in aligning MOPA involves the three passes through the Lumonics. The components for the three pass system are 2 pillar mounts and mirrors 7 through 10. See Figure 11 and 12.

1. The pillar mount for mirrors 7 and 9 is positioned 12.5" from the left side and 8" from the front of the Newport table. The HeNe beam from mirror 6 should center on mirror 7 and be reflected to the optical opening of the Lumonics. When this is done, secure the base of the mount with dogs.

2. The pillar mount for mirrors 8 and 10 is located at the back of the Lumonics. The positioning is 5" from the back of the Lumonics and 12.5" from the left side of the Newport table. Once the bottom is squared to the Lumonics secure the mount with dogs.

3. Mirror 7

Size - 1", 100% reflective, R = ∞, silver enhanced

The center of mirror 7 is 10.3" from the optical plate and is held by the first of the two mounts at a 45° angle. The optical path from mirror 7 to mirror 8 represents the 1st pass of the three pass system.

4. Before the three passes can be aligned, the center of the Lumonics must be determined. At the back of the Lumonics position a HeNe laser on two lab jacks so the beam is directed towards the front of the Lumonics. Place inside one of the Brewster mounts an aluminum aperture. On the back side of the Lumonics attach the mount so the Brewster surface is perpendicular to the Newport Table. Now place the ZnSe window in the mount. At the front end of the laser place the clear plexiglass aperture. Direct the laser beam through the center of both apertures. Once the beam is through the center of the laser take both apertures out and mount the ZnSe windows.

5. Mirror 9

Size - 2-1.5", 100% reflective, R = •, silver enhanced

Mirror 9 is actually 2 mirrors that form a porro retro-reflector. The top of the vertical mirror is 10.1" from the optical plate. The angle of the vertical mirror is 45° with respect to the center of the Lumonics. The horizontal mirror is brought to near contact with the vertical mirror to form a right angle whose apex is 9.6" from the optical plate.

6. Place the positioning card in front of the retro-reflector so the HeNe beam aligned to the center of the Lumonics, strikes the center hole in the positioning card. Adjust mirrors 7 & 6 so the MO HeNe beam passes through the punched hole marked first pass. Now place the positioning card at the back of the Lumonics optical opening and make the same needed adjustments to mirror 7, so the first pass beam passes into and out of the Lumonics at the same reference height.

7. Mirror 8

Size - 1", 100% reflective, R = 4m, silver enhanced

Place mirror 8 in its mount and center its height 10.3" from the optical plate. Reflect the HeNe beam that comes from mirror 7 to the retro-reflector.

8. Place the positioning card in front of the retro-reflector. Adjust mirror 8 so that the second pass is at the correct relative position to the first pass (2nd pass on reference card).

9. The retro-reflector should direct the HeNe beam back towards mirror 8, but displaced downward the diameter of the beam waist. The second and third passes are controlled by adjusting mirror 9.

10. Mirror 10

Size - 1", 100% reflective, R = ∞, silver enhanced

Mirror 10 is positioned directly in front of mirror 8 and covers the bottom third of the mirror. The mirror is used to direct the final pass of the system to a testable position.

OPERATING INFORMATION

The three subassemblies (the Lumonics, the Master Oscillator, and Gain Cell) act as separate discharge modules within the MOPA system. Being separate lasers they have individual operating information. This operating information includes start-up procedures, shut-down procedures, and problems that may arise during the operation.

Master Oscillator

A. Start-Up Procedure:

In the operation procedures of the MO it is assumed that mirrors 1 and 2 have been aligned with laser cavity and that all systems are operable. To clean debris from the insides of the system, purge the MO with a heavy supply of nitrogen for five minutes, with the windows off and the blower on.

1. Plug in AC power to cathode and reservoir and allow 1/2 hour to warm up.[1]

2. Place beam block in front of mirror 3.

3. Turn on the water cooling system.

4. Turn on the vacuum pump.

5. Switch on the vacuum pump snap valve to pump down system.

6. Purge system 4 or 5 times. The purging involves filling the laser with a gas mix to 500 torr (with the pump snap valve off) and then pumping the mix out.

[1] Steps 2-13 can be done while reservoir is heating

7. Open the three tank valves and set the regulators to 40 psi.

8. Turn on the gas snap valves and set flow meters to the He (S.S)[2] - 35, N_2 (S.S) - 70, and CO_2 (S.S) - 68.

9. Turn the pump valve off.

10. Fill laser cavity with the gas mix to 500 torr (reading taken from outlet side of laser). When pressure reaches 500 torr, turn the pump snap valve on. If the pump does not balance flow at 500 torr, make the needed adjustments using the Nupro valve. Adjustments to discharge circuit are necessary if laser is to be operated at more than 600 torr.

11. Turn on the power to the cabinet.

12. Turn on the blower to 7.5 volts.

13. Turn on internal or external pulse to driver at 10 Hz.

14. The outside of the windows should be blown off before lasing.

15. Turn on the power to the MO steadily until 11.5kV is read on the power supply's voltmeter (the discharge will be heard breaking down). Caution: do not operate at more than 13kV.

16. a) To optimize power, place a power meter between mirror 3 & 4, remove the beam block and tweak mirror 2 until maximum power is reached.

    b) Now walk mirror 1 & 2.

[2] S.S means stainless steel ball height B.

17. The final step is to adjust for a good transverse mode. This can be achieved by centering an iris aperture to the CO_2 beam between the hybrid cell and the TEA module. Now replacing the power meter with a phosphor plate, walk mirrors 1 and 2 until a roundish, solid image is seen on the phosphor. Then close the iris until the image becomes TEM_{oo}.

B. Problems with Start-Up:

The Master Oscillator is a very forgiving unit whose problems are easily corrected. Here is a list of problems that may be encountered and their remedies.

1. The discharge will not breakdown (ampmeter on power supply hangs up)

   a. Check to see if system is being triggered
   b. Thyratron may not warmed up
   c. Repetition rate too fast
   d. Laser may have to be purged a few more time

2. Arcing

   a. Breakdown voltage from power supply is too low
   b. The system is contaminated and needs further purging
   c. Blower is not on or at too low a voltage
   d. Wrong mix, flow meters not at proper height, tanks shut off
   e. Pressure not at 500 torr - if a higher operating pressure is desired more breakdown voltage is needed or a richer helium mix should be used.

3. No output power

   a. Mirrors 1 and 2 need adjusting - when adjusting mirrors, always tweak mirror 2 for maximum power before touching mirror 1

b. If adjusting mirrors does not help, then mirrors 1 and 2 must be realigned with the HeNe laser

4. A good mode can not be achieved

   a. New adjustments must be made for the cavity aperture, because mirrors were walked off the iris center
   b. Beam path must be realigned because it does not travel down center of the system

C. Shut-down Procedure

1. Turn off the power to the MO
2. Turn off the gas snap valves
3. Pump down the system
4. Turn off the blower motor
5. Turn off the trigger
6. Turn off the external trigger
7. Turn off the cooling system

D. Operating Parameters

1. Laser Head

Overall Length - 14.5" (approximate)
Cavity Length - 72.5" (approximate)
Active Length - 10.5 (approximate)
HR mirror - AR coated, silver enhanced, silicon substrait, reflectivity >99%, 10.6 μm, R = ∞
Output coupler - ZnSe, reflectivity - 80% or 90%, 10.6μ, 1" dia, plano-concave, R = 5m
Cooling - water

2. Gas Control System

Output Pressure - 500 torr

Flow rates:

GAS	STAINLESS STEEL BALL HEIGHTS	MIX RATIO
He	35	5
CO_2	68	1
N_2	70	1

Tank Regulator pressure
He - 40 psi
CO_2 - 40 psi
N_2 - 40 psi

3. Power Supply

Input power - 115V ac
Output power - 3mA - 7mA, 11.5 KV - 13.0 KV

4. Triggering

Thyratron driver to Hy 10 spark gap
Input power - 115V ac
Output power - 0 - 600V, externally or internally triggered to 10 Hz

5. Output Parameters

Output power - 10 pulses/sec. average .5w - .9w, 50 mj - 90mj
Transverse mode - TEM_{oo}
Transition - P-20

GAIN CELL

A. Start-up Procedure

As with the MO the hybrid cell is assumed to be aligned and all systems operable. The operating steps are:

1. Place beam block in front of mirror 3

2. Turn on the water cooling system

3. Turn on the vacuum pump

4. Switch on the vacuum pump snap valve to pump down system

5. Evacuate laser for 5 minutes at 0 torr

6. Open the three tank valves and set the regulators to 40 psi

7. Set the vernier needle valves to He - 5.50, N_2 - 3.25, CO_2 - 3.25

8. Leave the vacuum pump snap valve on and turn on the gas snap valves. Fill the cavity with the gas mix until 20 torr on the outlet side of laser is reached. Make any pressure adjustments using the Nupro valve.

9. Turn on the power to the cabinet

10. Turn the ionizing voltage on evenly and moderately quick to 10mA. Two people are needed when the system is turned on, one person to turn the power on and the other person to observe that the system is being ionized properly.

11. The same as step 15 in the MO start-up procedure

12. The same as step 16 in the MO start-up procedure

B. Problems with the Start-Up

1. The laser won't ionize

   a. The mix is not right

      1. Check to make certain tanks are open
      2. Check the vernier needle valve for the correct settings

   b. The pressure is not at 20 torr

2. Improper Ionizing

   a. Ionized down gas line

      1. Power turned on too quickly
      2. Wrong pressure

   b. Ionized down side of the anode

      1. Grounding not sufficiently contacted
      2. Wrong pressure

3. The same as step 3 in the problems with starting-up the MO

4. The same as step 4 in the problems with starting-up the MO

C. Shut Down Procedures

1. Turn off the power to the MO

2. Turn off the gas snap valves

3. Pump down the system

4. Turn off the cooling system

D. Operating Parameters

1. Plasma tube assembly

Overall length - 33" (approximate)
Cavity length - 72.5" (approximate)
Active length - 24" (approximate)
HR mirror - same as MO
Output Coupler - same as MO
Cooling - water

2. Gas Control System

Outlet pressure - 20 torr
Flow Rates:

GAS	VERNIER READING	PARTIAL PRESSURE MIX
He	5.50	16
CO_2	3.25	2
N_2	3.25	9

Tank Regulator Pressure
He - 40 psi
CO_2 - 40 psi
N_2 - 40 psi

3. Power Supply

Input power - 115V ac
Output power - 10mA, 10kV DC

4. Output Parameters

Output power - cw 3w to 10w
Transverse mode - TEM_{oo}
Transition - P-20

LUMONICS

The instruction manual is supplied by Lumonics.

SYNCHRONIZED PULSED TRIGGERING OF THE LUMONICS AND MO

The MO and the Lumonics must be synchronized to achieve maximum amplification. This synchronization is accomplished by triggering both systems with a double pulsed generator. The generator sends one signal to the Lumonics and another signal to the MO. The signals are then controlled by the generator's internal timer. This enables the operator to adjust both signals by tuning the pulsed generator.

The Lumonics is triggered by the pulsed output of the generator through a bnc cable. This cable is teed at the generator so the signal is sent to the Lumonics and to an oscilloscope. The bnc cable is connected to the Lumonics at the external trigger outlet (top left hand corner). The mode select must be on external trigger and the multiplier must be on X10.

The MO is triggered by the trigger output of the generator. A bnc tee is connected to the generator trigger output so the signal can go to the thyratron driver and an oscilloscope. The thyratron driver is connected at the external trigger in and the mode selector (range PPS) is set at ext.

The oscilloscope is used to maintain a 10Hz rep rate and to show the relationship of the pulsed signal to the triggered signal.

The other pertinent controls on the generator are set at:

DIAL	Setting
Trigger Mode	Int.
Int. Rep Rate	.01-.1
(Left) Vernier	1
Pulse Position	10-100
Pulse Timing	Pulse Advance
(Middle) Vernier	5
Pulse Width	1-10
Trigger Output	+
(Right) Vernier	Straight up
Pulse Amplitude	5 volts
Pulse Output	+

PLACE A
EADS.

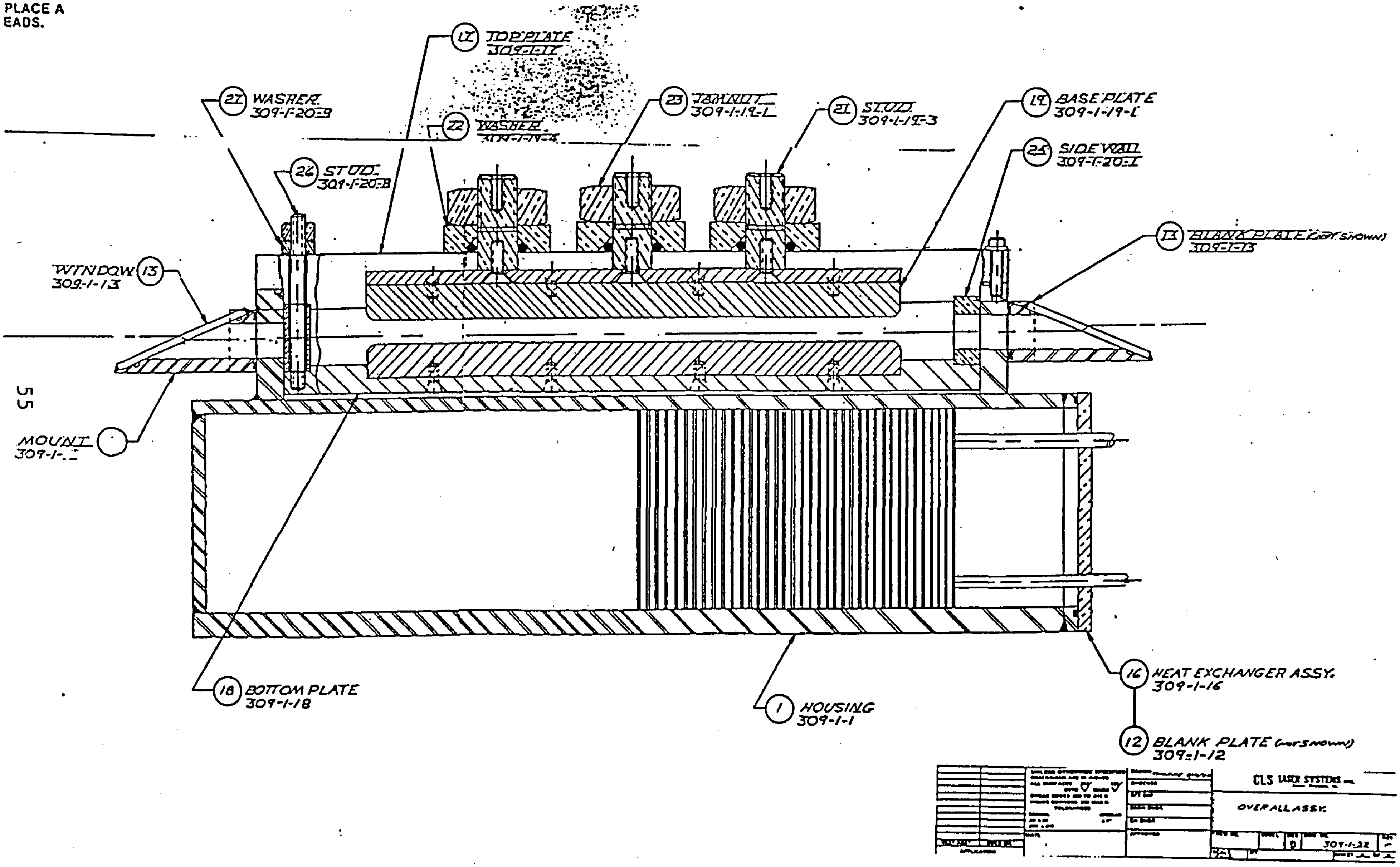
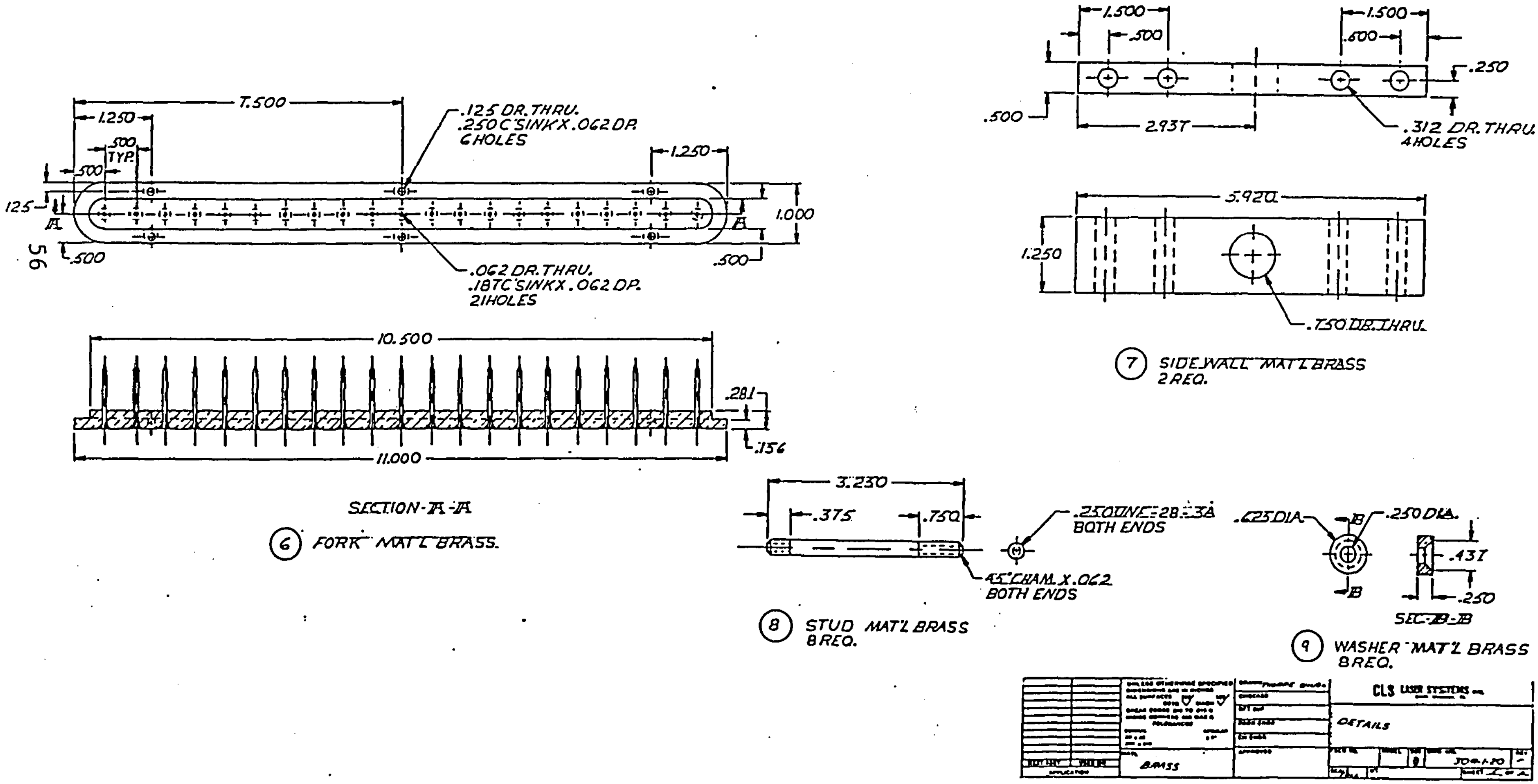


FIG 1



7.500
1.250
.500 TYP.
.500
.125 DR. THRU.
.250 C'SINK X .062 DP.
6 HOLES
1.250
1.000
.062 DR. THRU.
.187 C'SINK X .062 DP.
21 HOLES
10.500
.281
.156
11.000
SECTION-A-A
6 FORK MAT'L BRASS.
1.500
.500
.600
.250
.312 DR. THRU.
4 HOLES
2.937
5.920
1.250
.750 DR. THRU.
7 SIDEWALL MAT'L BRASS
2 REQ.
3.230
.375
.750
45° CHAM. X .062
BOTH ENDS
BOTH ENDS
8 STUD MAT'L BRASS
8 REQ.
.625 DIA.
.250 DIA.
.437
.250
SEC-B-B
9 WASHER MAT'L BRASS
8 REQ.
CLS LASER SYSTEMS
DETAILS
BRASS

56

FIG 2

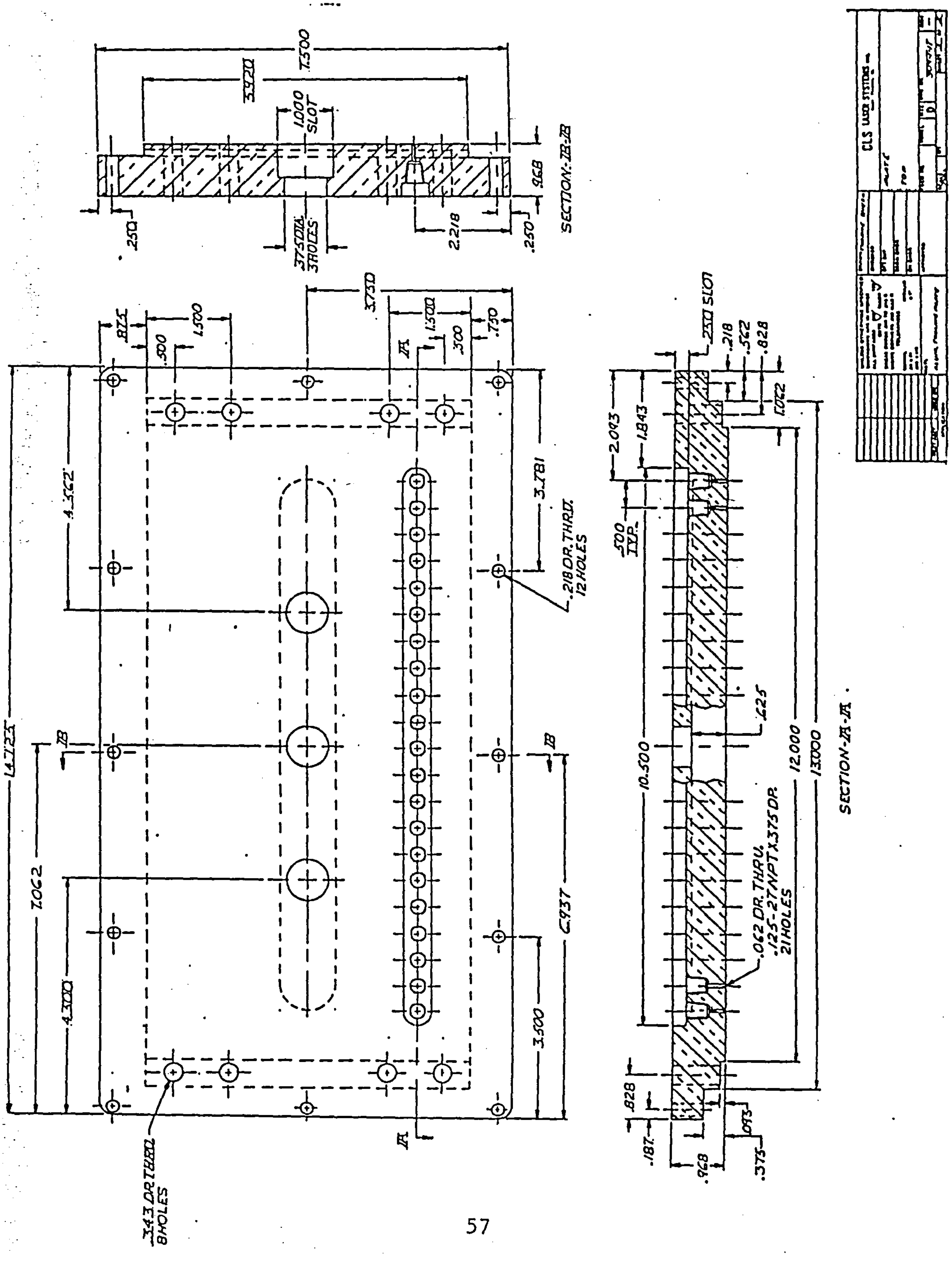
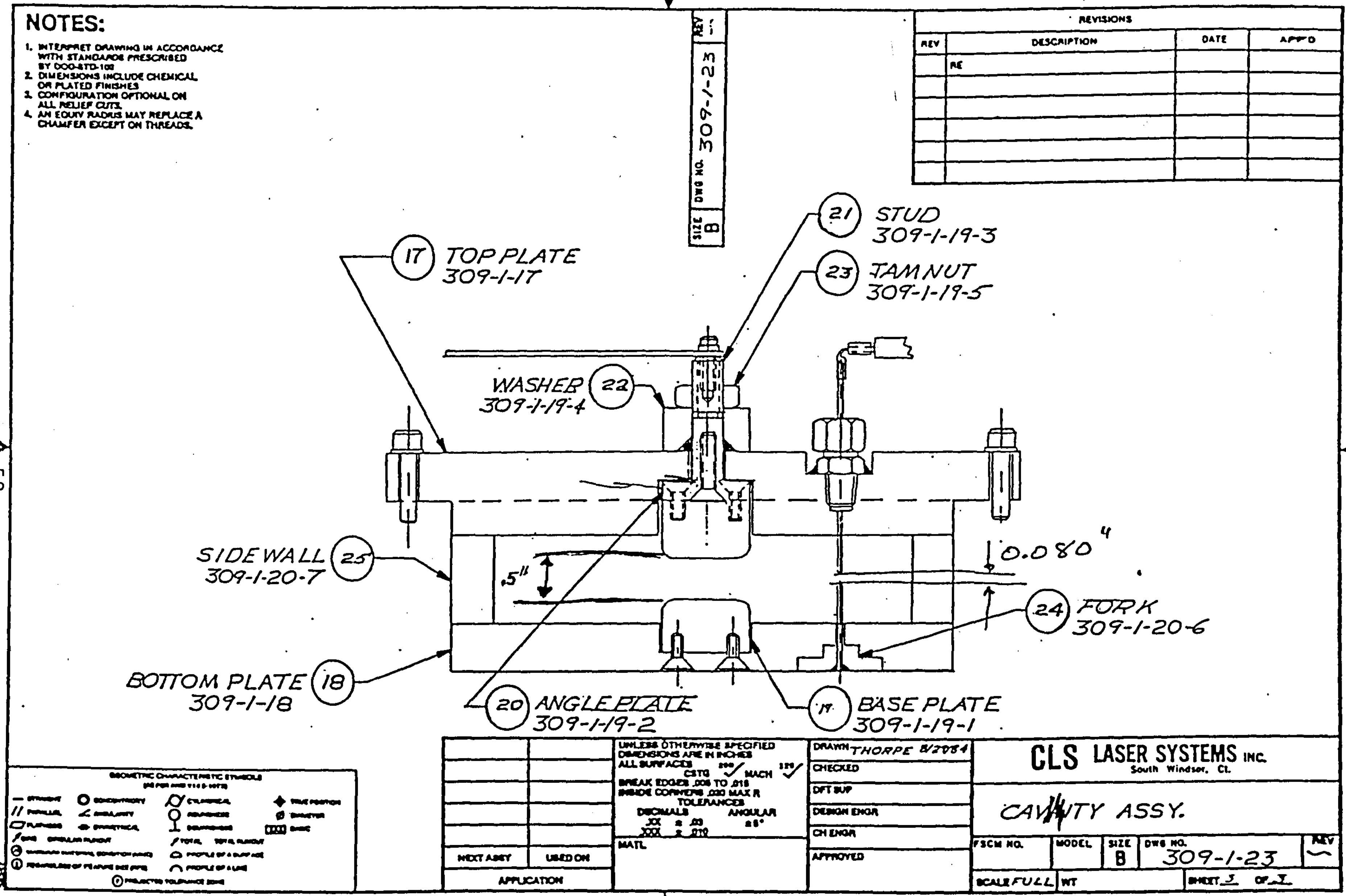

7.500
5.920
1.000 SLOT
.968
.250
.375 DIA. 3 HOLES
2.218
.250
SECTION: B-B
14.125
4.562
7.062
4.300
.875
.500
1.500
3.750
1.500
.300
.750
3.781
.218 DR. THRU. 12 HOLES
6.937
3.500
.343 DR. THRU 8 HOLES
2.093
1.843
.500 TYP.
10.500
.250 SLOT
.218
.562
.828
1.062
12.000
13.000
.625
.062 DR. THRU. .125-27NPT X .375 DP. 21 HOLES
SECTION-A-A
.828
.187
.968
.093
.375
CLS LASER SYSTEMS

FIG 3



NOTES:
1. INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY DOD-STD-100
2. DIMENSIONS INCLUDE CHEMICAL OR PLATED FINISHES
3. CONFIGURATION OPTIONAL ON ALL RELIEF CUTS
4. AN EQUIV RADIUS MAY REPLACE A CHAMFER EXCEPT ON THREADS.
SIZE B DWG NO. 309-1-23 REV
REVISIONS
REV DESCRIPTION DATE APP'D
RE
17 TOP PLATE 309-1-17
21 STUD 309-1-19-3
23 JAM NUT 309-1-19-5
WASHER 22 309-1-19-4
SIDEWALL 25 309-1-20-7
.5"
0.080"
24 FORK 309-1-20-6
BOTTOM PLATE 18 309-1-18
20 ANGLE PLATE 309-1-19-2
19 BASE PLATE 309-1-19-1
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
ALL SURFACES CSTG MACH
BREAK EDGES .005 TO .015
INSIDE CORNERS .030 MAX R
TOLERANCES
DECIMALS ANGULAR
.XX ± .03
.XXX ± .010
MATL
NEXT ASSY USED ON
APPLICATION
DRAWN THORPE 8/20/84
CHECKED
DFT SUP
DESIGN ENGR
CH ENGR
APPROVED
CLS LASER SYSTEMS INC. South Windsor, Ct.
CAVITY ASSY.
FSCM NO. MODEL SIZE B DWG NO. 309-1-23 REV
SCALE FULL WT SHEET 3 OF 3

FIG 4

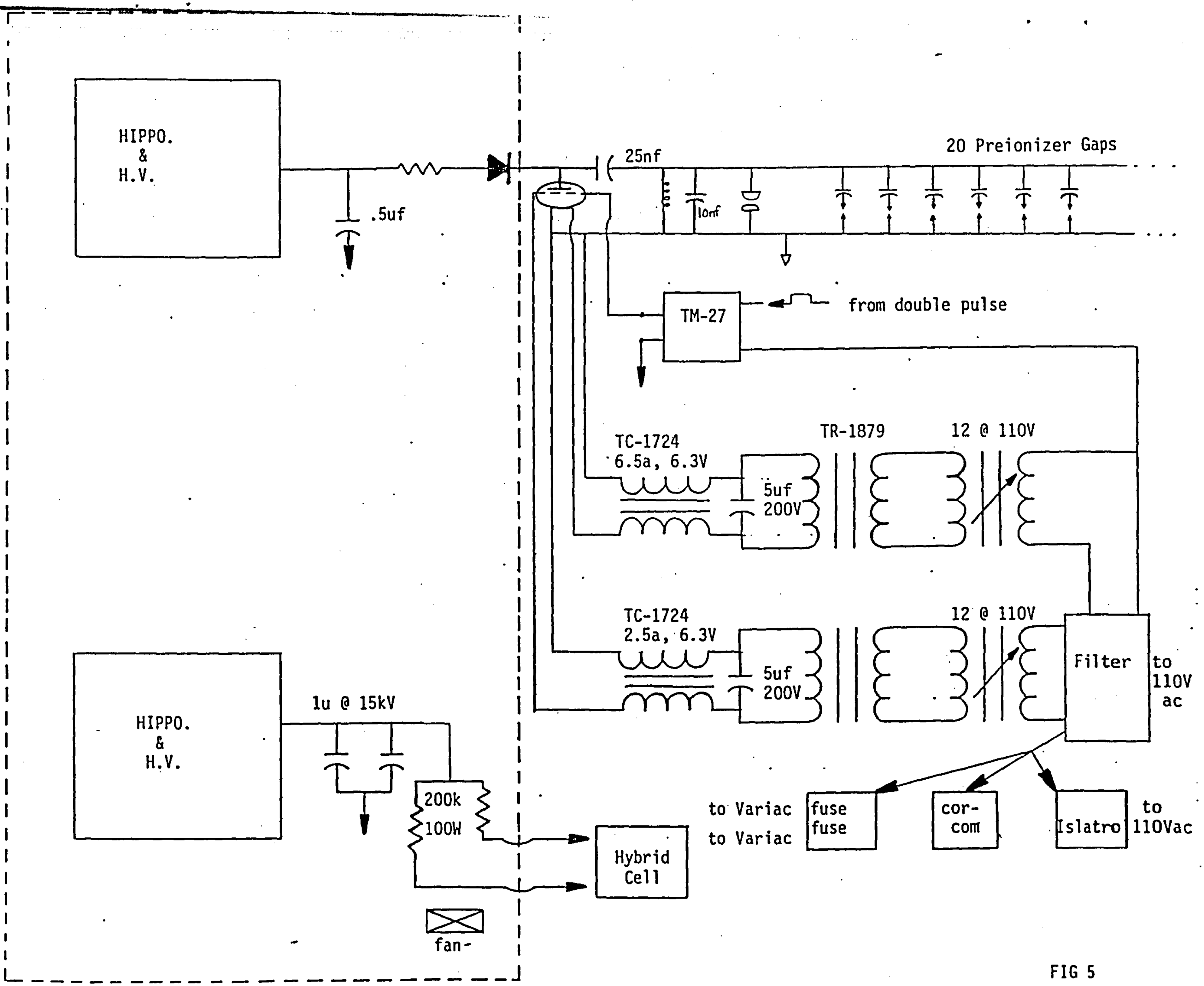
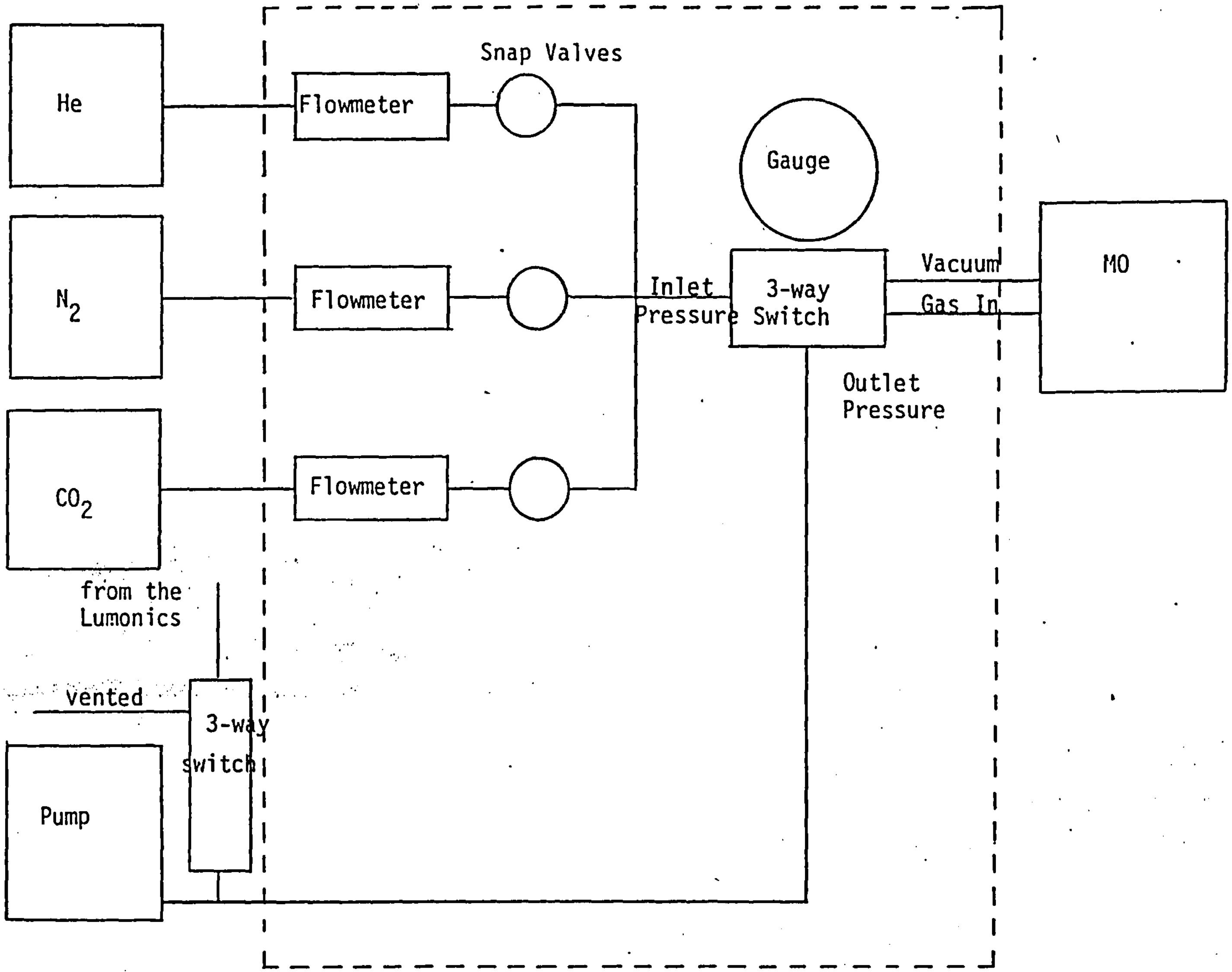

HIPPO.
&
H.V.
.5uf
25nf
20 Preionizer Gaps
10nf
TM-27
from double pulse
TC-1724
6.5a, 6.3V
5uf
200V
TR-1879
12 @ 110V
TC-1724
2.5a, 6.3V
5uf
200V
12 @ 110V
Filter
to
110V
ac
HIPPO.
&
H.V.
1u @ 15kV
200k
100W
Hybrid
Cell
fan-
to Variac
to Variac
fuse
fuse
cor-
com
Islatro
to
110Vac

FIG 5



MO Gas Control System

FIG 6

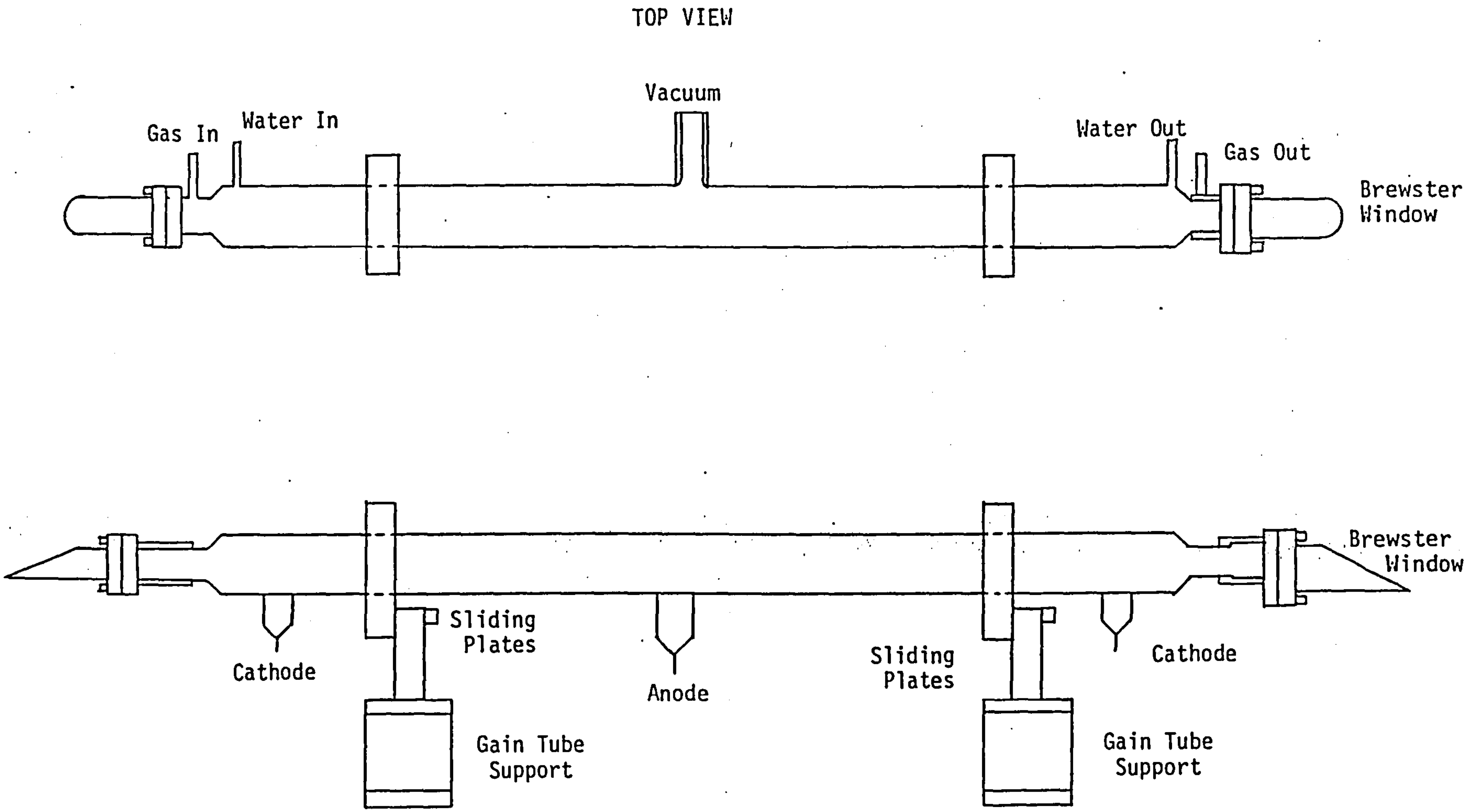

TOP VIEW
Vacuum
Gas In
Water In
Water Out
Gas Out
Brewster Window
Brewster Window
Sliding Plates
Cathode
Anode
Sliding Plates
Cathode
Gain Tube Support
Gain Tube Support

FIG 7

GT GAS CONTROL SYSTEM

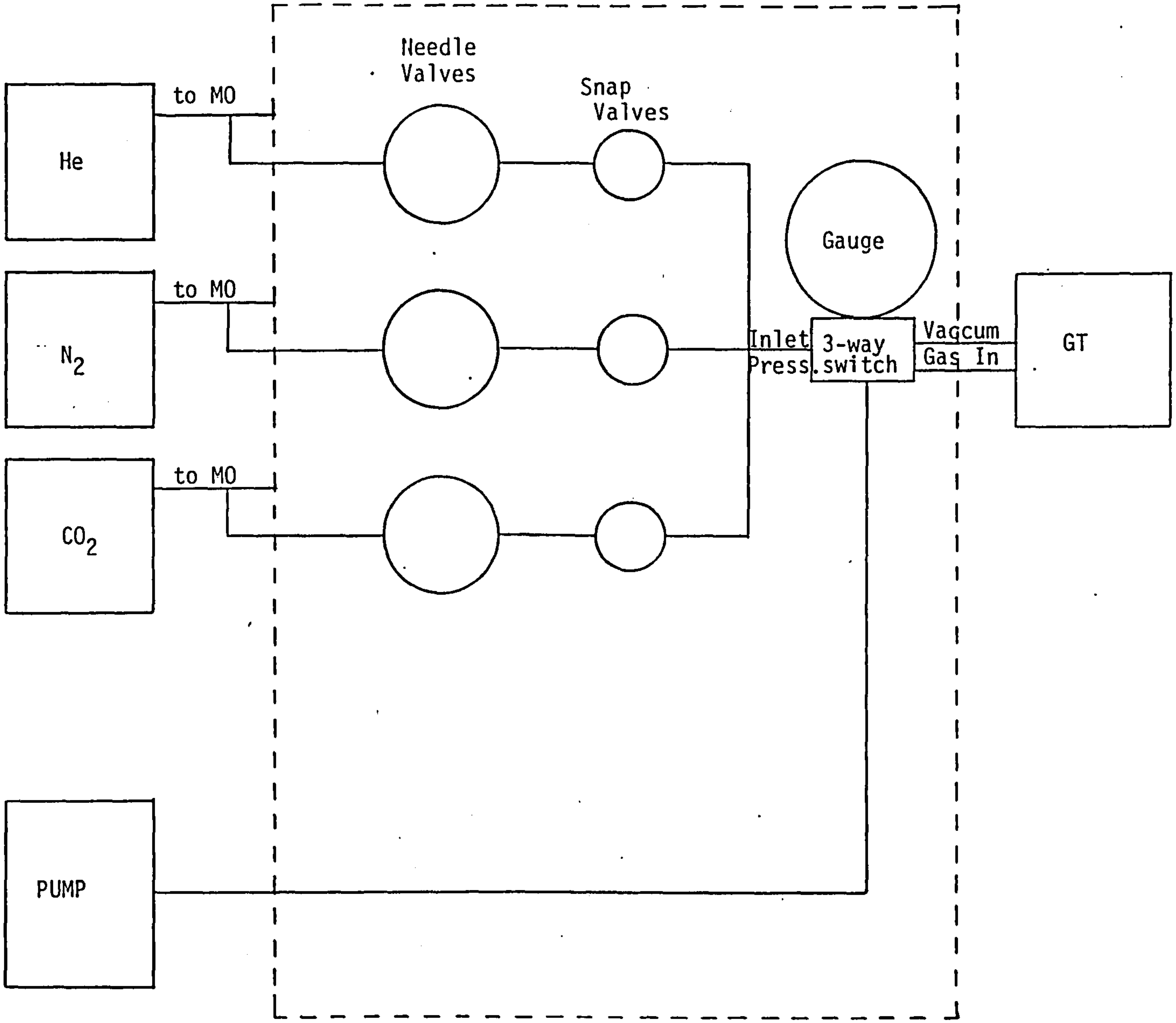


FIG 6

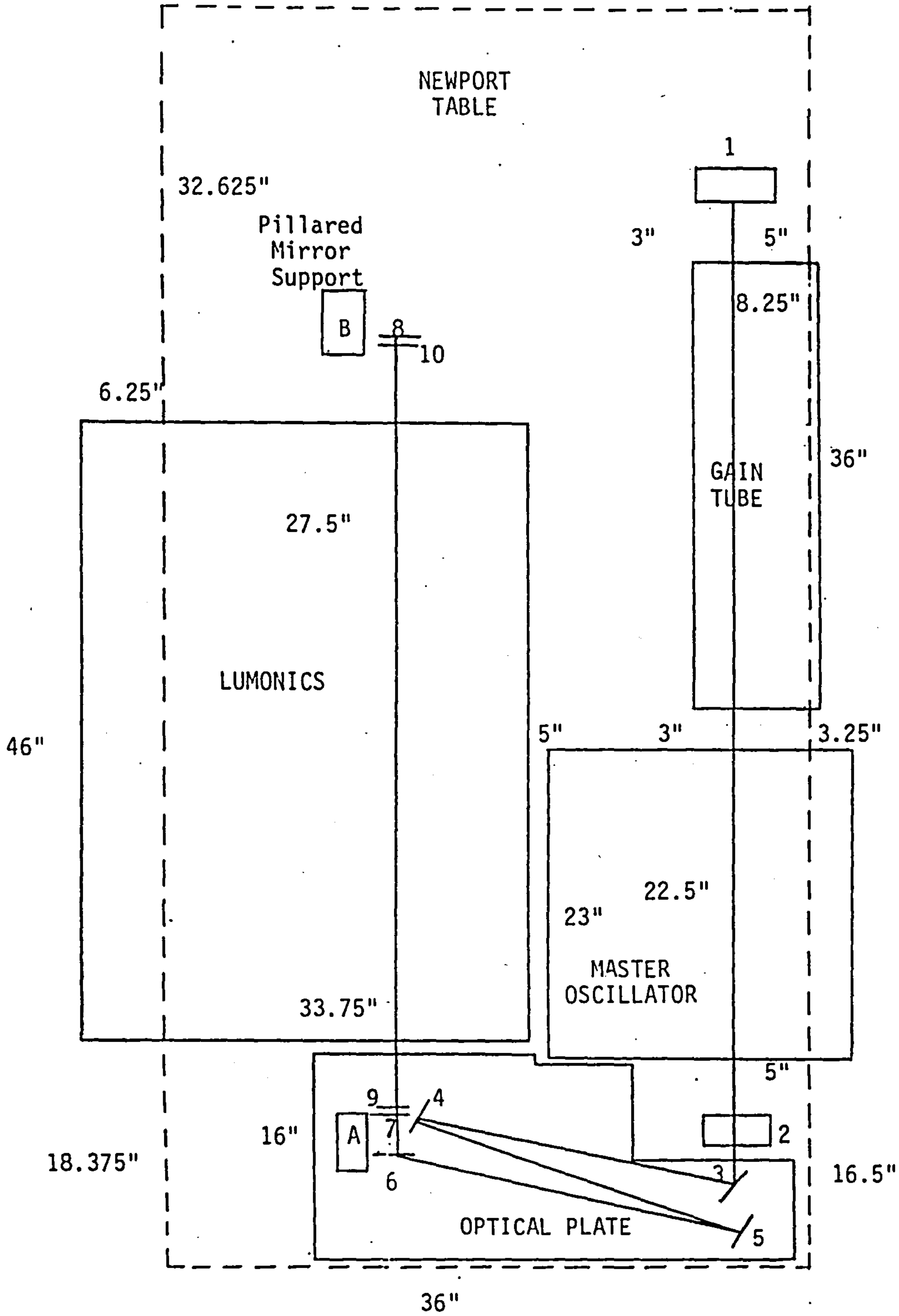
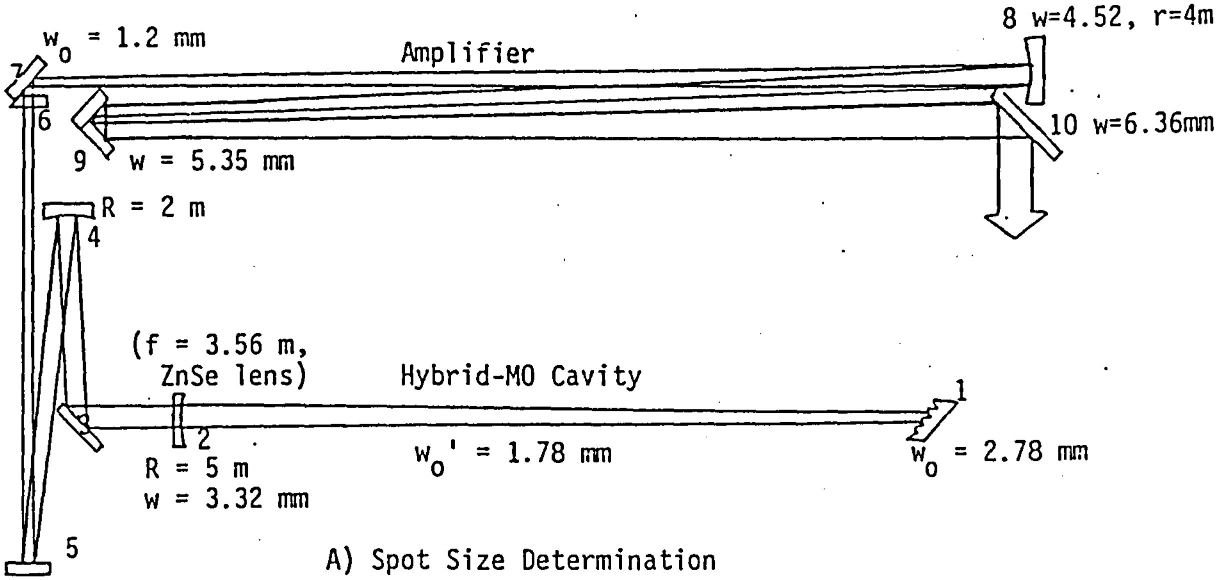
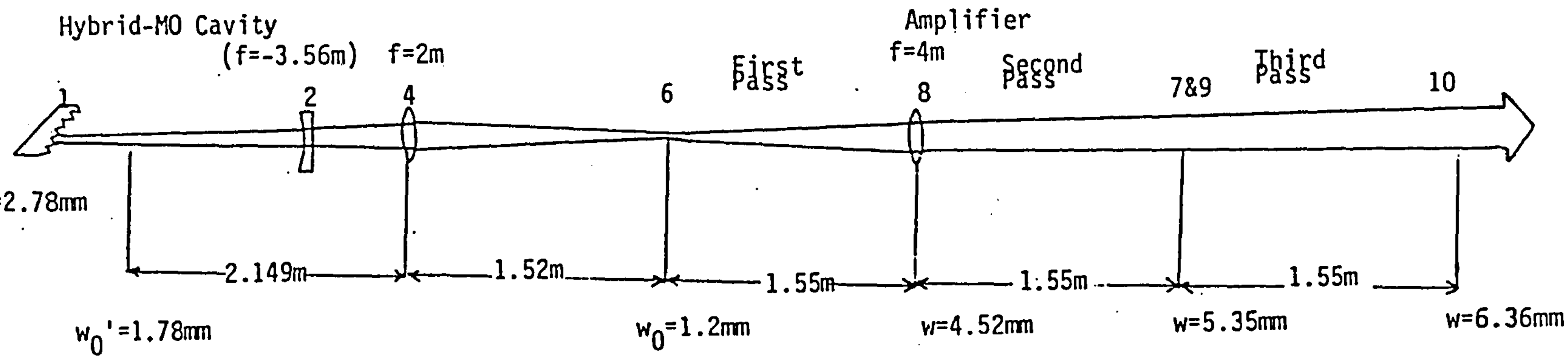

NEWPORT TABLE
1
32.625"
Pillared Mirror Support
3"
5"
8.25"
B
8
10
6.25"
36"
GAIN TUBE
27.5"
LUMONICS
46"
5"
3"
3.25"
22.5"
23"
MASTER OSCILLATOR
33.75"
5"
9
4
16"
A
7
2
18.375"
6
3
16.5"
OPTICAL PLATE
5
36"

FIG 9

MOPA OPTICAL DESIGN



A) Spot Size Determination



B) Unfolded Beam Paths

FIG. 10

MOPA DESIGN

Schematic Component Layout

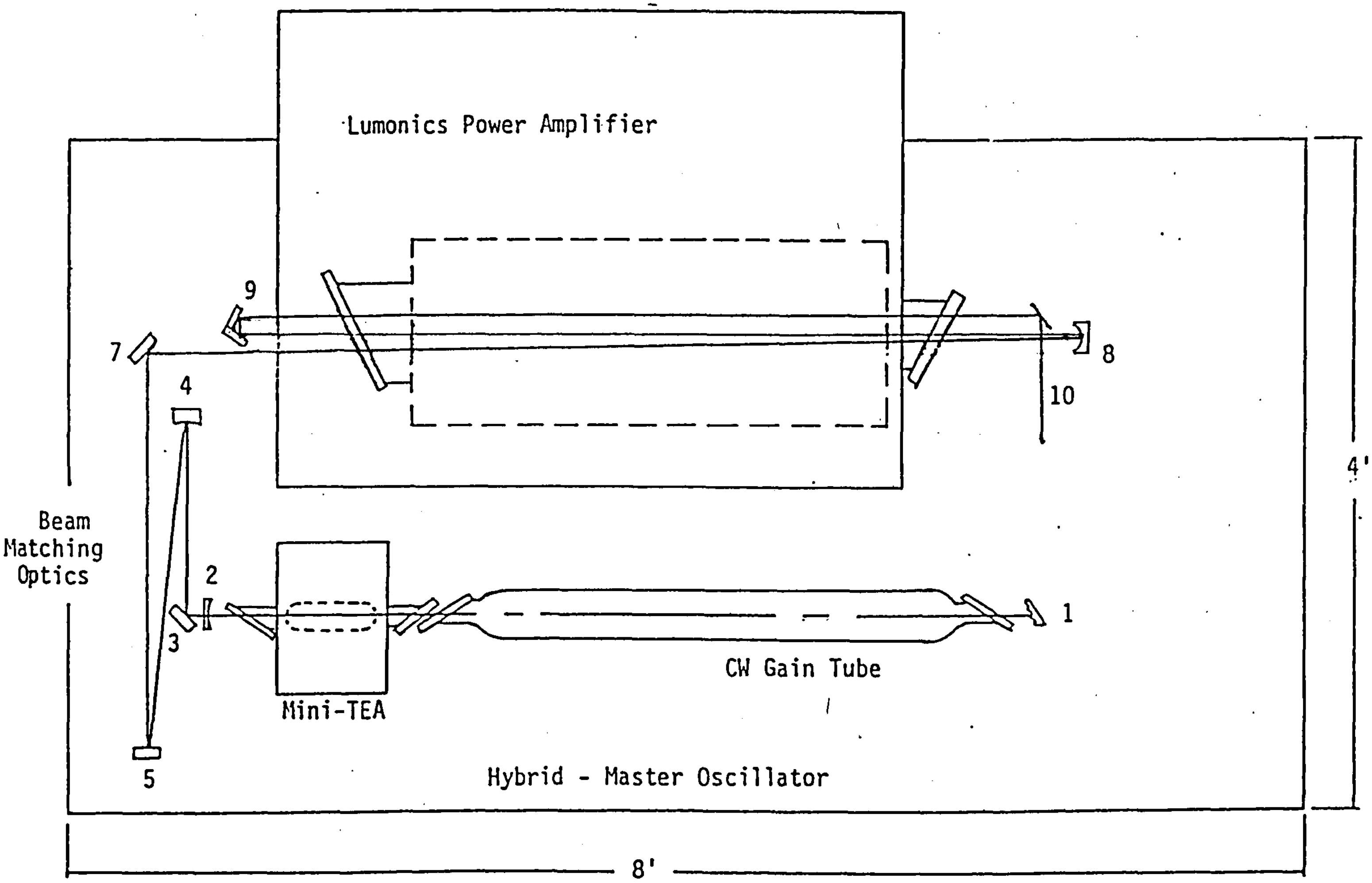


FIG. 11

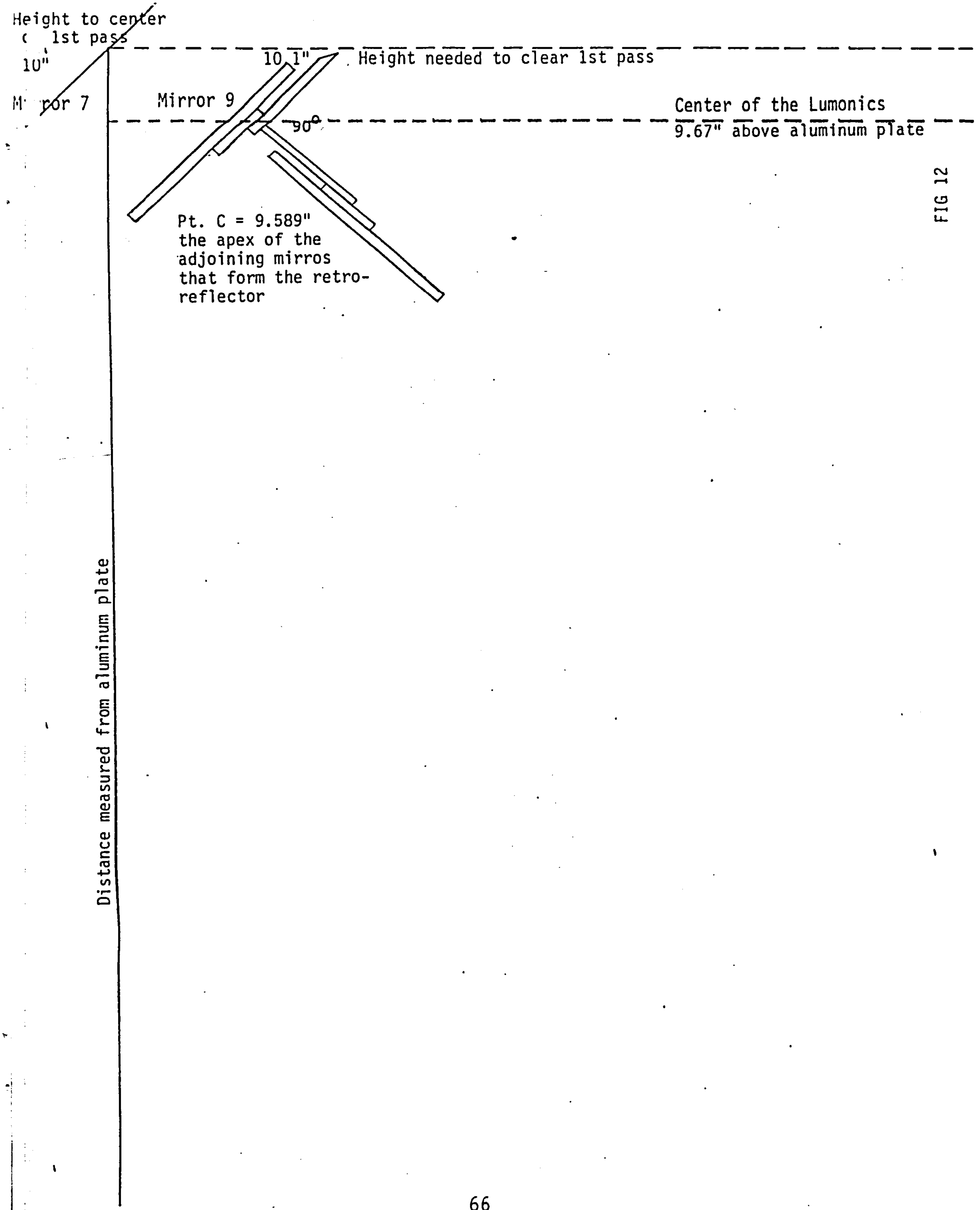
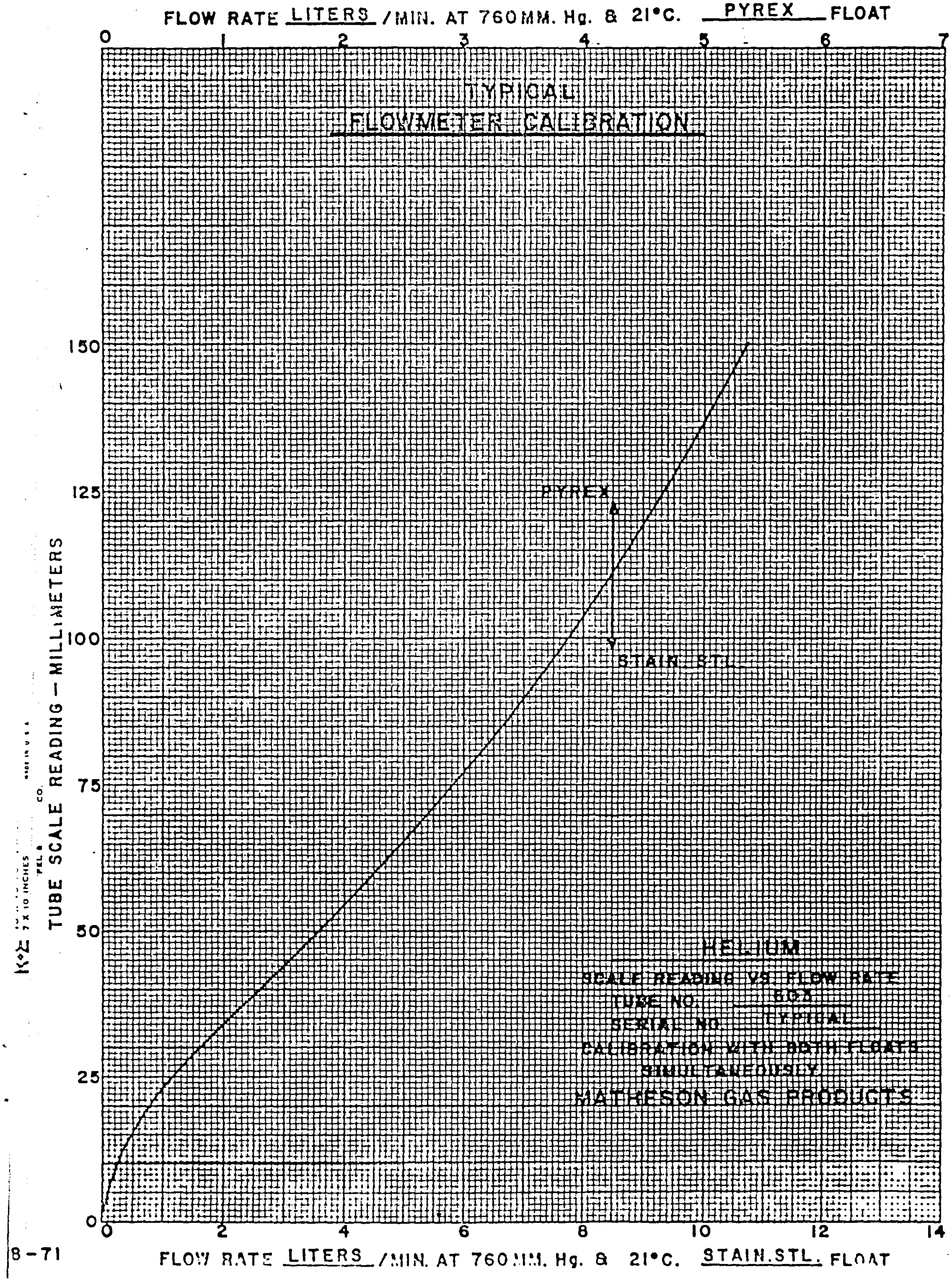
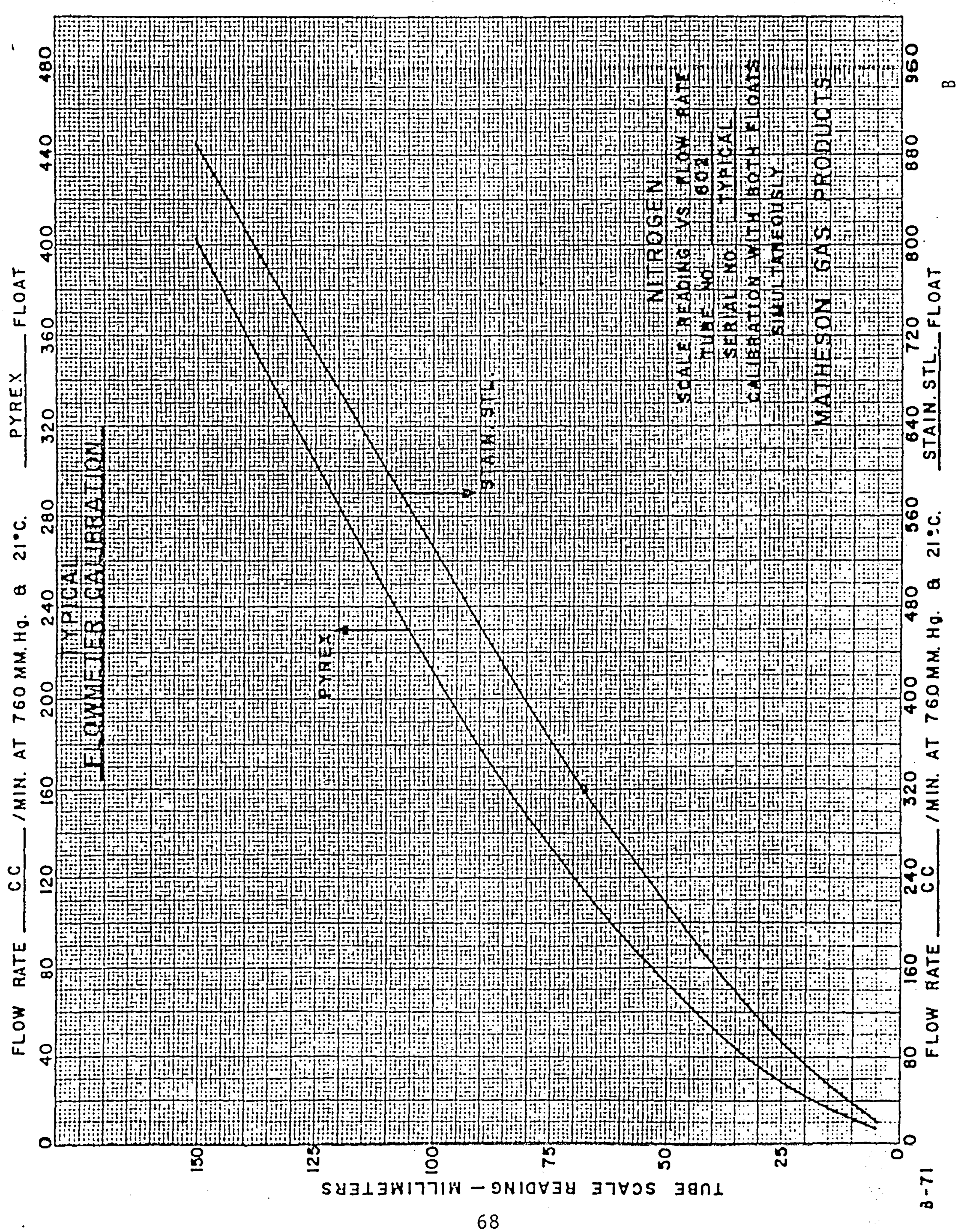
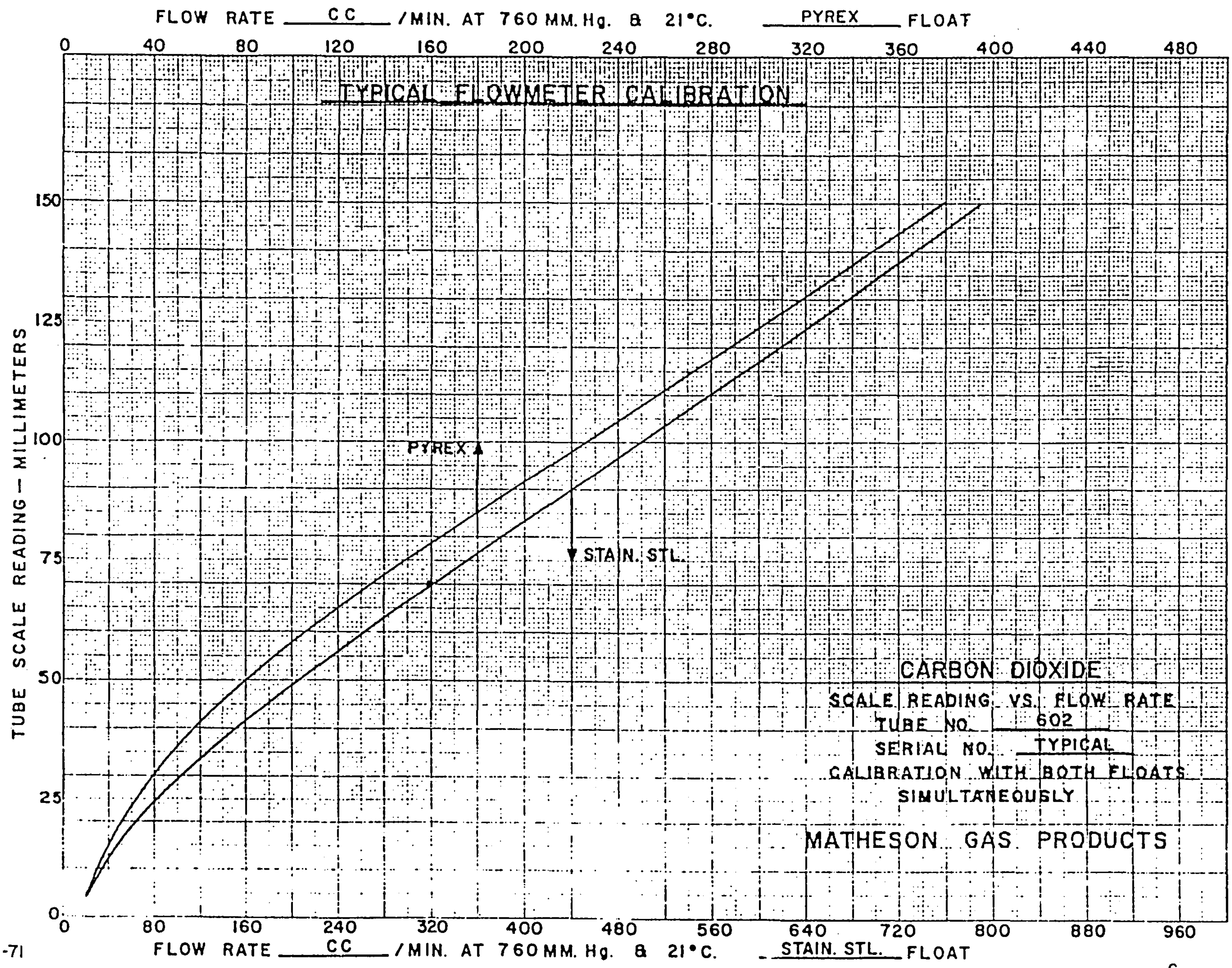

Height to center
1st pass
10"
10.1"
Height needed to clear 1st pass
Mirror 9
Center of the Lumonics
9.67" above aluminum plate
90°
Pt. C = 9.589"
the apex of the
adjoining mirros
that form the retro-
reflector
Distance measured from aluminum plate

FIG 12


FLOW RATE LITERS /MIN. AT 760MM. Hg. & 21°C. PYREX FLOAT
0
1
2
3
4
5
6
7
TYPICAL
FLOWMETER CALIBRATION
TUBE SCALE READING — MILLIMETERS
150
125
100
75
50
25
0
PYREX
STAIN. STL.
HELIUM
SCALE READING VS. FLOW RATE
TUBE NO. 603
SERIAL NO. TYPICAL
CALIBRATION WITH BOTH FLOATS SIMULTANEOUSLY
MATHESON GAS PRODUCTS
0
2
4
6
8
10
12
14
FLOW RATE LITERS /MIN. AT 760MM. Hg. & 21°C. STAIN.STL. FLOAT

8-71


FLOW RATE CC /MIN. AT 760 MM. Hg. @ 21°C. PYREX FLOAT
0 40 80 120 160 200 240 280 320 360 400 440 480
TYPICAL
FLOWMETER CALIBRATION
PYREX
STAIN. STL.
NITROGEN
SCALE READING VS FLOW RATE
TUBE NO. 602
SERIAL NO. TYPICAL
CALIBRATION WITH BOTH FLOATS
SIMULTANEOUSLY
MATHESON GAS PRODUCTS
0 80 160 240 320 400 480 560 640 720 800 880 960
FLOW RATE CC /MIN. AT 760 MM. Hg. @ 21°C. STAIN. STL. FLOAT
0 25 50 75 100 125 150
TUBE SCALE READING — MILLIMETERS
B-71
B


FLOW RATE CC /MIN. AT 760 MM. Hg. & 21°C. PYREX FLOAT
0 40 80 120 160 200 240 280 320 360 400 440 480
TYPICAL FLOWMETER CALIBRATION
TUBE SCALE READING — MILLIMETERS
150
125
100
75
50
25
0
PYREX
STAIN. STL.
CARBON DIOXIDE
SCALE READING VS. FLOW RATE
TUBE NO. 602
SERIAL NO. TYPICAL
CALIBRATION WITH BOTH FLOATS
SIMULTANEOUSLY
MATHESON GAS PRODUCTS
0 80 160 240 320 400 480 560 640 720 800 880 960
FLOW RATE CC /MIN. AT 760 MM. Hg. & 21°C. STAIN. STL. FLOAT

8-71

C

ACOUSTO-OPTIC MODULATOR CONTROL UNIT

CLS Laser Systems, Inc. designed, assembled, tested and delivered an Acousto-Optic Modulator Control Unit to NASA Langley. This device served as the triggerable "switch" that controlled a commercial germanium acousto-optic modulator to allow injection control of a pulsed TEA gain medium. The injection control signal was provided until the optical pulse evolved in the TEA gain medium, at which time the unit terminated the drive signal to the modulator, thus terminating the cw injected optical signal for 500 microseconds. This served to preclude feedthrough of the cw injection optical signal into the optical receiver of the LIDAR system during the period in which a return pulse was expected. A complete description of the AOMC, interconnect diagram, and schematics are contained in the following pages.

CLS ACOUSTO-OPTIC MODULATOR CONTROL: FUNCTIONAL DESCRIPTION

The Acousto-Optic Modulator Control (AOMC) unit is designed to allow electronic control of a 40 MHz frequency shifted 10.6 μm beam for injection control of a pulsed CO_2 TEA oscillator. The output of the AOMC is amplified by using a single RF amplifier (ie: ENI Model 510L) to drive a 50 ohm load (such as an acousto-optic modulator, ie: Intra-Action Model AGM406) at 10 Watts RF power at a frequency of 40 MHz. The AOMC is designed to plug into a standard Tektronix TM 504 power-module mainframe.

The unit may be operated in either a cw mode or pulsed mode and can be externally triggered. It provides a separate output pulse for modulation blanking, ie: clamping the correction voltage and ac dither voltage applied to the injection laser source and the injection controlled oscillator piezoelectric elements by separate lock-in stabilizer units. In the pulse mode, the period of time that the frequency shifted beam is allowed to continue after the trigger pulse is received is externally controllable from 2 - 12 microseconds. This assures injection control of the pulsed TEA gain medium during the optical pulse build-up time. After that period, the frequency shifted beam remains off for a fixed period of 500 microseconds before automatically turning back on, until the next trigger pulse is received.

A brief explanation of the operator controls and output-input jacks is given below:

RF OSCILLATOR ON/OFF Switch -
Provides primary power from the TM 504 mainframe to the AOMC unit.

OUTPUT Jack -
Output terminal of the AOMC. The 40 MHz RF signal at this jack should be connected via 50 ohm coax to a single ENI 510L amplifier and then to an IntraAction AGM-406 acousto-optic modulator. The AOMC is internally adjusted to provide a fixed 10 watts of 40 MHz RF power when connected in this manner.

MODE SELECT Switch - PULSE/CW
In the CW position, the 40 MHz RF output of the AOMC is on continously. In the PULSE position, the unit will generate a 1 ms PZT HOLD signal and shut off the RF signal to the modulator for a fixed period of 500 usec (after an adjustable 2-12 usec delay) upon receiving a positive TTL level input triggering pulse.

PZT HOLD Jack
Provides a 1 millisecond open collector output pulse (logic zero or effective ground) (commensurate with the trigger input signal) for triggering modulation blanking circuits that clamp the piezoelectric transducer voltage applied to the laser(s) PZT elements by any Lansing Model 80.215 Lock-In Stabilizer units. The duration of the modulation blanking cycle is separately controllable on the Lansing units. The PZT HOLD signal is generated only in the PULSE mode of the AOMC.

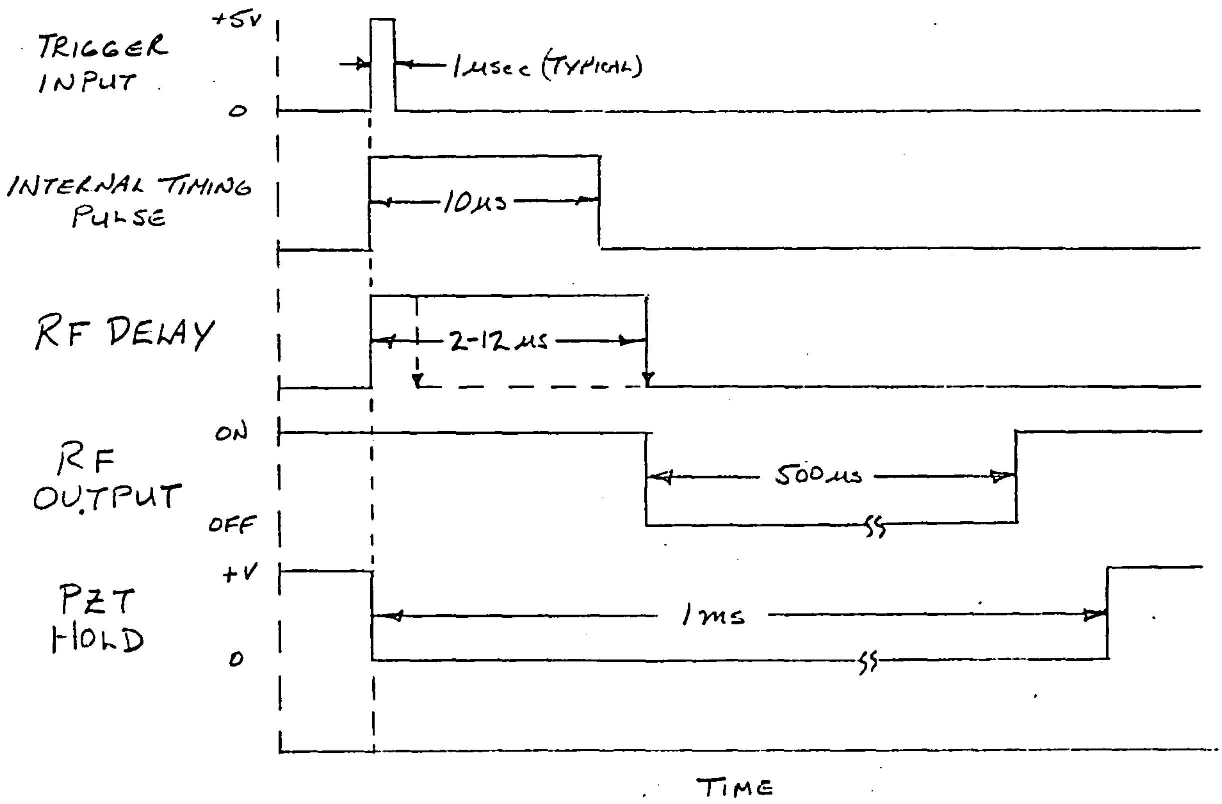
PULSE MODE - RF DELAY Potentiometer

Allows front panel selection of the duration of the RF OUTPUT signal after receipt of a TRIGGER INPUT signal by the AOMC. This delay is adjustable from 2 to 12 microseconds. After the delay period, the RF OUTPUT signal is terminated for a fixed period of 500 microseconds, after which time the RF signal is automatically re-established. This feature assures injection control of a pulsed CO_2 gain medium even if the triggering signal is derived before the gain has time to establish and the optical pulse to form (ie: when the trigger is derived from the same signal that triggers the preionizer or main discharge circuits of the pulsed laser)

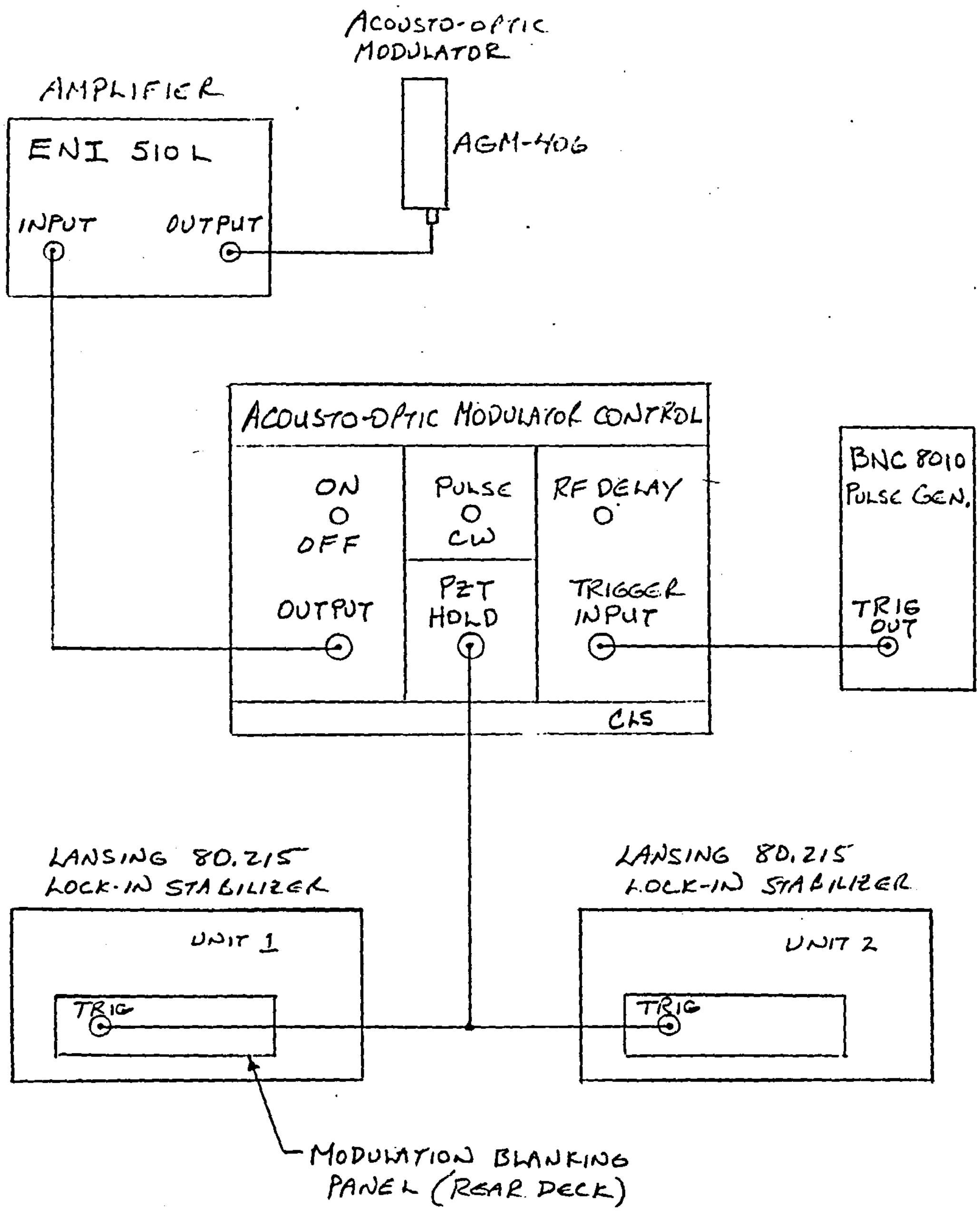
TRIGGER INPUT Jack

Accepts a 5 volt TTL level trigger pulse from an external triggering source. The AOMC unit may be triggered, for example, from the 5 volt output signal delivered by the NASA owned BNC 8010 Pulse Generator that is also used to trigger data scopes and the Biomation unit.

A typical timing sequense for the AOMC in the PULSE mode of operation is shown below:



ACOUSTO-OPTIC INJECTION CONTROL SYSTEM INTERCONNECT DIAGRAM



NASA LIDAR OPTICAL SCHEMATIC AND ELECTRONIC INTERCONNECT DIAGRAM

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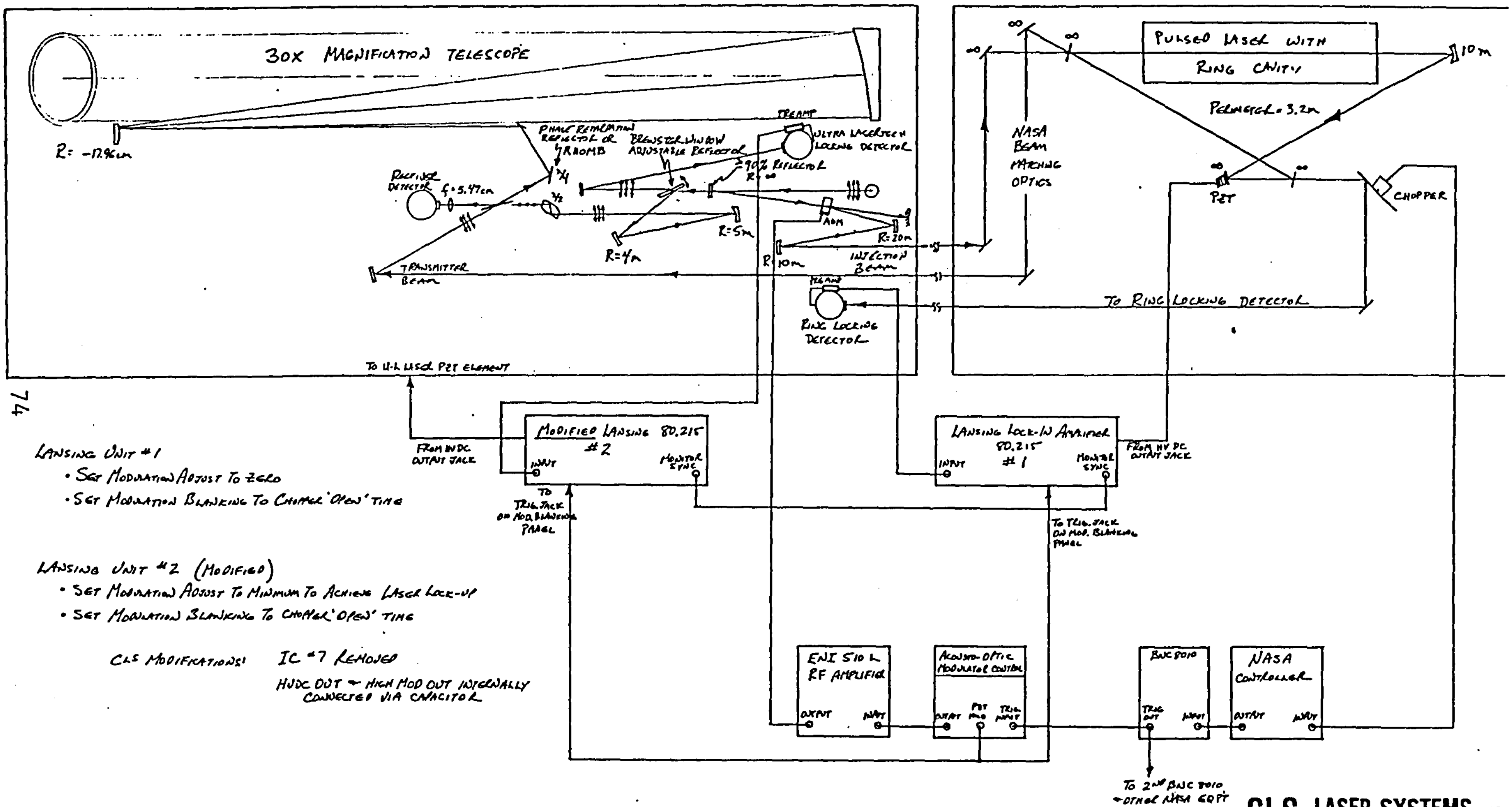

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LANSING UNIT #1

- SET MODULATION ADJUST TO ZERO
- SET MODULATION BLANKING TO CHOPPER 'OPEN' TIME

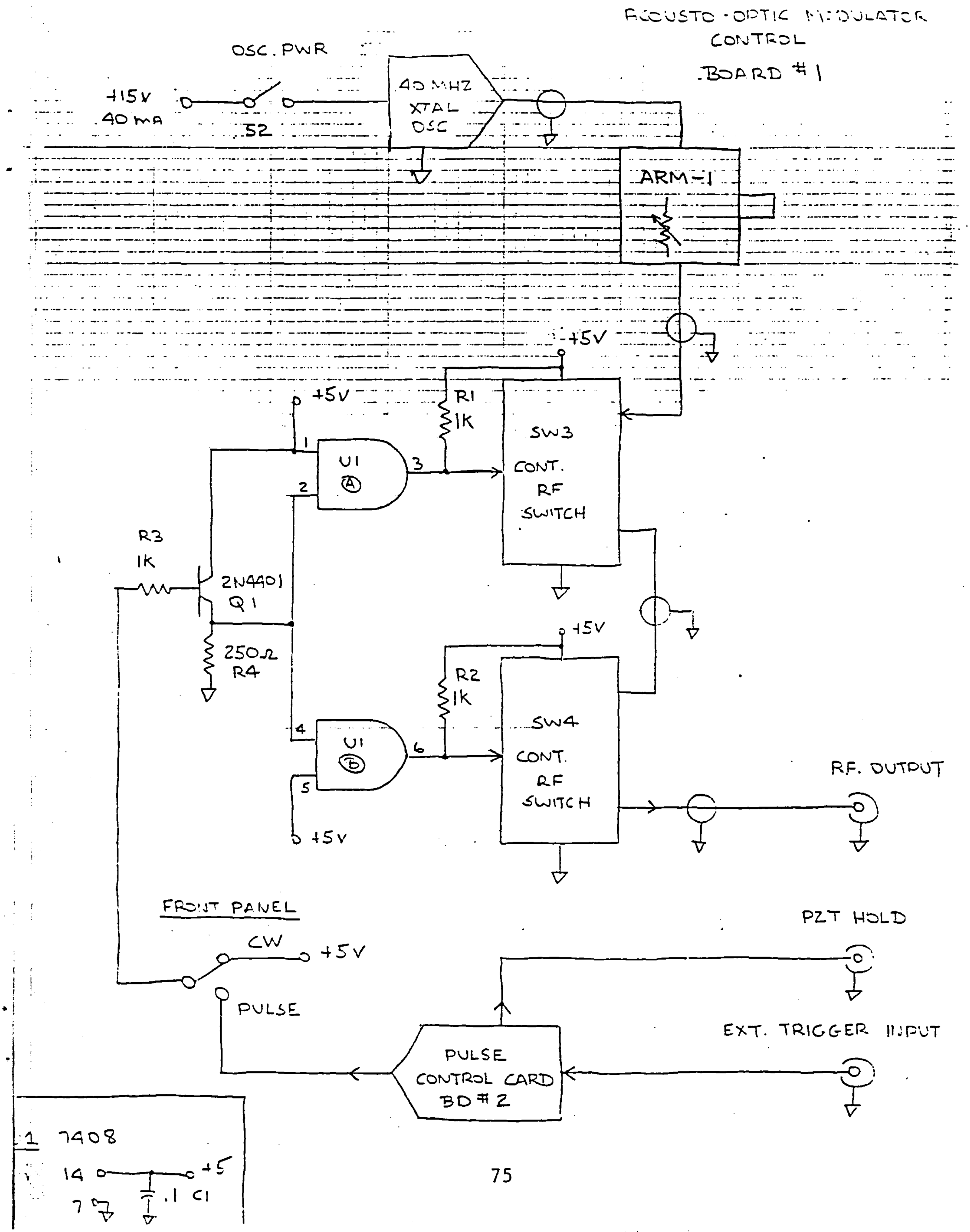
LANSING UNIT #2 (MODIFIED)

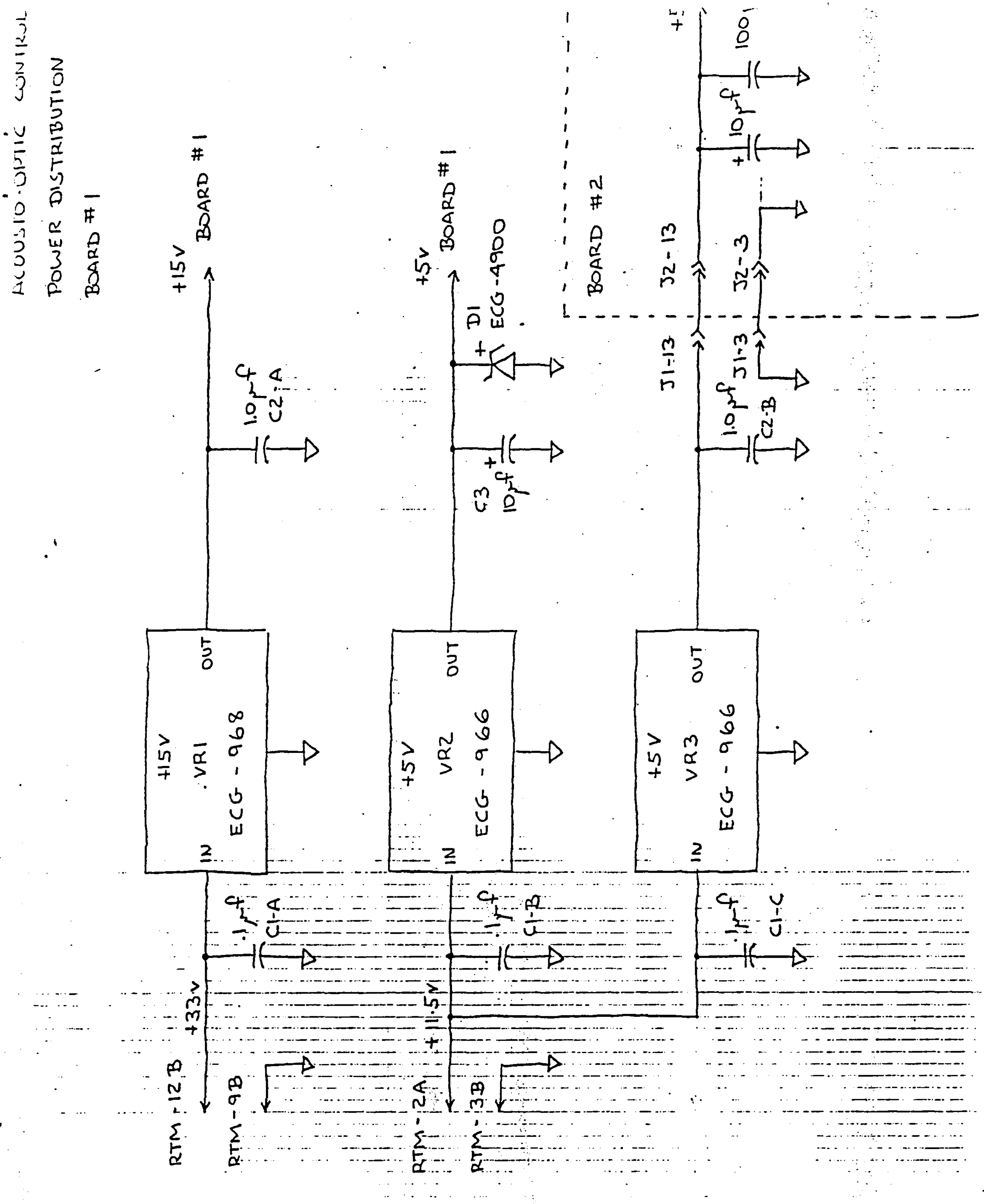
- SET MODULATION ADJUST TO MINIMUM TO ACHIEVE LASER LOCK-UP
- SET MODULATION BLANKING TO CHOPPER 'OPEN' TIME

CLS MODIFICATIONS: IC #7 REMOVED

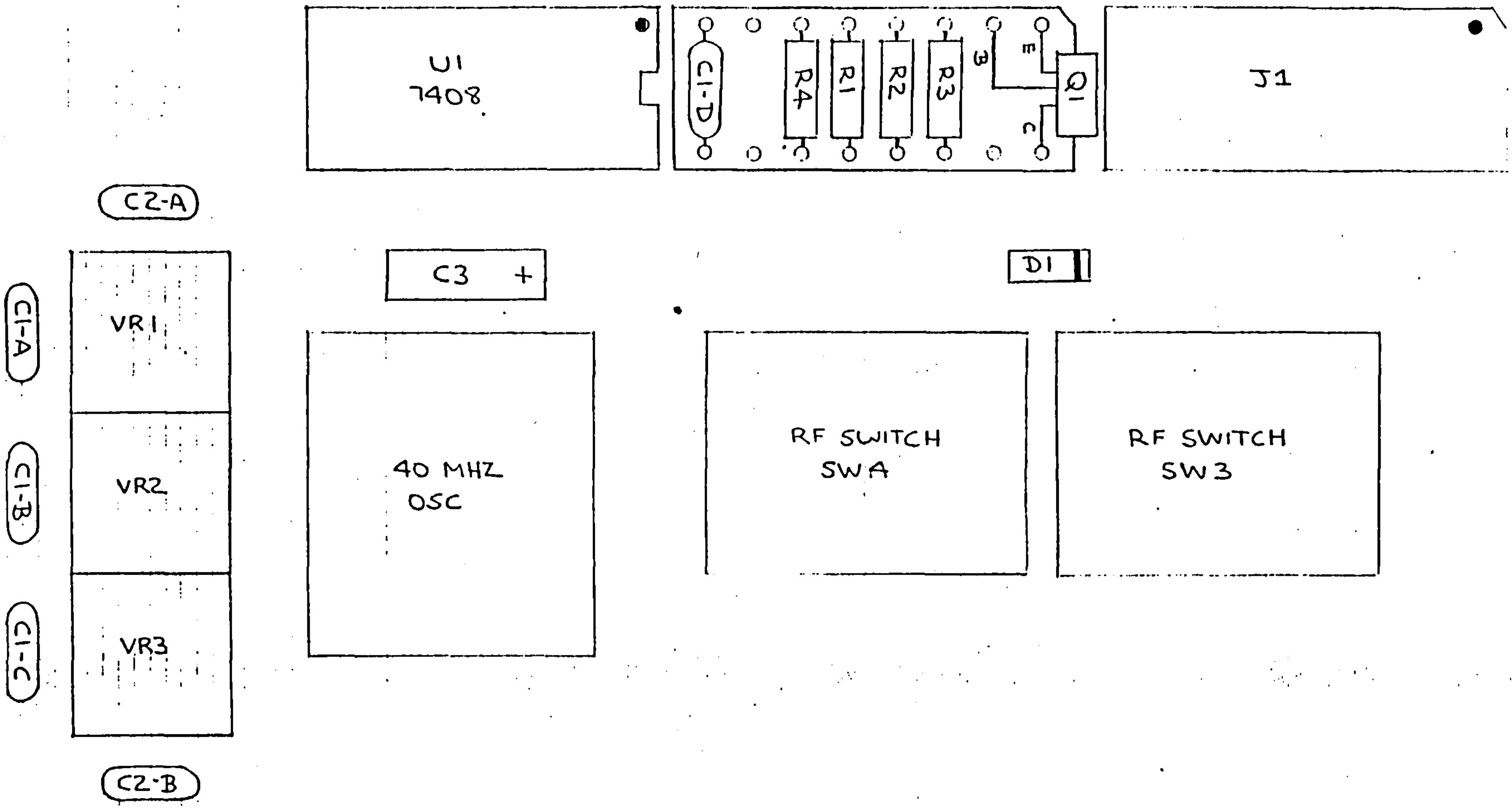
HVDC OUT → HIGH MOD OUT INTERNALLY CONNECTED VIA CAPACITOR

CLS LASER SYSTEMS INC.
South Windsor, Ct.


ACOUSTO-OPTIC MODULATOR CONTROL
BOARD #1
OSC. PWR
+15V 40 mA
S2
40 MHZ XTAL OSC
ARM-1
+5V
R1 1K
U1 Ⓐ
SW3 CONT. RF SWITCH
R3 1K
2N4401 Q1
250Ω R4
R2 1K
U1 Ⓑ
SW4 CONT. RF SWITCH
RF. OUTPUT
FRONT PANEL
CW
PULSE
PZT HOLD
EXT. TRIGGER INPUT
PULSE CONTROL CARD BD #2
U1 7408
14 +5
7
.1 C1

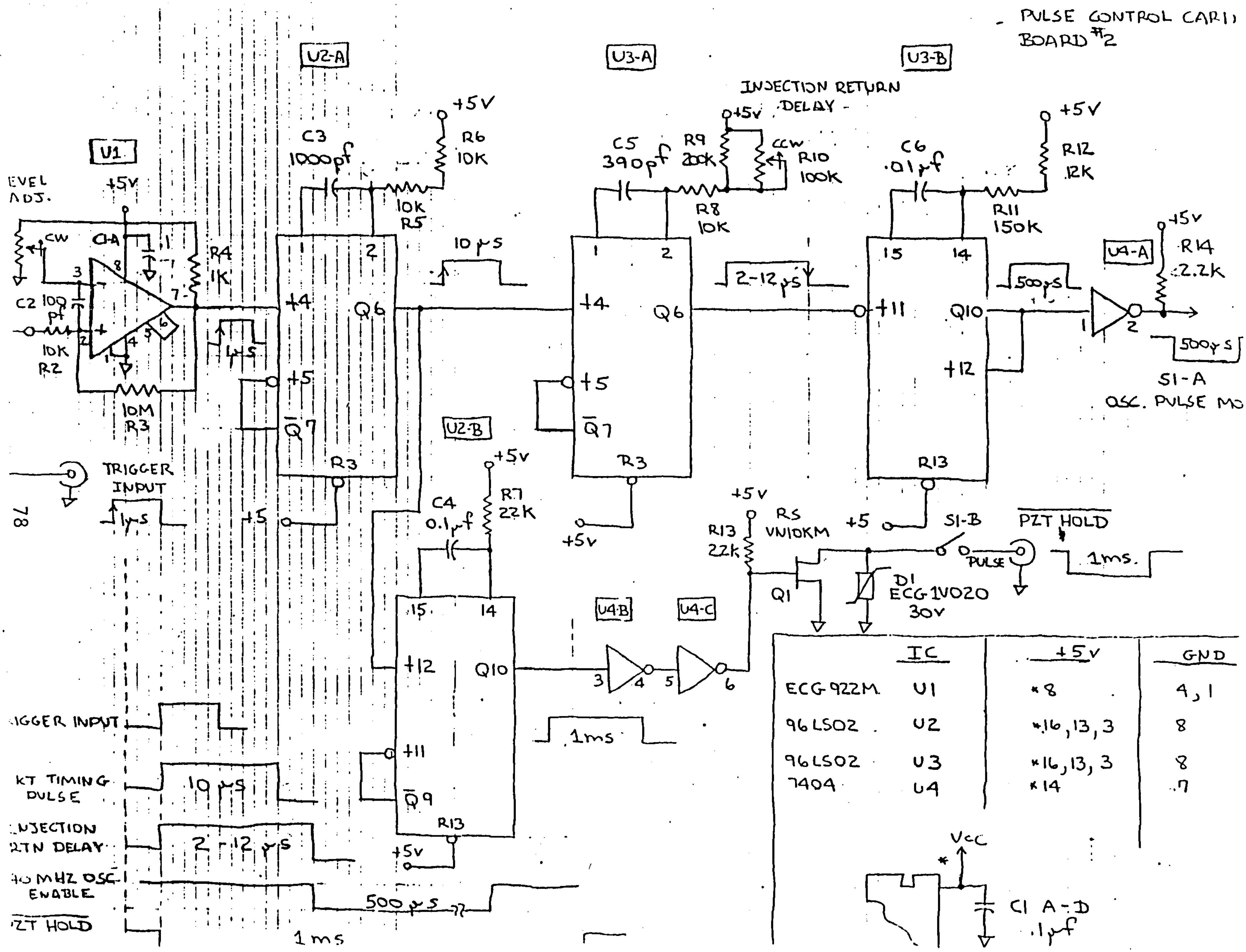


ACOUSTO-OPTIC CONTROL
POWER DISTRIBUTION
BOARD #1
+15V
BOARD #1
1.0μf
C2-A
+15V
VR1
ECG - 968
IN
OUT
.1μf
C1-A
+33V
RTM-12B
RTM-9B
+5V
BOARD #1
D1
ECG-4900
C3
10μf
+5V
VR2
ECG - 966
IN
OUT
.1μf
C1-B
+11.5V
RTM-2A
RTM-3B
BOARD #2
J2-13
J2-3
J1-13
J1-3
1.0μf
C2-B
10μf
+5V
VR3
ECG - 966
IN
OUT
.1μf
C1-C



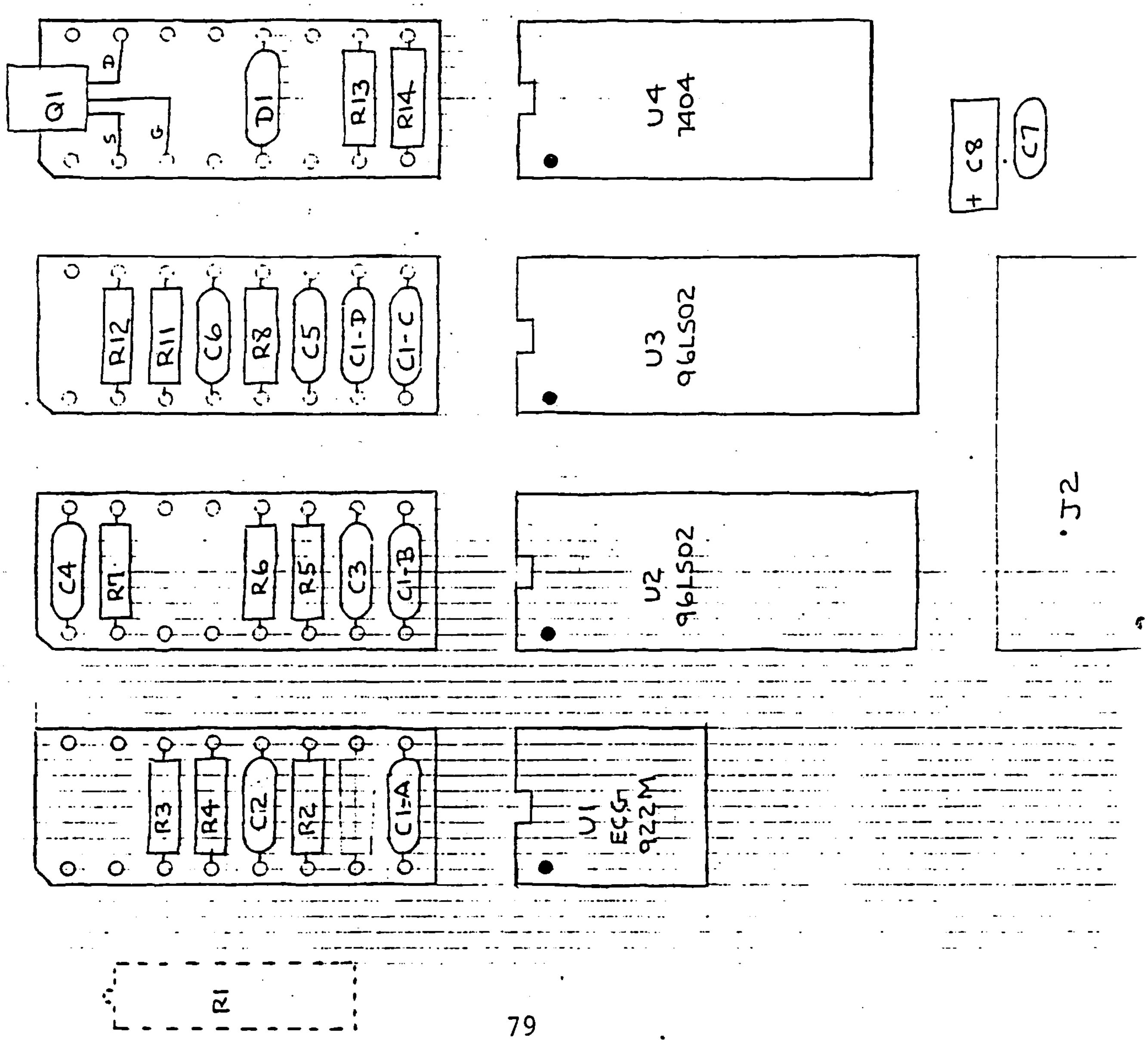
ACOUSTO-OPTIC
MODULATOR CONTROL
BOARD #1

PULSE CONTROL CARD
BOARD #2



	IC	+5v	GND
ECG 922M	U1	*8	4, 1
96LS02	U2	*16, 13, 3	8
96LS02	U3	*16, 13, 3	8
7404	U4	*14	7

ACOUSTO-OPTIC MODULATOR
PULSE CONTROL
BOARD #2



ACOUSTO-OPTIC MODULATOR
CONTROL

CONNECTORS J1, J2

J1	40 MHZ OSC	16	S2 Osc. On	Blue
	+5v	1	S1-A CW Mode	Green
	+15v	15	S2 Common	Yellow
	NC	2	NC	Orange
	U1 pin 2	14	S1 Common	Red
2	Gnd	3	J1-3	Brown
	+5V	13	J1-13	Black
	NC	4	J1-4	White
	NC	12	J1-12	Gray
	U3A-2	5	S1 Pulse Select Mode	Violet
	R2	11		Blue
	+5V	6	CW INJECTION RTN DELAY	Green
	Q1-D	10	PZT HOLD	Yellow
	Gnd	7		Orange
	R7	9	EXT TRIGGER IN	Red
	Gnd	8		Brown

				COST (EA)	
1	142-0261-001	Miniture Coax Conn.	✓		
		BNC Chassis			
1	999-226	BNC Feed through			

ACOUSTO-OPTIC
MODULATOR
CONTROL

			INV.	COST (EA.)
2	ECG-966	Voltage Regulator +5v		
1	ECG-968	Voltage Regulator +15v		
1	ECG-922M	Op Amp		
1	7404	IC, TTL		
1	7408	IC, TTL		
2	ECG-96LS02	IC, TTL		
1	2N4401	Transistor NPN		
1	VN10KM	Transistor VMOS		
1	ECG-1V020	Diode Suppressor		
	RV6 NAYSD 104A	Potentiometer 100K	✓	4.02
1	89PR1K	Trimpot 1K	✓	.99
9		IC Sockets 16 pin WW		
2		" " 14 pin WW		
		" " 8 pin WW		
5		Component Carrier 16		
		DIP Connector 16 pin		
		Switch SPST		
		Switch DPDT		
	WEF 507A	Heat Sink Assembly		

OPTICAL DESIGN FOR THE NASA LIDAR

During the early phases of our contractural effort with NASA Langley, CLS Laser Systems consulted on the details of the optical design of the LIDAR system then in operation at NASA. Hardware for this system that was provided by CLS included a bias/preamp unit for their SAT receive detector and an acousto-optic modulator control unit.

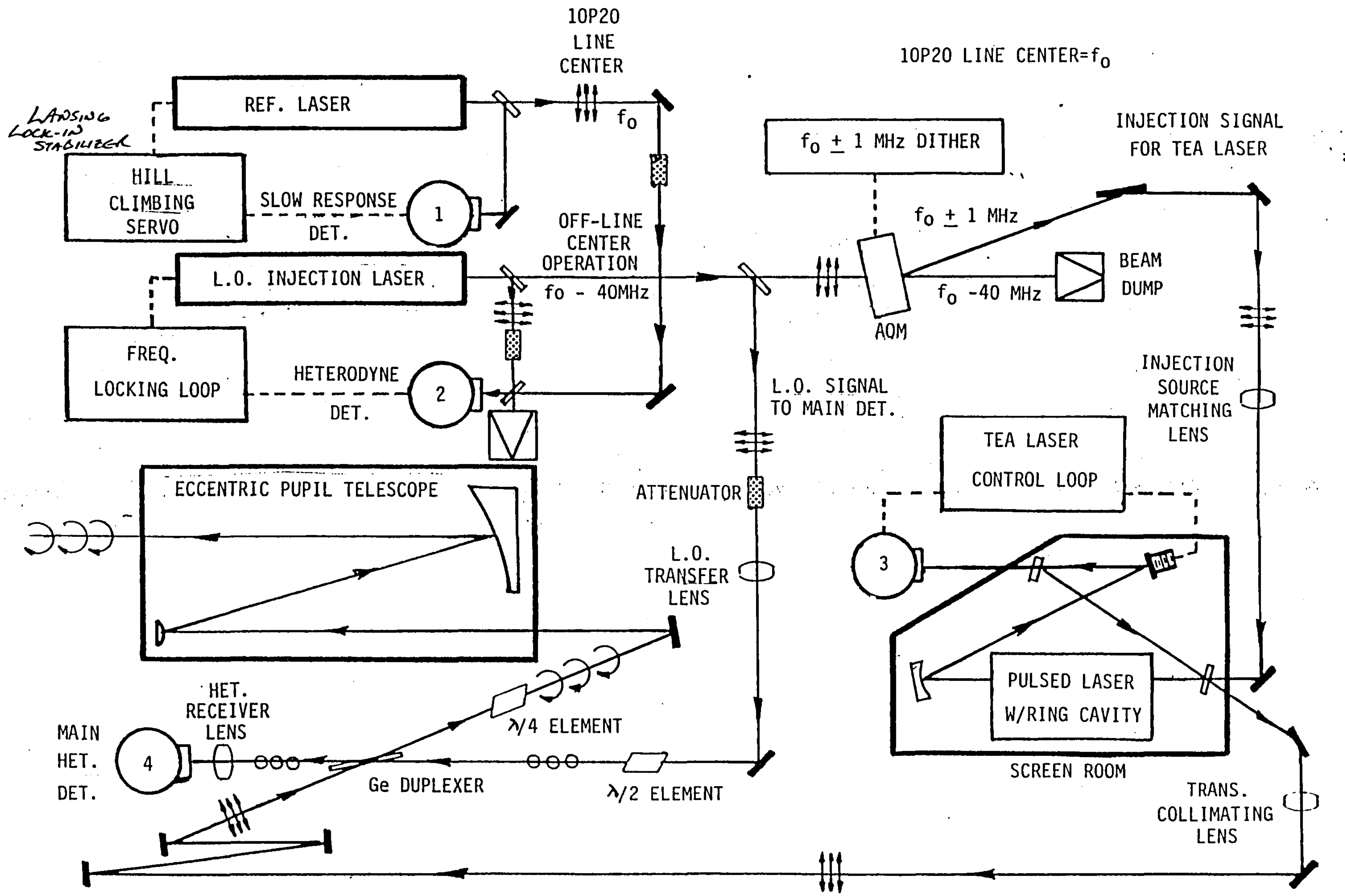
The NASA LIDAR system is shown in block diagram form in figure 1. A cw CO_2 Reference Laser is dither stabilized to 10 P(20) line center using a commercial Lansing lock-in stabilizer and a relatively slow response optical detector (detector #1). The output of this laser is matched into a relatively fast, widebandwidth response detector (detector #2). Another cw CO_2 device (an Ultra Lasertech laser) is used as a combined Local Oscillator/Injection Laser. It is frequency locked at 40 MHz away from 10P(20) line center by mixing its beam with the line center stabilized Reference Laser on detector #2. A portion of this Local Oscillator/Injection laser beam is matched onto the LIDAR heterodyne receive detector (detector #4) to provide the local oscillator bias and IF offset for the LIDAR. Another portion of the Local Oscillator/Injection Laser beam is propagated through an acousto-optic modulator crystal to shift a portion of its beam back into coincidence with 10P(20) line center. A $\pm$1MHz "dither" in the frequency is added at this point. The electronics to drive this modulator crystal also serve to gate off the injected signal when the LIDAR is expecting an aerosol return pulse. This prevents optical feedthrough from the cw injected flux from becoming incident on the receive detector. Using the line center $\pm$ 1 MHz dithered optical signal, a high power pulsed CO_2 TEA laser gain medium, which serves as the transmitter laser, is injection controlled for single longitudinal frequency, 10P(20) operation. The ring cavity itself serves as a resonant cold cavity during the inter-pulse period and the $\pm$ 1MHz modulation on the injected signal is sufficient to generate a discriminant for locking the ring cavity at a 10P(20), TEM_{00} mode, longitudinal mode frequency resonance (using detector #3). Another Lansing stabilizer is used for this purpose. The output pulse from the pulsed TEA laser is made circularly polarized and then transmitted through a 30x magnification eccentric pupil telescope for propagation into the atmosphere. The return optical signal is orthogonally polarized after its round trip through the quarter wave element and a germanium brewster plate serves as the transmit/receive duplexer for the coherent radar.

During the program it was decided that a three laser system added too many uncertainties and complications to the initial understanding of the LIDAR system. It was subsequently decided to delete the Reference Laser and lock the Ultra Lasertech to 10P(20) line center and operate the ring laser transmitter 40MHz away from 10P(20) line center.

Elements of the optical design for which CLS consulted or provided analysis and calculation included the following:

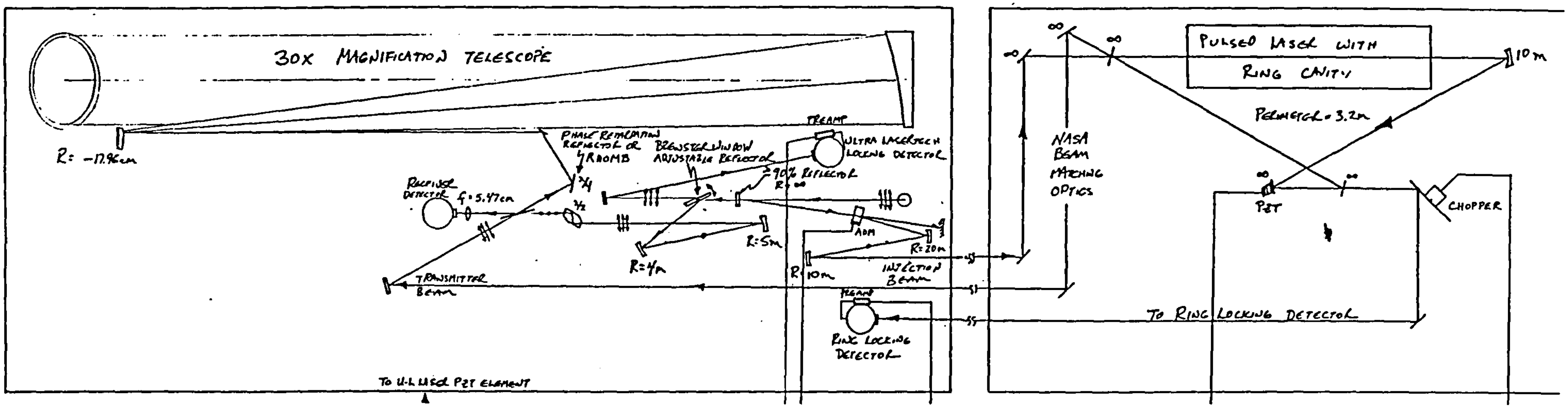
- Ring resonator analysis for beam propagation parameters
- Beam matching analysis of the ring resonator beam into the 30x telescope
- Telescope geometry: beam locations and centerline heights
- Beam matching analysis of the local oscillator/injection laser into the ring cavity
- Receive detector focussing lens analysis
- Beam matching analysis of the local oscillator/injection laser into the receive detector lens
- Optical analysis of the acousto-optic modulator
- Focussing the local oscillator/injection beam into the acousto-optic modulator
- Optical schematics of four different LIDAR optical configurations

A diagram of the final, recommended optical layout for the NASA LIDAR is shown in figure 2.



CLS LASER SYSTEMS INC.
South Windsor, Ct.

NASA LIDAR OPTICAL SCHEMATIC



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15. Supplementary Notes

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Final Report

16. Abstract

This report covers a series of lidar design and technology demonstration tasks in support of CO_2 lidar program. The first of these tasks is discussed in Section VI of this report under the heading of "NASA Optical Lidar Design" and it consists of detailed recommendations for the layout of a CO_2 Doppler lidar incorporating then existing NASA optical components and mounts. The second phase of this work consisted of the design, development, and delivery to NASA of a novel acousto-optic laser frequency stabilization system for use with the existing NASA ring laser transmitter.

The second major task in this program encompasses the design and experimental demonstration of a master oscillator-power amplifier (MOPA) laser transmitter utilizing a commercially available laser as the amplifier. The MOPA design including the low chirp master oscillator is discussed in detail. Experimental results are given for one, two and three pass amplification are given. The report includes operating procedures for the MOPA system.

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