LA-UR-76-2299

CONF-761106--5

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SUBMITTED TO: IEEE International Pulsed Power Conference, Lubbock, Texas November 9-11, 1976

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Form No. 836
St. No. 2629
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UNITED STATES
ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

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PULSED POWER SYSTEMS FOR THE LASL HIGH ENERGY GAS LASER FACILITY*

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ABSTRACT

The laser division at Los Alamos Scientific Laboratory is designing a CO_2 laser fusion experiment with the goal of delivering 100 kJ to the target in a one nanosecond pulse. The laser will be pumped by an electron-beam-controlled discharge. The pumping power supply will be a number of parallel Marx generators, with an output voltage of 500 kV, and a total energy storage of about 5 MJ. The electron gun is a "cold cathode" triode, also operating at about 500 kV.

Preliminary design considerations for the pulsed power systems are presented. Some pulse forming network designs are discussed with calculated waveforms shown.

1. Introduction

The present CO_2 Laser Fusion Program at the Los Alamos Scientific Laboratories has evolved in several steps from a 1 kJ single beam machine to a 2.5 kJ double beam machine, both presently in operation, to a 10 kJ eight beam machine, which is under construction. To achieve break even a larger experiment is being prepared with the aim to deliver an energy of 100 kJ with a power of 100 TW to the fusion target. This machine (Fig. 1) is presently in the early design stages, where concepts are evaluated, trade-off studies performed and the intricate relationships between target requirements and the necessary optical, mechanical, electrical and control systems are established.

The purpose of the paper is to present some thoughts regarding the design of the amplifier module which comprises the power amplifier per se and the high voltage pulse generators driving the pumping chambers and the electron-beam gun.

2. Power Amplifier

The basic design criteria for the power amplifier is the maximum permissable energy flow density of 2 J/cm^2 imposed by properties of large state-of-the-art salt window. This limitation results in a required total laser beam area of 5 x $10^4 cm^2$. Based on experience with the existing 2.5 kJ

* Work done under the auspices of the US Energy Research and Development administration.

two beam machine and the largest available size of state-of-the-art salt windows, a single beam cross-sectional area of about 700 cm^2 has been chosen, resulting in a total number of 72 beams.

To minimize the number of optical chains which all have to be aligned and focused independently, 6 large annular beams were chosen, each consisting of 12 individual beams. The twelve pumping chambers producing the laser beams are wrapped around a central cylinder containing the electron-beam gun (Fig. 2). This arrangement greatly reduces the number of independent electron-beam guns and improves the gain uniformity in the lasing volume because of the radial geometry. A gain length product of about $g_0 L = 9$ is necessary to produce an energy flow density of 2 J/cm^2. Therefore, for reasonably achievable gains of about 3 m^{-1} a total pumping volume length of about 3 m is required. Circumferential magnetic fields associated with the gas current in the pumping volume limit the length of individual anodes to something like 1 m for gas current densities of about 8 A/cm^2 if gas current pinching is to be avoided. Essentially this dictates, grossomodo, the design of the power amplifier. Obviously, much further refinement and trade-off studies are needed to zero in on a final design.

Presently a 4:1 CO_2N_2 helium-free gas mixture is envisioned requiring an electric field of 18 kV/cm at a pressure of 1800 Torr, a pumping time of about 1.25 μs, and an energy density of 180 J/ℓ. Translated into the power amplifier geometry this means a requirement exists for approximately 500 kV, 70 kA and 43 kJ per beam at a chamber resistance of about 7 Ω; or an energy of 500 kJ into an impedance of 0.6 Ω is required per power amplifier. To provide a reasonably uniform ionization profile in the pumping volume and achieve the above gas current density, electron beams of approximately 450 keV energy and between 25 and 50 mA/cm^2 density through the foil are required. Translated into the electron beam gun geometry this means a gun is required per power amplifier which can deliver an e-beam density of up to 100 mA/cm^2. Because of its relative simplicity a cold cathode e-gun is being considered with a resistively self biased grid to provide blade ignition voltage and low current density at the same time. The requirements per power amplifier are a voltage of 500 kV, an energy of 21 kJ and a pulse duration of 2.5 μs.

3. Pumping Pulsed Power Supplies

The design of the pulsed power supplies for pumping of HEGLF is determined by the design of the power amplifier module, described above, which in turn is influenced by considerations of pulsed power supply design. Since the design of the power amplifier module is still undergoing trade-off studies, with input from the optical design, mechanical design, electrical design, and laser design, we have performed a preliminary design analysis of the pulsed power supplies, based on a preliminary set of specifications. We assumed a discharge volume, for one laser beam, with dimensions 331 cm long, 25 cm wide, and 28 cm anode-cathode spacing. In order to provide some safety factor, a calculated gain of 3.0 m^{-1} is required. This requires a current density near 8 A/cm^2 at a field of 18 kV/cm, for about 1.25 μs. The input per beam is calculated to be 70 kA at 500 kV, and the energy is 43 kJ per beam, or 3 MJ total. This will require some number of parallel, high voltage pulse forming networks. However, it is not necessary that there be one pulser for each of the 72 beams. A pulser may drive two, three, or four beams, if inductance permits. The factors which we considered in selection of the design were:

- Implications for reliability
- Simplicity of circuit and components
- Fault modes
- Efficiency

Reliability will require a trade-off between the number of components (capacitors, spark gaps, trigger systems) and the duty imposed on the components (energy per capacitor, current per gap). Analysis of fault modes will be primarily concerned with the voltage transients caused by open circuit loads. Efficiency is not of great importance.

The approach to the design was heavily influenced by our previous experience with high energy CO_2 laser systems. Our 10 kJ, eight beam, 1 ns pulse CO_2 laser is pumped by eight pulse forming networks. These are 120 kA, 300 kV (matched load), 2.5 μs Type C Guillemin/Marx networks (Fig. 3). They have been built and tested into dummy loads. The whole system is presently undergoing checkout.

For the HEGLF pulsed power supplies, we compared the various types of Guillemin networks, in Marx generator configurations, using one and two meshes. We found that, for the purpose of pumping a CO_2 laser, the single mesh network gives satisfactory performance. Although the waveform (Fig. 4) has a risetime and a falltime comparable to the pulse length, the efficiency is not seriously effected. The total energy stored will be about 5 MJ. This circuit has the advantage of simplicity. Open circuit fault voltage is calculated to be higher than with a two mesh network, but the fault protection system should be no more complicated.

The calculated circuit parameters are:

- 36 Marx Generators
- 1.08 MV open circuit
- 0.25 μF capacitance
- 3 μH inductance

Fewer parallel units would require lower unit inductance. From analysis and measurements on Marx mock-ups, we find that, for large energy storage systems, 2.5 μH is about the minimum for a 1 MV Marx generator.

<u>Reference</u>:

1. K.B. Riepe, "Pulse Forming Networks for Fast Pumping of High Power Electron-Beam-Controlled CO Lasers", proceedings of 1975 Laser Exposition, Anaheim, Calif., Nov. 1975.

FIGURE CAPTIONS

1. High Energy Gas Laser Facility.
2. Longitudinal Section HEGLF Power Amplifier.
3. Two mesh Type C Guillemin/Marx with waveform for ideal circuit.
4. One mesh network with waveform.

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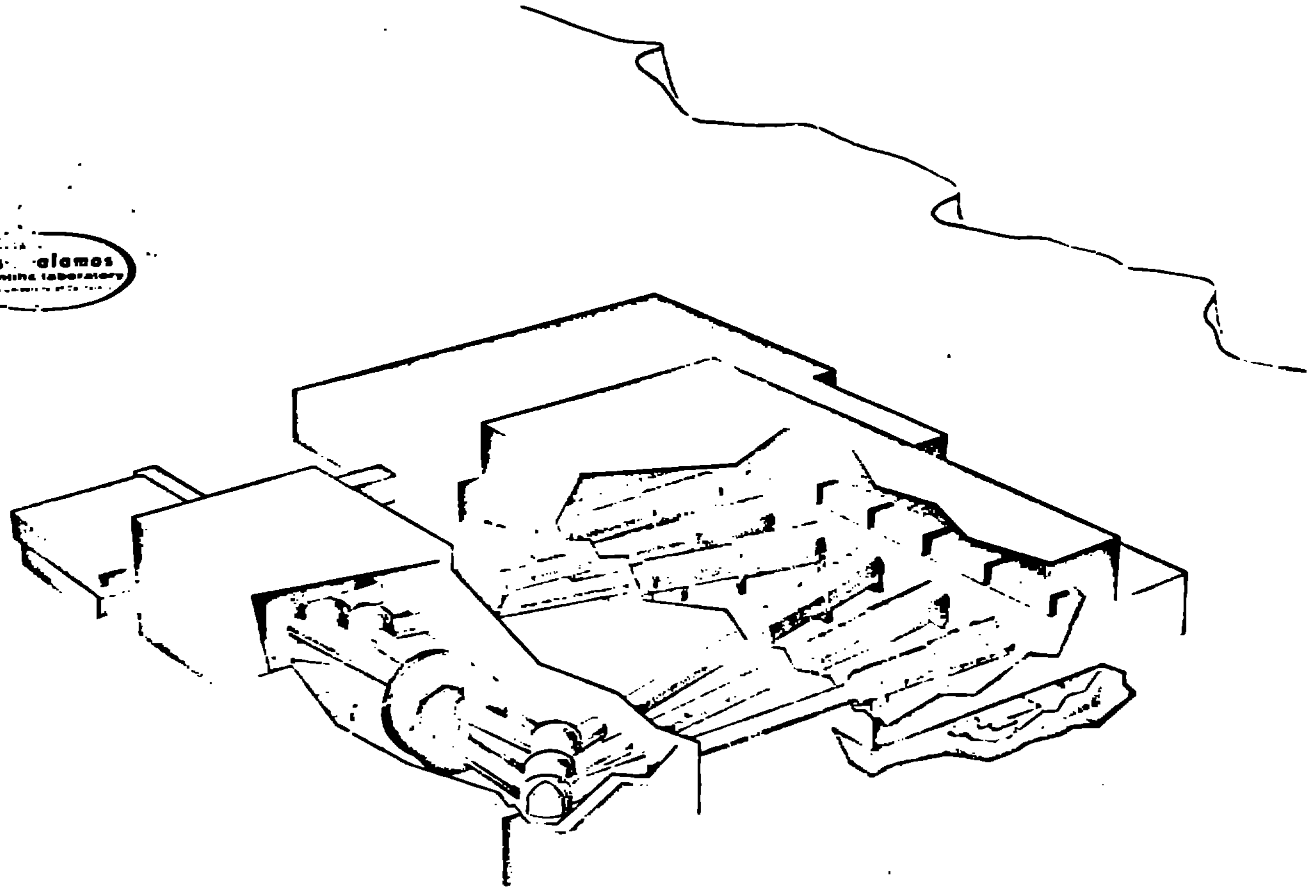
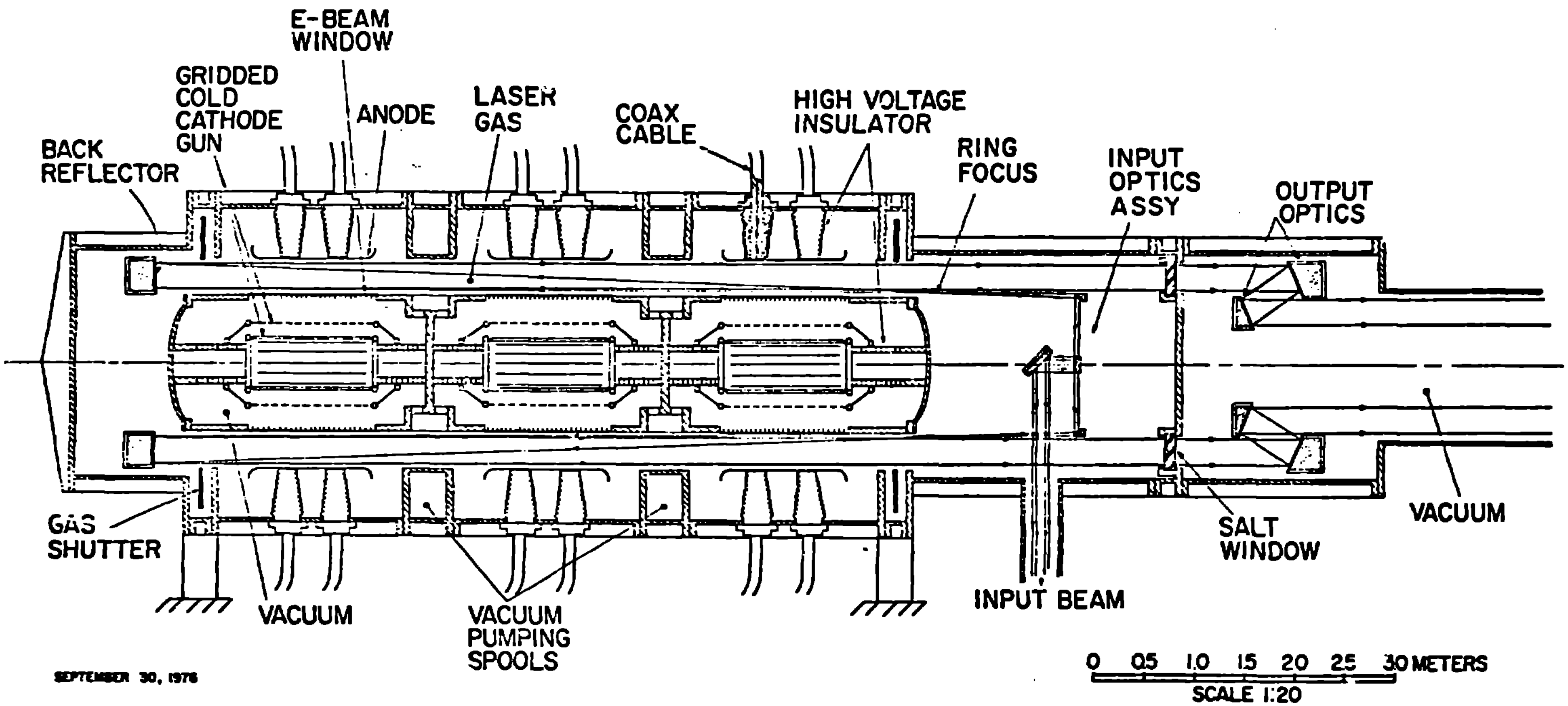


HIGH ENERGY GAS LASER FACILITY



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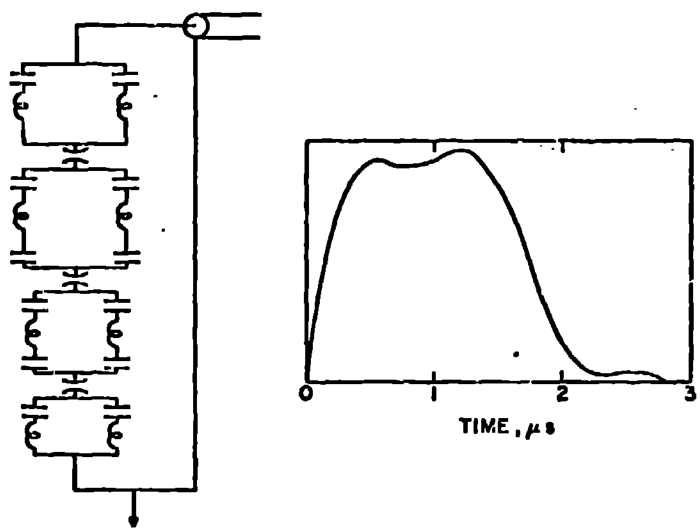
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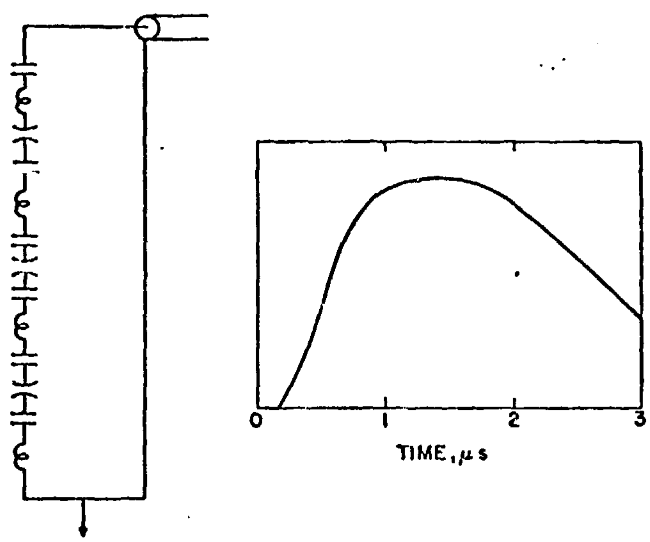
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