WATER DIELECTRIC PULSE POWER DRIVER FOR RARE-GAS-HALIDE LASERS[T]

J.D. Shipman, Jr.[*], B.L. Wexler and W.H. Lupton

Naval Research Laboratory
Washington, DC 20375-5000

ABSTRACT

A water dielectric double Blumlein pulse generator has been designed that could deliver a 790 KV prepulse and then sustain 800 KA for about 300 ns in a novel low inductance Excimer laser head.

INTRODUCTION

The goal of this design was a laboratory pulse generator to drive rare-gas-halide lasers such as XeCl having the following assumed properties.

1) Once conducting at steady current, the laser head will operate at 600 volts per cm per atmosphere of gas pressure. Thus at an electrode spacing of 40 cm and a gas pressure of 5 atmospheres the operating voltage (regulated by the laser gas) will be 120 KV.

2) The electrode spacing will be 40 cm with a current path width of 20 cm and the active length of the lasing gas will be 3 meters, resulting in a lasing gas volume of 240 liters. The maximum energy deposited in the gas is limited by HCl depletion to 25 joules per liter per atmosphere; therefore, at 5 atmospheres, the laser will turn off when 30 KJ is delivered.

3) In order to achieve rapid breakdown and good discharge in the laser gas, a preconditioning high voltage pulse at least 4 to 6 times the regulated operating voltage is necessary. This pulse should rise rapidly and persist until breakdown in the lasing gas is initiated, starting current flow. Until such breakdown occurs, the laser head is an open circuit except for it's shunt capacitance.

Thus the required generator should have the following features.

1) Provide a preconditioning pulse of about 720 KV or more during the early nonconducting phase of the laser. This pulse should have a fast rise time of about 100 ns or less and persist until the breakdown process (current initiation) starts. This time may be as long as 100 ns.

2) Minimize the current rise time into the lasing gas.

3) Provide a current of about 750 KA minimum to the lasing gas during the period that the voltage is regulated to 120 KV until a minimum of 30 KJ has been delivered.

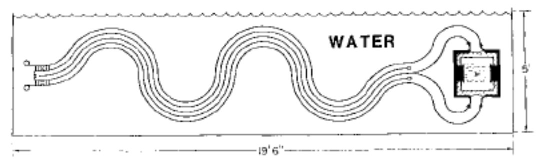
4) Provide a means for safely dissipating residual energy in the system after 30 KJ has been delivered.

5) Since the driver is to be a research tool to study gas lasers in the laboratory and not a field model, the above features should take precedence over efficiency of energy transfer from the driver to the lasing gas.

PULSE POWER SYSTEM

A schematic cross section of the water dielectric Blumlein pulse forming line is shown in Figure 1 and nicknamed Dragon I for obvious reasons.

The line was to be fabricated of flat aluminum



DRAGON I

Figure 1. Schematic cross section of the water dielectric Blumlein pulse forming line

plates rolled into the corrugated cross section shown. This corrugated shape conserved physical length for a given pulse length and made it very stiff in the 3 meter dimension perpendicular to the cross section. Thus the five corrugated sheets could be hung from the outer edges with long insulating rods to the side walls without drooping too much, thereby eliminating the need for short insulating posts between the sheets with their inherent probability of voltage breakdown.

In the discussion to follow, the bottom sheet will be referred to as sheet number 1 and the next sheet up number 2 etc.

Sheets 1 and 5 are at ground potential at all times. Sheet 3 should be at ground potential at the end of the voltage charge of the system but tied to ground through an impedance of sufficient value so as not to effect the fast transient behavior of the system when initiated by the multichannel switches. Sheets 2 and 4 (connected together at the left end) will be resonance charged to a voltage level of 443 KV in a few micro-seconds from an appropriate Marx generator. The Marx generator will not be discussed in this paper. The water gap spacing between adajacent sheets is 6.9 cm, and the system will operate between about 60% and 90% of calculated water breakdown, depending on the charge time used. The switching in this generator occurs at the left side of Figure 1 between sheets 1 and 2 and between 4 and 5. These switches are in parallel and the inductance of the parallel combination of the two 3 meter long switches should be about 10 nH or less to provide the short risetime for the high voltage preconditioning pulse. This could be easily accomplished by any number of multichannel switch types such as midplane oil gaps, gas rail gaps, multichannel gas trigatrons, or even triggered solid dielectric switches, if super short risetime were desired. A major advantage to this switch arrangement is that one of the electrodes of each switch is grounded, making it easy to bring in coaxial trigger cables to each switch site. A second advantage is that the waves from each channel of the multichannel switches have plenty of distance to combine and form a uniform wavefront over the 3 meter width of the line before reaching the laser head, thereby assuring uniform preconditioning voltage and

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* Sachs/Freeman Associates, Inc., Bowie, MD 20715

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14. ABSTRACT
A water dielectric double Blumlein pulse generator has been designed that could deliver a 790 KV prepulse and then sustain 800 KA for about 300 ns in a novel low inductance Excimer laser head.

15. SUBJECT TERMS

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current per unit length in the laser. For systems with the multichannel switch near the laser head it is very difficult to achieve comparable current uniformity without many more channels. A further disadvantage to locating the switch near the laser head is that, in this location the switch inductance affects the current risetime in the head. In the system of this paper, if the laser gas were to instantly regulate the voltage, the current rise time constant in the head would be the head inductance, only, divided by the sum of the generator and head resistances. The switch inductance would not be involved.

In order to shorten the current rise time, a new cross sectional design for laser heads of this general type was originated to mate well with this driver. This head is shown at the right of Figure 1 and in detail in Figure 2 with static equipotential surfaces, at 5% intervals, plotted between the electrodes.

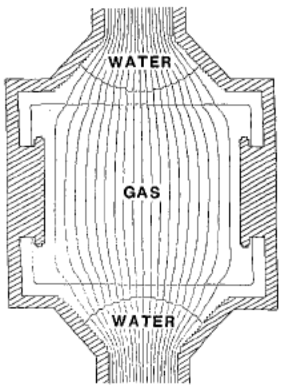

Figure 2. New laser head cross section with static equipotential surfaces, at 5% intervals, plotted between the electrodes

It dramatically reduces the inductance of such heads and the probability of insulator surface tracking, since there are no electric fields, of sufficient magnitude within the head, to drive charged particles from either electrode toward the insulator-gas interfaces. Therefore, these interfaces can be much closer to the electrodes and current path, thereby reducing the tube inductance. The total inductance for a 3 meter long discharge in this head calculates to be 15 nH. This head principle has been successfully tested experimentally on a small model at NRL.[1]

At the left end of the driver between the common connection of sheets 2 and 4 and the end of sheet 3 is a multichannel water gap. This gap will be spaced and field enhanced in the proper direction to hold off the original charge voltage but to close on field reversal. Experience at NRL on the Gamble II pulse power generator has shown that water switches are lossy and make good damping resistors. Therefore, this water gap will be used to absorb the excess energy in the system. In case the water gap itself does not have sufficient resistance, the required resistance will be added in series with the gap.

TRANSIENT ANALYSIS OF THE SYSTEM

Figure 3 is a circuit for the driver broken up into the appropriate transmission line elements for analysis by the NRL transmission line code.

Element 1, a 1 ns long 10 ohm line, is used to represent the 10 nH inductance of the energy absorbing water gap with .485 ohm resistance at node 1. Element 3 represents the 10 nH inductance of the triggered multichannel switch at node 5 which closes through 0 ohm at the start of the analysis. Elements 2 and 4

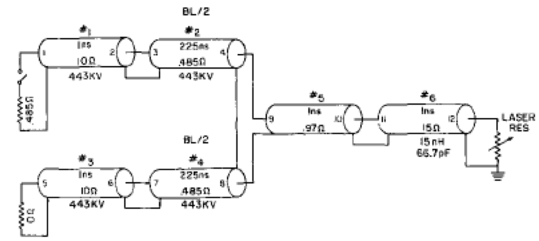

Figure 3. Transmission line circuit for the Blumlein pulse forming line system

represent the main pulse forming lines of the Blumlein generator. Element 5 is a short section of transmission line which matches the .97 ohm impedance of the generator and feeds the laser head. Element 6, a 1 ns long 15 ohm line, represents the 15 nH and 67 pF of the laser head. The laser resistance at node 12 is programmed to be an open circuit until breakdown is initiated and then regulate the laser voltage to 120 KV until the end of the Blumlein generator main pulse. In one analysis the voltage dropped to the 120 KV level with a time constant of 20 ns and in another it dropped abruptly. In the first case, the risetime (10% to 90%) of the laser current was 59 ns; and, in the second case, was 34 ns. In all analyses, the laser head was allowed to absorb energy until the end of the Blumlein generator main pulse rather than turning off after 30 KJ was absorbed, since the laser resistance was unknown after turnoff. In order to study the damping effect of the .485 ohm water gap resistance as the sole residual energy dump, the laser head was shorted out at the end of the main pulse when the current first reversed.

Figure 4 is computed voltage across the laser resistance until current starts and then programmed voltage until current reverses.

Figure 5 is the voltage across the head inductance and resistance that would be measured by a capacitive probe measuring the electric field on the grounded electrode (sheet 1 or 5 on Figure 1) on the water side of the water-plastic-gas interface (a convenient place to mount such a voltmeter). Note that the voltage rises to a value above 800 KV with a risetime of about 50 ns and then falls to a regulated value of 120 KV.

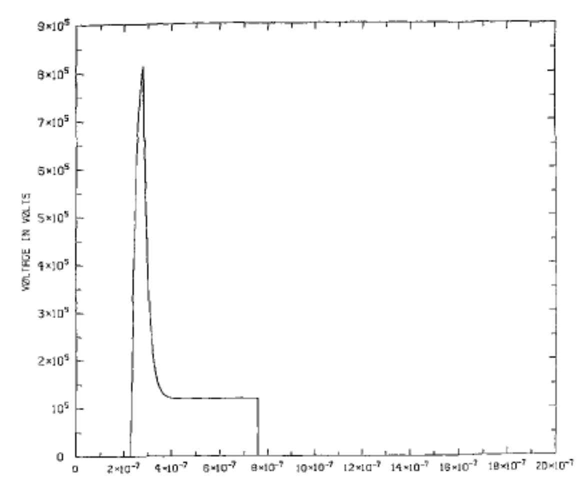

Figure 4. Calculated and programmed voltage across the laser resistance

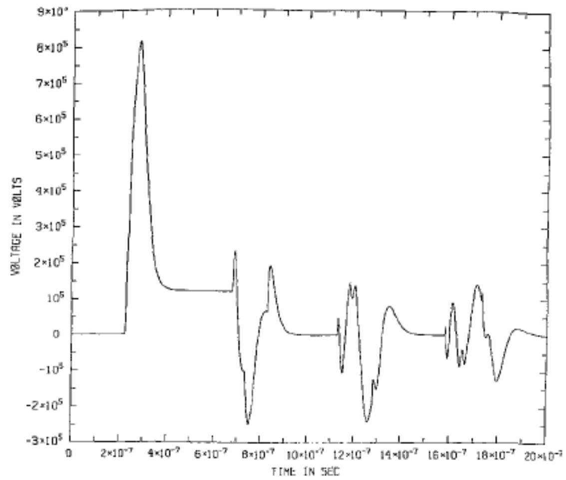

Figure 5. Total voltage across the laser head.

Figures 6 and 7 show the current into the laser head. Note that the 10% to 90% risetime of the current is 59 ns. The short rise in current at the end of the first pulse is due to the back and forth reflection of the early part of the generator pulse, initially reflected at the laser head until conduction starts. The long time scale of Figure 7 shows that the .485 ohm water gap switch absorbs the residual energy within a few μsec.

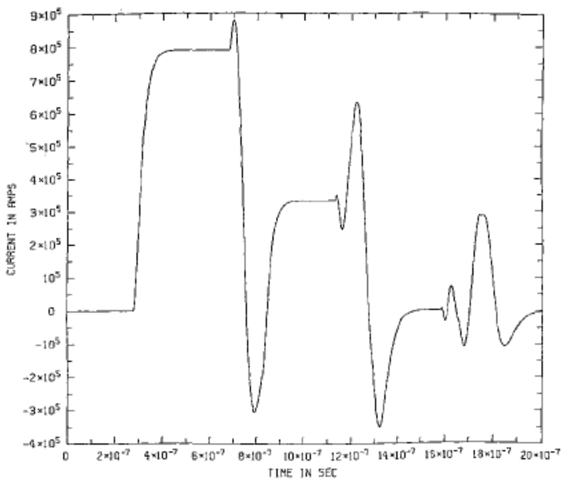

Figure 6. Current into the laser head

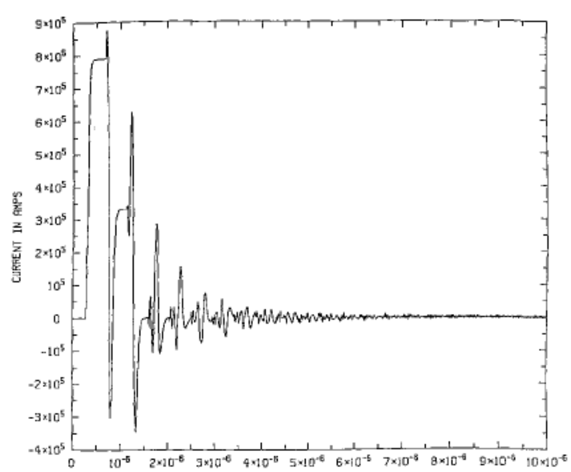

Figure 7. Current into the laser head

Figure 8 shows a power level near 0.1 TW delivered into the laser.

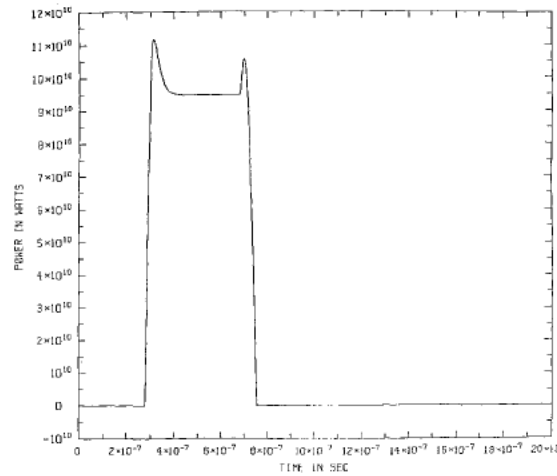

Figure 8. Power delivered into the laser gas

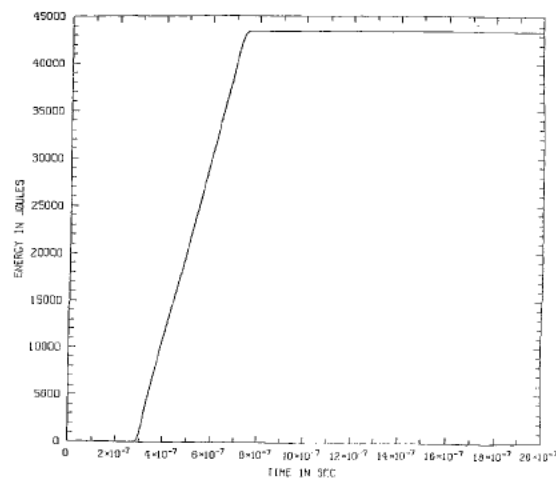

Figure 9. Energy delivered into the laser gas

Figure 9 shows 43 KJ delivered to the laser or 48% of the energy stored in the Blumlein generator. However, as mentioned before, the laser should turn off after absorbing 30 KJ.

Conclusions

This pulse power generator design will drive large rare-gas-halide lasers with a high voltage, fast rising preconditioning pulse of whatever length is required to initiate current conduction (up to ~100 ns), and then sustain the necessary fast rising current pulse to deliver 25 joules per liter per atmos. to the lasing volume.

The design delivers fast rising current without the need for a super low inductance multichannel switch near the laser head.

These features are attained with some loss in energy efficiency between the driver and the laser head.

The design includes a new and novel laser head designed to mate to this driver.

References

1. B.L. Wexler, A.P. desRosiers, J.D. Shipman, Jr. "Elimination of Surface Flashover for Low Inductance Laser Head Design" Conference on Lasers and Electro-Optics (CLEO '85), Paper: THQ-4