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Title: DEVELOPMENT LEADING TO A 200 KV, 20 KA, 30 HERTZ RADAR-LIKE MODULATOR SYSTEM FOR INTENSE ION BEAM PROCESSING.

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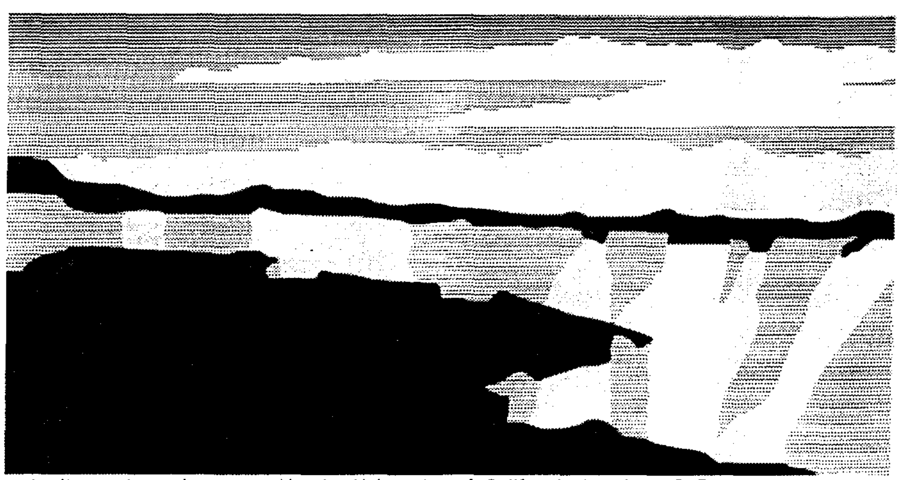

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DISCLAIMER

DEVELOPMENT LEADING TO A 200 KV, 20 KA, 30 HERTZ RADAR-LIKE MODULATOR SYSTEM FOR INTENSE ION BEAM PROCESSING

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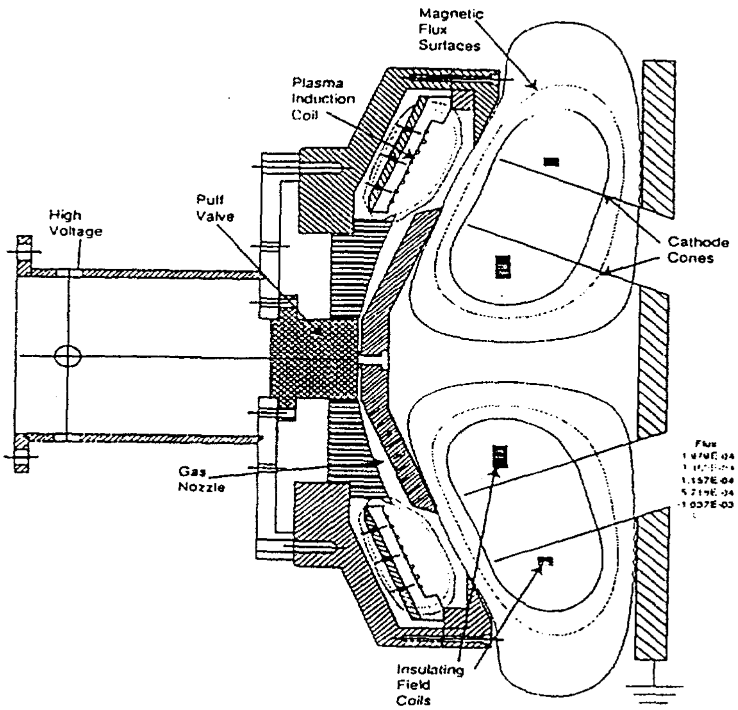
INTRODUCTION

This paper presents the electrical system design methodology we are developing for use in the Los Alamos "CHAMP" (Continuous High-Average Power Microsecond Pulser) program. CHAMP is a Magnetically confined Anode Plasma diode (MAP diode) intense ion source. The CHAMP diode ion source requires many synchronous modulator sub-systems slaved to that required by the diode discharge itself (200 kV, 20 kA). At common potential with the pulsed anode, a gas puff modulator and fast gas pre-ionization modulator sub-system are fabricated in a "hotdeck" chassis. Fiber optic cables provide the appropriate fast control and diagnostic I/O. A pair of Hemholtz-like field coils, surrounding the anode-cathode gap, provides an insulating field that prevents electrons from closing the anode-cathode gap. These field coils are also synchronized to the MAP diode and will utilize energy recovery techniques in it's final form. A dedicated fast sequence and monitor system ensure the proper sub-system parameters before the main diode discharge is initiated. The main diode modulator system will utilize 4 parallel type "E" Blumlein lines each switched with a CX1736AX thyratron. This tube is a 4.5" diameter, 70 kV, two gap, hollow anode device. The four parallel networks will drive a 3.33:1 transformer of Los Alamos design. A bifilar wound secondary provides power to the gas modulator system hotdeck. Although the complete system will not be operational for another year, computer modeling suggests we should easily be able to generate 1 uS pulses with a 300 nS rise and fall. The MAP diode is not particularly sensitive to pulse fidelity, which eases network design. A realizable system could use half-sine pulses, but at a sacrifice to peak ion energy distribution.

In addition to overall CHAMP diode system requirements, the design of the pertinent electrical pulse modulator systems will be presented.

MAP DIODE CONFIGURATION

A diagrammatic view of the MAP diode is shown in Figure 1. Key sub-systems include a gas puff valve and modulator , a plasma induction coil and modulator, and an insulation field coil and modulator system. These systems require proper sequential operation to achieve the desired ion beam energy, focus, and fluence. Once these systems have achieved their proper parameters, the ion beam can be initiated by discharging the Blumlein line PFN. Any improper sequence or anomaly, if not properly detected, can lead to high PFN reversals and deleterious thyratron waveforms. The insulating field coils require about 100 uS to reach peak current and are the first system to energize. This field provides long field lines in the anode-cathode gap and prevent electrons from shorting out the gap during the ion beam discharge. The gas puff modulator, operating at the anode pulse potential, initiates a gas puff from a circular plenum that is sealed by a washer (and o-rings). A flat pancake coil behind the washer operates with a 10 uS quarter period to reactively open the plenum. An acceleration nozzle then expands the gas out into the induction coil region. The induction coil modulator performs two functions, first to break down the gas and then to push the plasma out against the insulation field. The proper induction coil current will have the plasma stagnate in the map diode pole faces to await ion beam extraction during the PFN pulse. The main discharge of the induction coil circuit operates with a 1 uS quarter period. The Blumlein line as designed (and modeled) has a rather trapezoidal waveform that will deposit ion energy over a greater range of target depth that is better suited for some material process applications. An engineering advantage of this system is that pulse fidelity is not strongly dependent on pulse transformer leakage inductance. This PFN system will probably never see a well matched load during operation and will necessitate the use of hollow anode thyratrons. The MAP diode should present about a 16 Ohm load around 220 kV. The system block diagram is shown in Figure 2. The induction coil and puff



200 - 250 kV
15 Ohm
1 μs

FIGURE 1: VIEW OF "MAP" DIODE

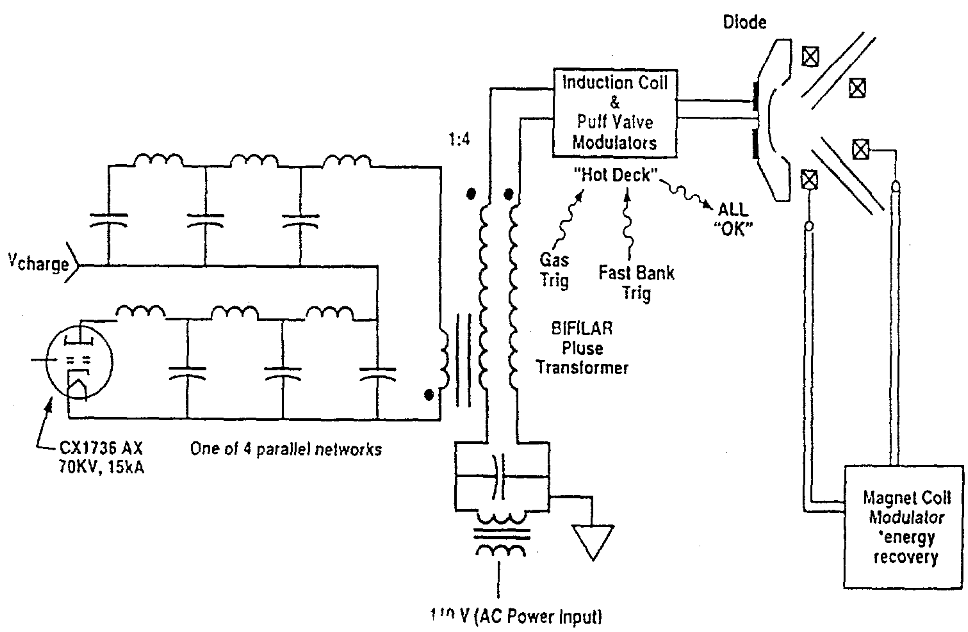


FIGURE 2: SIMPLIFIED BLOCK DIAGRAM OF CHAMP SYSTEM

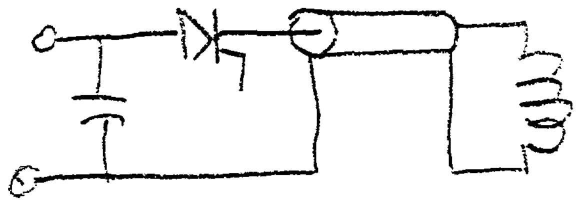


FIGURE 3: SIMPLIFIED GAS PUFF MODULATOR

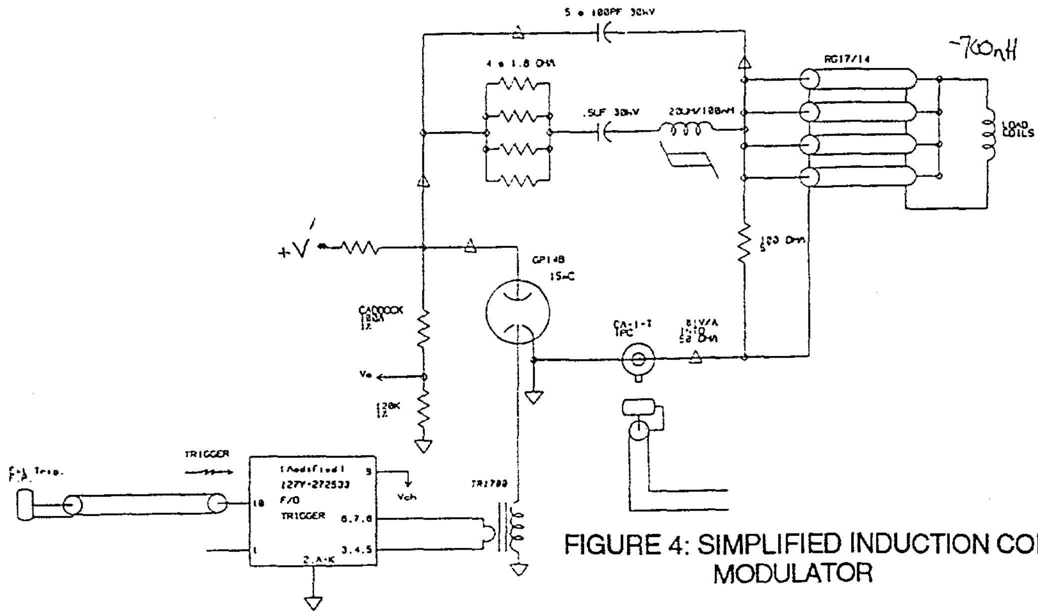


FIGURE 4: SIMPLIFIED INDUCTION COIL MODULATOR

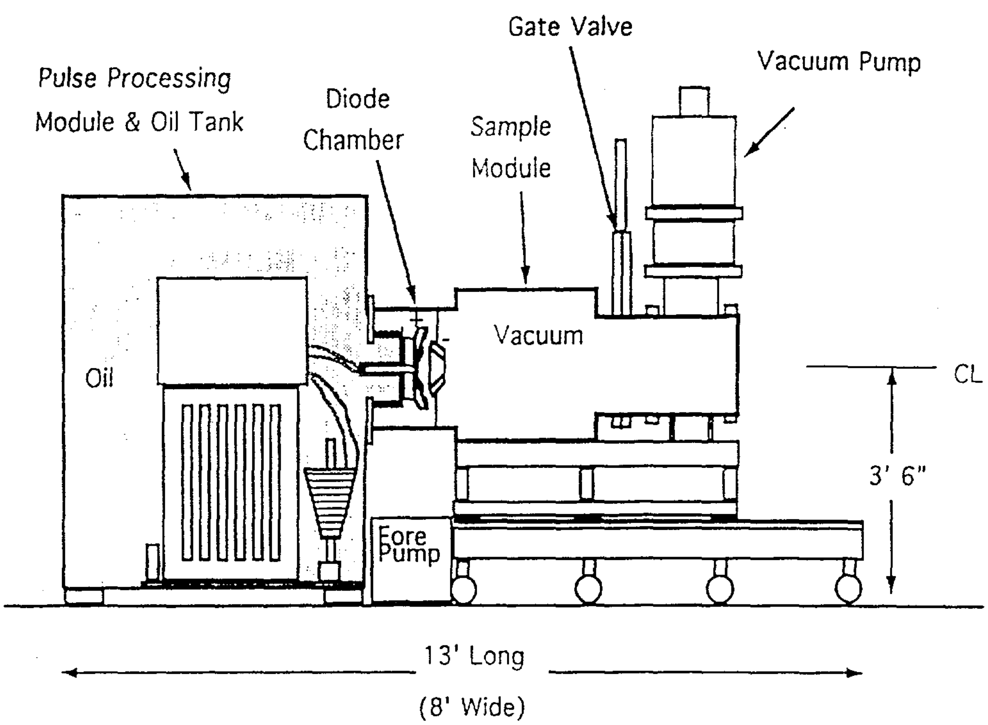


FIGURE 5: CHAMP SYSTEM LAYOUT

valve modulators are located in a hot deck and powered by the pulse transformer's bifilar winding. Fast fiber optic I/O ensure proper triggering and operational parameters. The insulating field coil modulator will eventually require energy recovery techniques to minimize coil power dissipation at 30 Hz, about 30 kW without energy recovery. Initial system operation will be at 5 Hz and below. The Blumlein lines are designed with our existing paper capacitors, rated for 100 kV. A significant engineering disadvantage of the Blumlein line is the 100% voltage reversal on the lower PFN capacitors. Mica capacitors may be better suited for this application.

GAS PUFF AND INDUCTION COIL MODULATORS

The gas puff modulator is relatively simple and is shown in Figure 3, a capacitor and SCR discharge circuit. The gas puff valve requires about a 7 kA pulse. Unfortunately at this time, the puff valve has mechanical design limitations above 5 Hz. Another technology may be required for eventual 30 Hz operation. The induction coil driver delivers an 8 MHz waveform superimposed on a 1 uS quarter period waveform. The circuit topology in Figure 4 shows a two loop circuit connected to the coils. When the spark gap is triggered, the load coils ring with the array of 100 pf capacitors. The coil voltage must ring through zero to initiate good gas breakdown. The voltage reversal is facilitated by the saturable reactor holding off the high current (20 kA) discharge from the second loop for a few tens of nS.

SYSTEM LAYOUT

The system layout is shown in Figure 5. The overall CHAMP modulator and process chamber require a small footprint, 8' X 13' X 7' high. The PFN will be in a low inductance configuration, the capacitor bushings down and the inductors near the return plane, at the bottom of the oil tank. The thyratrons will be partially enclosed in re-entrant metal cans extending below the return plane. Low inductance output bus will connect to the pulse transformer. The hotdeck is located above the PFN capacitors. A more optimal design would use the available shorter capacitors to lower the hotdeck assembly. The vacuum and process chambers are placed on roller tracks to permit their separation and maintenance.

CONCLUSION

The push to commercialize the CHAMP system is very strong. Their are many exciting and promising ion beam processes that are being patented for large scale consumer application. To achieve required rep-rates and system reliability, for high process production, iterations in component technologies and sub-system designs will be required. Equipment must also be designed that can be easily maintained or repaired by the manufacturers technicians that won't necessarily be pulse modulator specialists. Los Alamos looks forward to working with equipment manufacturers to help facilitate these important goals.