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Title: TOTEM POLE DRIVE DECKS FOR THE HIGH-VOLTAGE, PULSED-POWER MODULATOR FOR A LARGE-SCALE PLASMA SOURCE ION IMPLANTATION SYSTEM

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TOTEM POLE DRIVE DECKS
FOR THE HIGH-VOLTAGE, PULSED-POWER
MODULATOR FOR A LARGE-SCALE
PLASMA SOURCE ION IMPLANTATION SYSTEM

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Abstract

A new program is underway at Los Alamos National Laboratory to investigate on a large-scale, plasma source ion implantation (PSII). PSII is an industrially-relevant technique to change the surface composition of materials, thereby improving the mechanical, chemical, electrical, or optical properties of the base material. Pre-manufactured parts are immersed in a plasma and are pulsed with a high voltage source that accelerates the ions to the surface, where they become implanted, modifying the surface characteristics. The high voltage applied to the "workpiece" is supplied by a high-voltage, pulsed-power modulator capable of operating to 120 kV, with an output pulse width to 20 uS at a repetition rate of up to 2 kHz. Output currents of up to 60 A, and average powers of 225 kW (6.6 MW peak) will be the ultimate capability.[1] Initial system start-up will be limited by a 60 kV, 1 A charging power supply. This paper describes the totem pole drive decks, the "on" deck and "off" deck, used as a pre-driver to the main high voltage switch tubes which applies power to the workpiece. The pulse length and frequency are externally controlled and then fiber-optically coupled to the modulator totem pole drive decks. The circuitry of the planar triode drivers will be presented in addition to experimental results.

PSII Overview

The large-scale PSII facility at Los Alamos is comprised primarily of a large vacuum vessel, an rf plasma source, and a high-voltage pulsed power modulator. The vacuum vessel is a 1.5-meter-diameter, 5-meter-long, stainless steel cylinder, operated at approximately 6.0 10^{-6} torr base pressure, with a nitrogen plasma density of 1 x 10^{14} and 1 x 10^{15} m^{-3}. The plasma is initiated and sustained with a 13 Mhz, variable (0 to 1000 Watt) CW, rf power source. The rf power level applied to the plasma, is determined by the work piece and the operating power level of the modulator. The plasma density can have a dramatic effect on the voltage rise time of the modulator pulse, i.e. as the plasma density is increased the rise time increases. However, if the density is too low the plasma will be extinguished. For a desirable system throughput, a balance between fill pressure, rf power, and modulator pulsed power is required. The process is pictorially represented in Fig. 1.

Plasma Source Ion Implantation

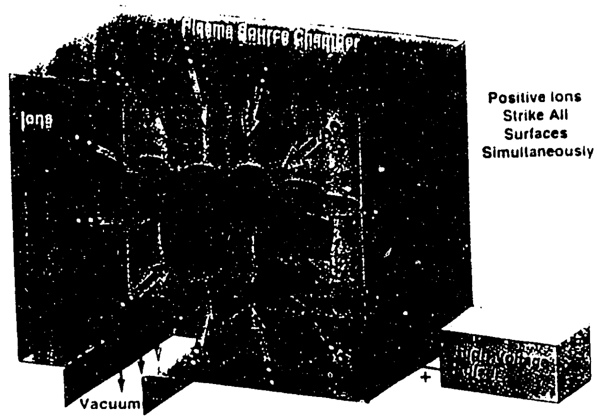


Figure 1.

The pulsed, high-voltage applied to the workpiece to accelerate the ions is supplied by a modulator,[2] schematically shown in Fig. 2, presently containing two Litton L-3408 hollow beam switch tubes in a parallel configuration to maximize the output current capability. These are hard modulator tubes designed for 135 kV, 25 A, 20 us pulse width operation in floating deck modulator applications. The modulating anodes of these two switch tubes are driven by the totem pole drive decks. Gate pulses for the drive decks are 20 uSec long. The frequency is set by the operator from the PC (personal computer) - PLC (programmable-logic-controller) based control system and checked by the electronics to be between 1 Hz and 2 kHz. The modulator dimensions are 1 m x 1.5 m x 1.5 m, and is designed to be upgraded from the present L-3408 switch tubes to three Litton L-5097 tubes, capable of providing 175 kV, 200 A, 20 us pulses.

Totem Pole Drive Decks

The planar triode drive decks ("on" deck and "off" deck) are almost identical, except that the "on" deck has an extra Eimac 8941\Y690 planar triode tube for increased drive capability. This results in improved rise time and "DC" drive capability to the L-3408 mod-anodes, particularly near saturation. The 8941's are rugged tubes capable of switching 12 Amps and 16 kV, but have a limited grid dissipation (2 W). To insure minimal grid dissipation at the rated repetition frequency and drive voltage, the grids are not driven positive. Utilizing a grounded cathode design, a solid-state grid driver provides pulses with rise, fall, and delay times better than 300 ns as shown in Fig. 3. A grounded cathode design reduces switching loop inductance, minimizes output ringing (non-existent in our design), and reduces drive circuit complexity. The drive decks were

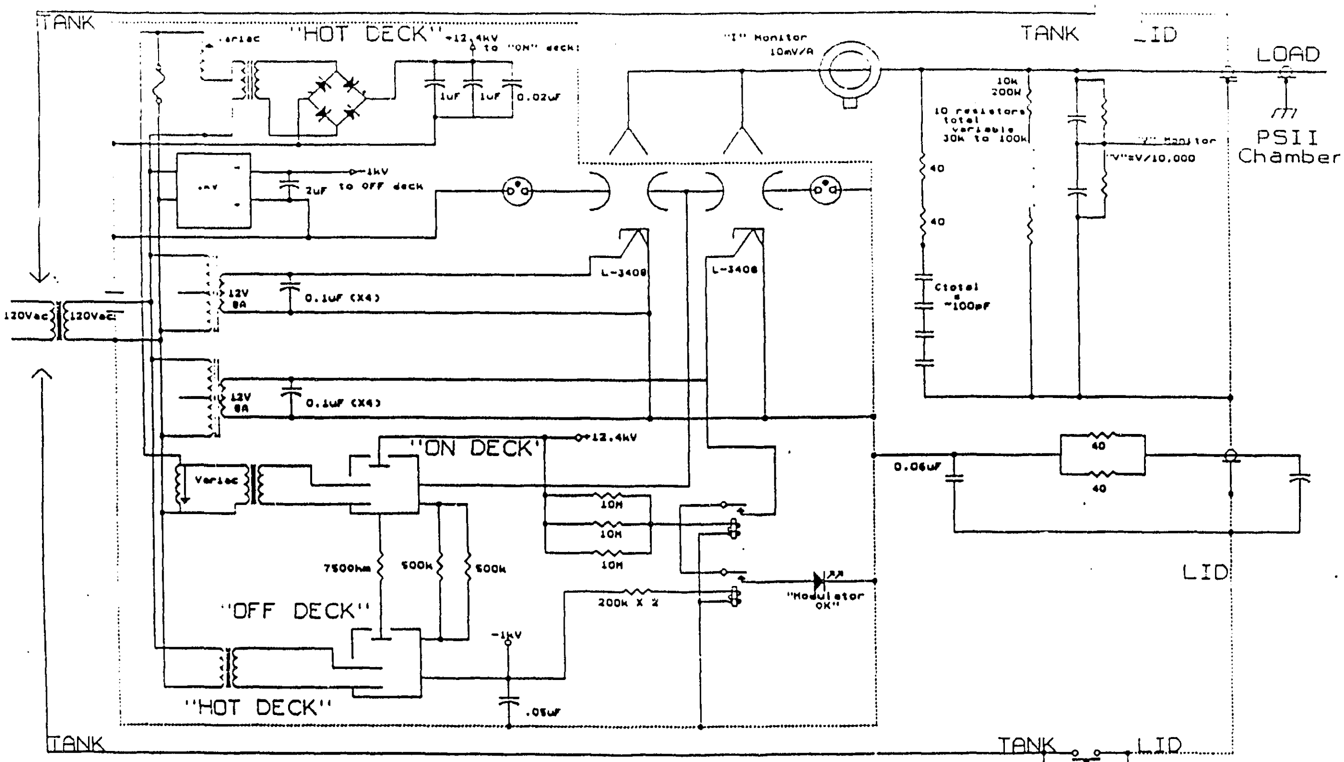


Figure 2.

PSII MODULATOR

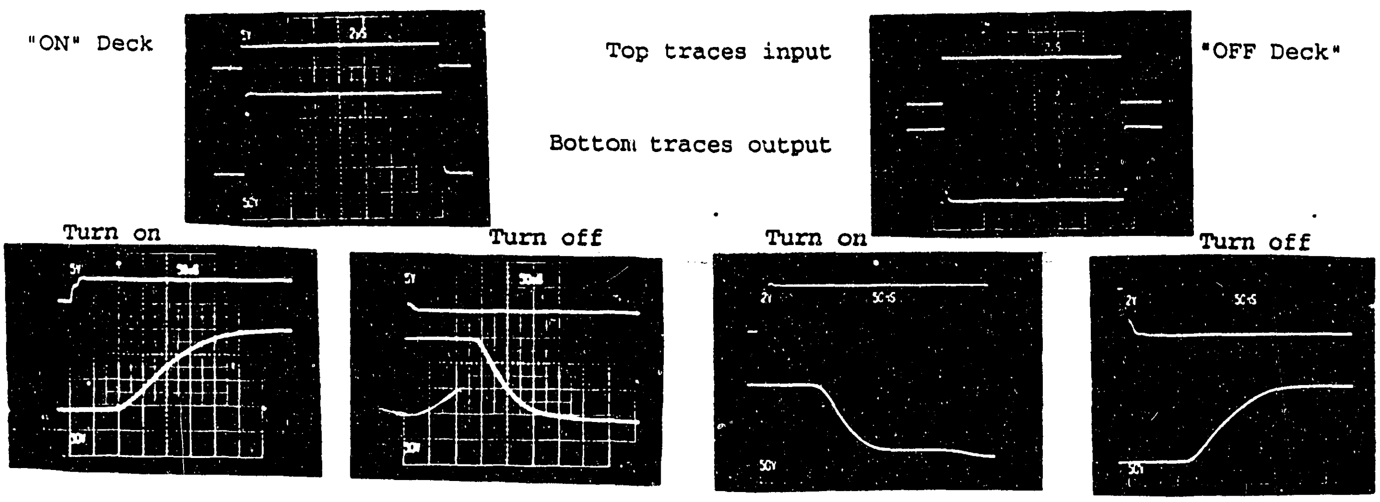


Figure 3.

designed, as shown in Fig. 4, to be simple and reliable containing the minimum number of components consistent with a fast rise and fall time and flat top pulse. Our solid state drive circuit, although not complicated or optimized for radical rise and fall times, works efficiently, and is suitable for both the "on" and "off" decks. Reliability is essential for industrial applications requiring maximum continuous, fault-free operation. A fast integrated fiber-optic receiver with TTL output directly drives a high current, high speed differential line driver. The receiver has less than 50 ns delay and typical TTL rise time. Either line driver output may be selected (phase inversion) for the "on" or the "off" deck. These drive a common base amplifier, without peaking, where the collector resistance is chosen such that saturation is just avoided.

This results in the complementary symmetry driver swinging from tube cut-off to a few volts negative. This drives the grids of the Eimac 8941\Y690 planar triode output stage. During the gate pulse the "on" deck planar triode is switched full on and the "off" deck planar triode is switched full off. Between gate pulses the triodes are in the reverse states. The "off" deck is at a potential of -1 kV and the "on" deck is at +12.4 kV. Varying the "on" deck voltage controls the L-3408 output current capability. The resulting drive deck output waveforms (both decks) driving the two L-3408 hollow beam switch tubes are shown in Fig. 5.

Power for the drive deck circuits is obtained from the planar triode filament transformer. The "on" deck filament transformer is a low-capacitance, 30 kV (in air) isolation

PSII Modulator "On Deck"

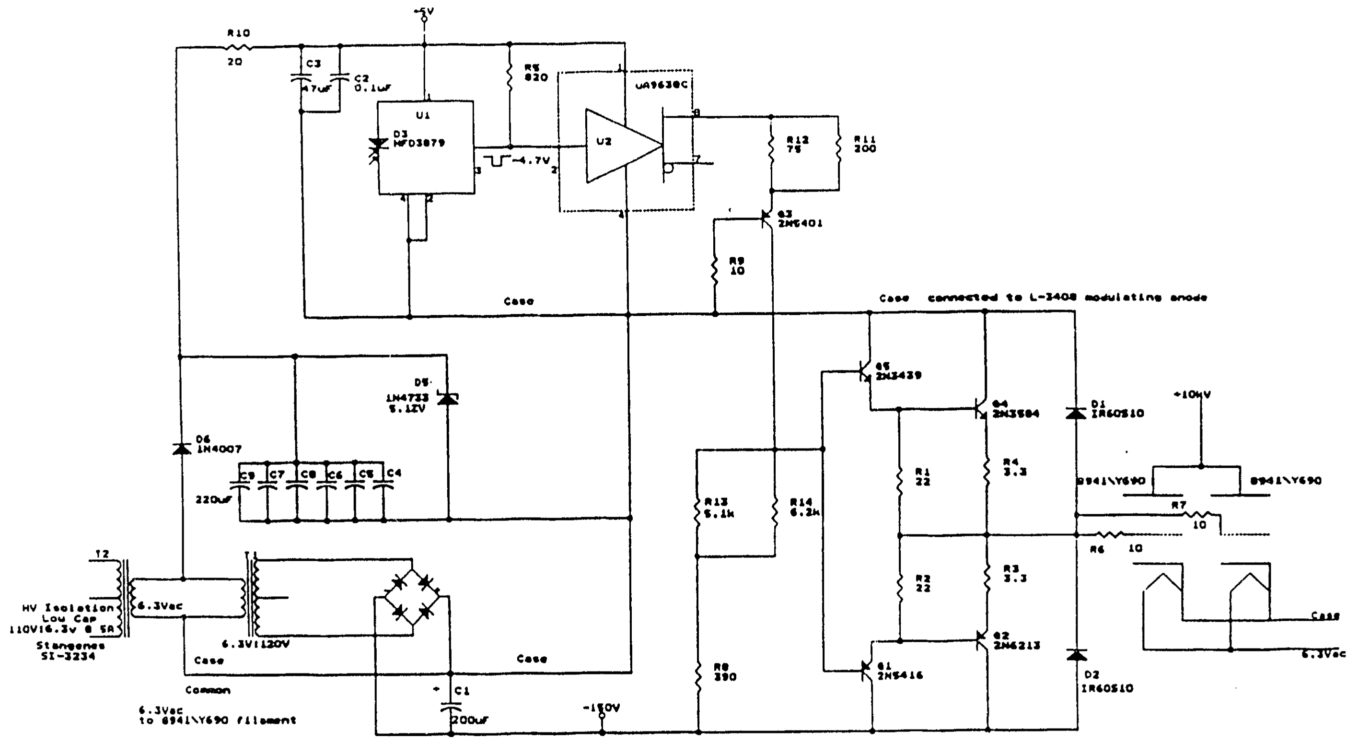
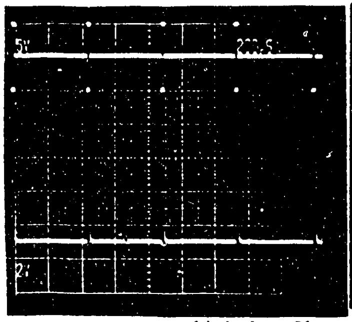
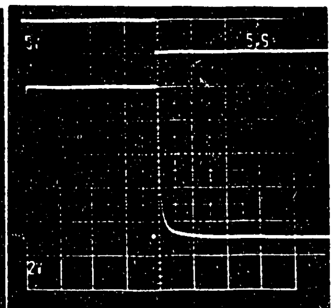


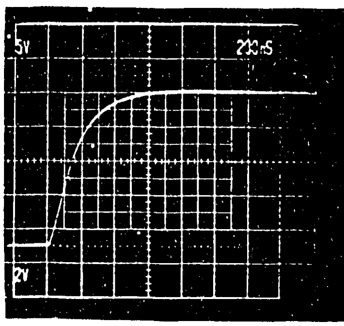
Figure 4.



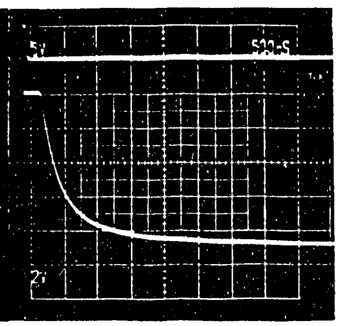
1. Frequency slightly >2kHz



2. 20 uSec pulse width



3. Rise time



4. Fall time

"ON" and "OFF" Decks pulse characteristics driving L-3408 mod anodes L-3408s @ 25 kV - measurements in air

Figure 5.

transformer. The filament transformers are located outside the drive deck housing. A second transformer in each drive deck, mounted inside the housing, steps the 6.3 Vac up to 150 Vac which is rectified for the planar triode drive voltage. The input circuitry is powered by rectifying and zener regulating the 6.3 Vac filament voltage.

Results

The LANL PSII facility started operating in May 1993. Initial operation was at 50 kV, 50 A, 500 Hz, and 20 us pulse width. Initial analysis of implanted coupons, specially fabricated for dose analyzation, indicate that the implanted dose is consistent with the values predicted by the calculations.

References

[1] B. P. Wood, J. T. Scheuer, M. A. Nastasi, W. A. Reass, D. J. Rej, and I. Henins, "Design of a Large-Scale Plasma Source Ion Implantation Experiment,"presented at Materials Research Society 1992 Fall Meeting, Boston, Massachusetts, Nov. 30 - Dec. 4, 1992.

[2]William Reass, Don Rej, Jay Scheuer, and Blake Wood, "Optimal Pulse Modulator Design Criteria for Plasma Source Ion Implantors," these Proceedings.

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