High Current Arc Modulation with Solid-State Switching Power Supply

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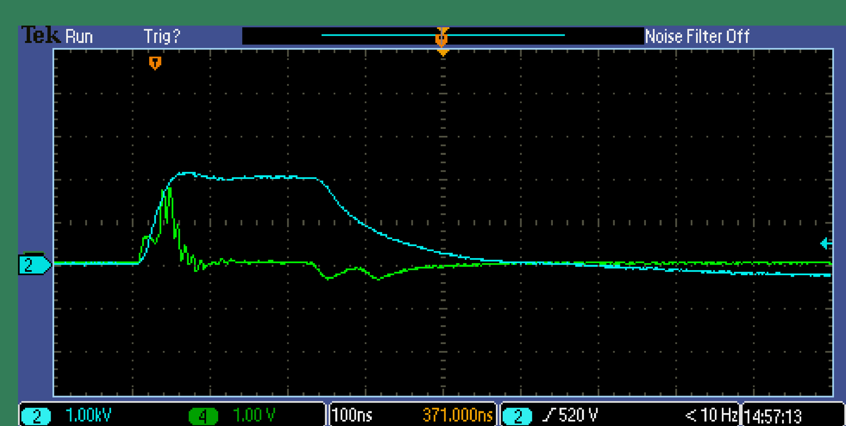
EAGLE HARBOR TECHNOLOGIES

Introduction

Modulation of high current arcs is important for both research and industrial applications. Eagle Harbor Technologies, Inc. (EHT) has constructed a test system using an EHT Nanosecond Pulser to initiate the discharge and four EHT Integrated Power Modules (IPM) to drive and modulate the current in the arc. The EHT Nanosecond Pulser can produce high voltage pulses up to 20 kV with adjustable pulse width (30 - 250 ns), and high pulse repetition frequency (10 kHz). The EHT IPM is a solid-state high current switch that can be operated at several megahertz. We will present the circuit diagram, test setup, and waveforms demonstrating current modulation at high frequency (2 MHz).

Nanosecond Pulser

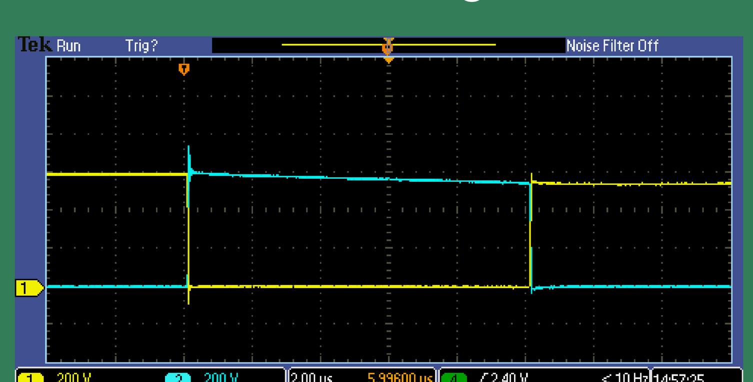
The EHT Nanosecond Pulser (NSP) is designed to drive capacitive loads like dielectric barrier discharges and pseudosparks. This pulser can produce output pulses up to 20 kV with rise times down to 20 ns and pulse widths 40 - 500 ns. These pulses can be repeated at frequencies up to 10 kHz. The high voltage EHT NSP was used to initiate the discharge in this work.

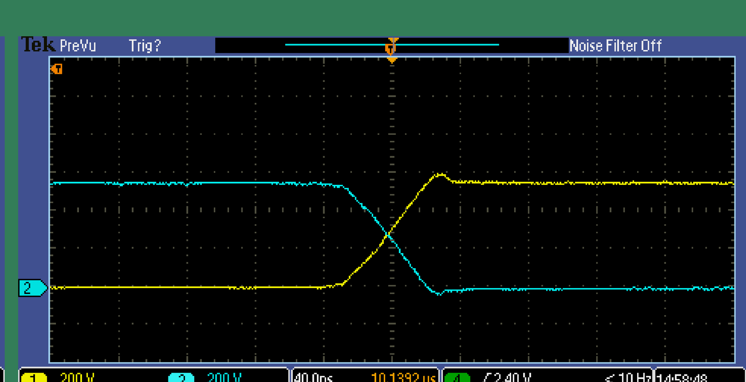


Left: EHT NSP-120-20-P-500. Right: Voltage (blue) and current (green) measurements of a dielectric barrier discharge driven by the NSP.

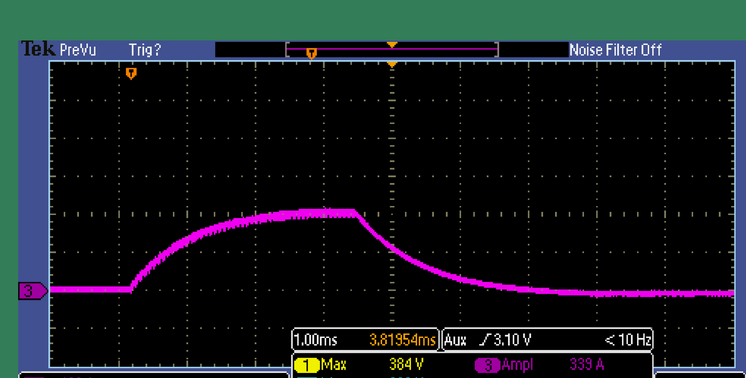
Integrated Power Module

The EHT Integrated Power Model (IPM) is a solid-state switch that was designed to simplify high current magnet control. Additionally, the EHT IPM can hard switch high currents into resistive loads.





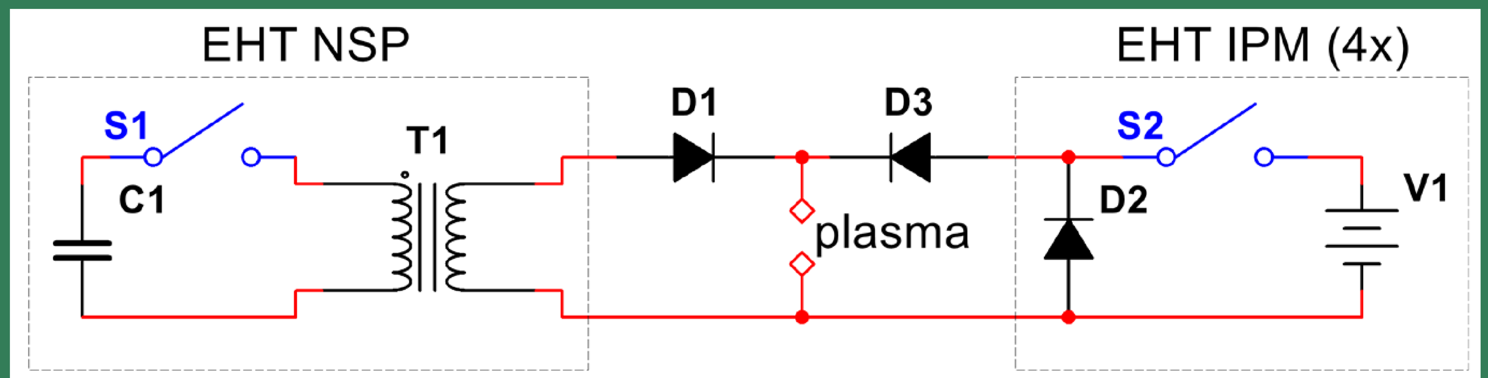
Left: Clean switching waveform into 1 Ω load. Right: Same waveform showing fast voltage and current rise time (< 40 ns).



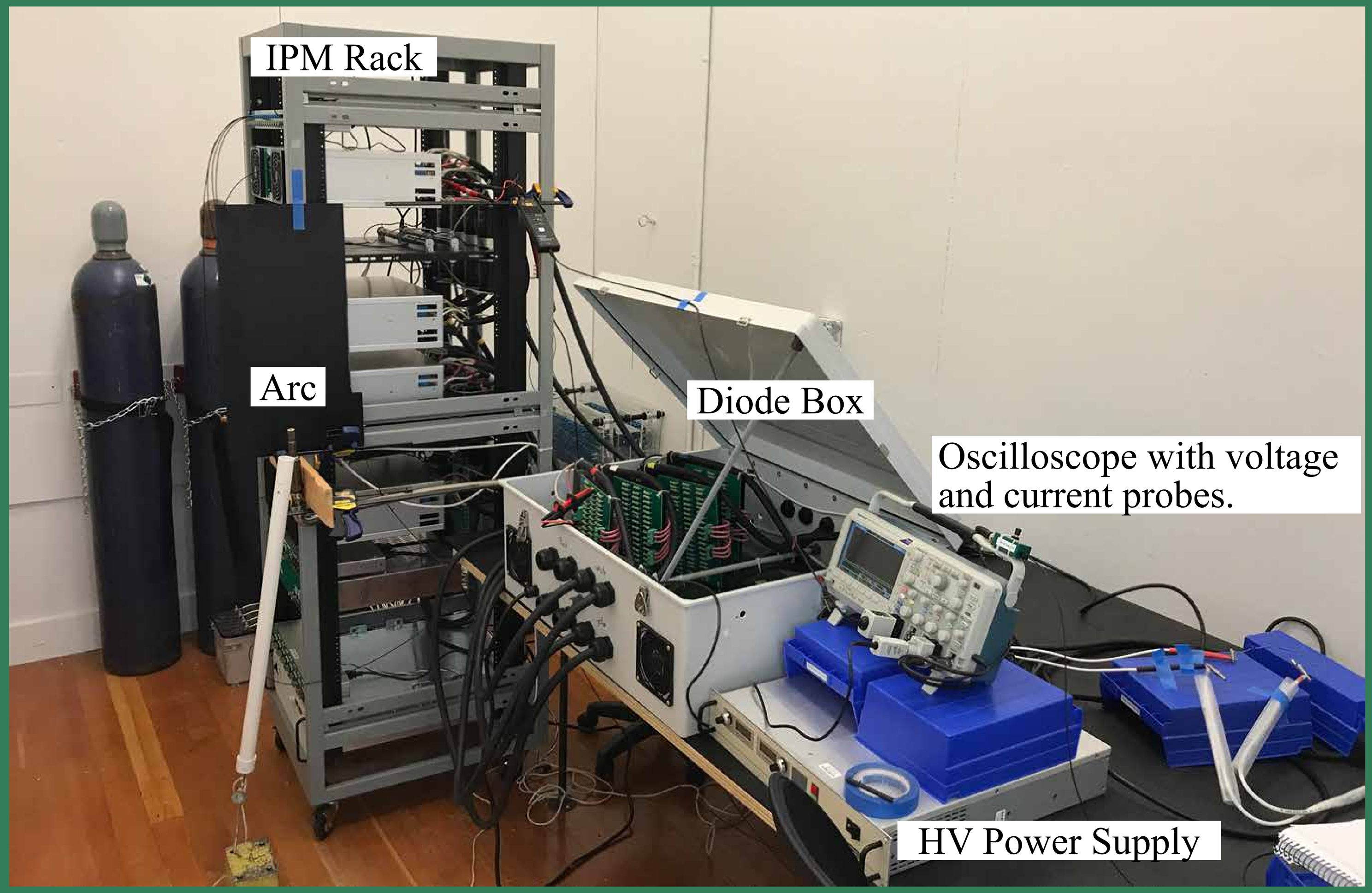
Left: EHT IPM Right: Current waveform. IPM driving a 85 μH inductor at 350 V and 340 A with a PWM drive frequency of 30 kHz.

Experimental Setup

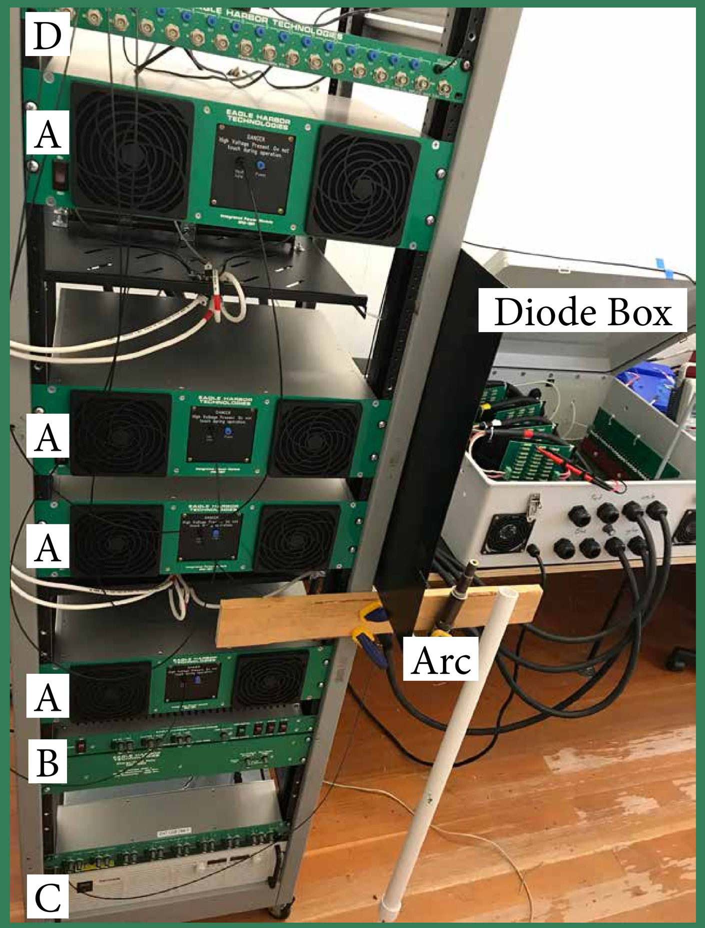
EHT used an NSP and four IPMs to create and modulate an arc. The NSP produced the high voltage necessary to initiate the discharge. The EHT IPMs were used to drive high current in the arc. The IPMs can be operated with short pulse widths and high pulse repetition frequencies. The PWM frequency was 2 MHz, which allowed for precision control of the flattop.



Circuit diagram showing the EHT NSP and four EHT IPMS connected to an arc system. D1 and D3 are isolation diodes that prevent high current from flowing into the NSP and high voltage from being generated on the IPMs.



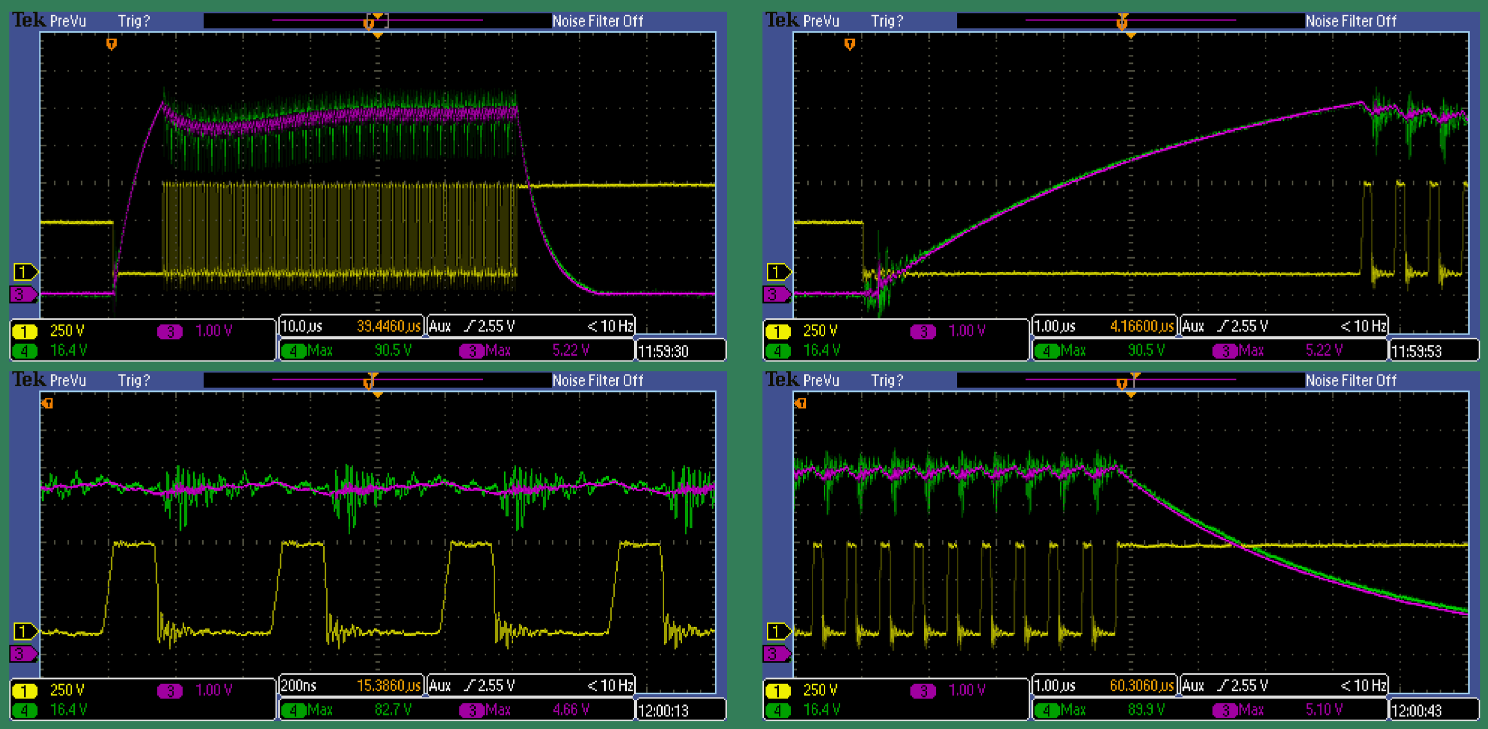
Experimental setup showing IPM rack, arc, diode box, high voltage power supply, and oscilloscope.



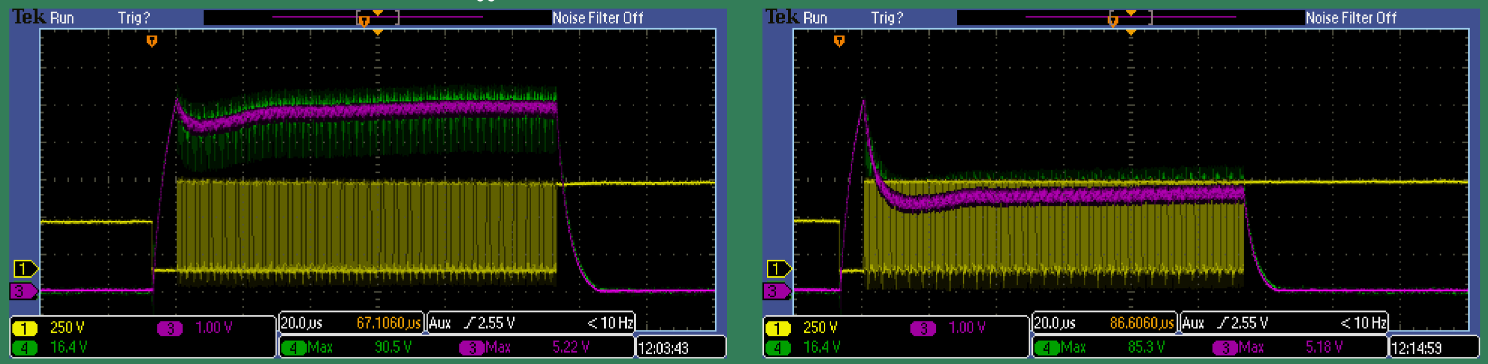
Left: Rack containing four EHT IPMs (A), charge dump system (B), DC charging supply (C), and fiber optic trigger system (D). Right: Plasma arc.

Arc Current Modulation

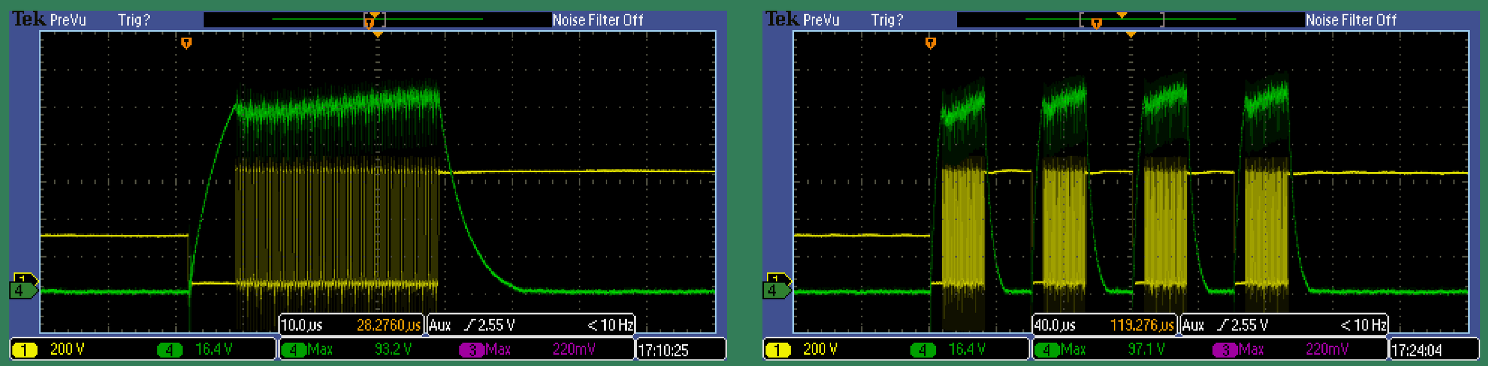
For most shots, the NSP was operated at 20 kV and 500 ns pulse width. The IPMs were operated at 2 MHz. The IPM voltage, pulse width, and number of pulses were used to control the current in the arc.



IPMs operated at 600 V, 350 ns pulse width, for 120 pulses at 2 MHz. Flattop current is 2.0 kA. Traces shown are V_{ce} (yellow), current probe (pink), and shunt resistor (green).



IPMs operated at 600 V for 240 pulses with a pulse width of 350 ns (left) and 200 ns (right), which produced flat top currents of 2.0 kA (left) and 1.1 kA. Traces shown are V_{ce} (yellow), current probe (pink), and shunt resistor (green).



IPMs operated at 600 V with a pulse width of 375 ns for 240 pulses which produced flat top currents of 2.0 kA. Single burst (left) and four bursts at 17 kHz (right). Traces shown are V_{ce} (yellow) and shunt resistor (green).

Conclusion

EHT has successfully used a NSP and four IPMs to generate an arc and modulate the arc current. By operating the IPMs at 2 MHz and short pulse widths, low ripple in the arc can be obtained. The bursts can be repeated at high pulse repetition frequency (17 kHz).

The current in the arc can be controlled by the IPM voltage (on slow timescales) and by the pulse width of the IPM on fast timescales. With a control system capable of fast loop times, the IPMs could be used to modulate the current in an arc in real time.

For more information: http://www.eagleharbortech.com/