Fast Rise Time and High Voltage Nanosecond Pulses at High Pulse Repetition Frequency

K.E. Miller*; T.M. Ziemba; J.R. Prager; J. Picard; A. Hashim
*kemiller@eagleharbortech.com

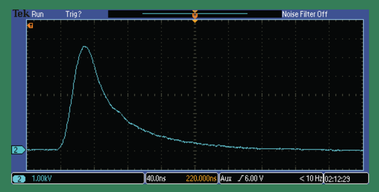
EAGLE HARBOR TECHNOLOGIES

Introduction

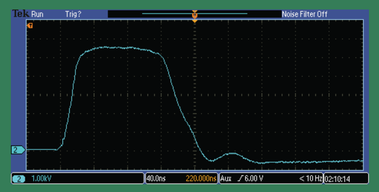
Eagle Harbor Technologies (EHT), Inc. is conducting research to decrease the rise time and increase the output voltage of the EHT Nanosecond Pulser product line, which allows for independently, user-adjustable output voltage (0 – 20 kV), pulse width (20 – 500 ns), and pulse repetition frequency (0 – 100 kHz). The goals are to develop higher voltage pulses (50 – 60 kV), decrease the rise time from 20 to below 10 ns, and maintain the high pulse repetition capabilities. These new capabilities have applications to pseudospark generation, corona production, liquid discharges, and nonlinear transmission line driving for micro-wave production.

High Voltage

EHT has developed a prototype board to demonstrate techniques of reducing stray inductance and capacitance to improve the pulse rise time. The 40 kV output voltage was measured with 7 kΩ resistive load with a 1:7 voltage division ratio. The rise times are defined as 10% - 90% of the peak output voltage across the load. The next goal will be to produce similar pulses into lower impedance loads.

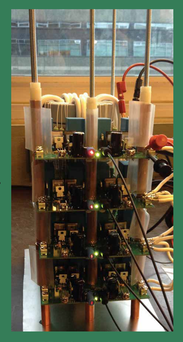


T_{rise} ≈ 20 ns, Pulse width ≈ 40 ns FWHM

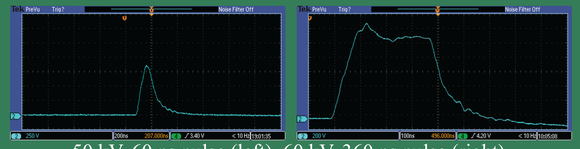


T_{rise} ≈ 20 ns, Pulse width ≈ 130 ns FWHM

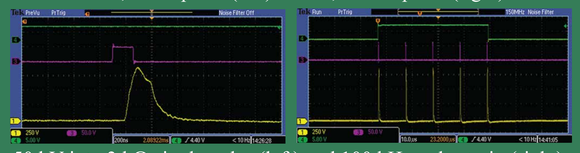
Previous work has focused on higher voltage (50 - 60 kV) at high pulse repetition frequency (100 kHz). This technique also allowed for unique waveform shapes.



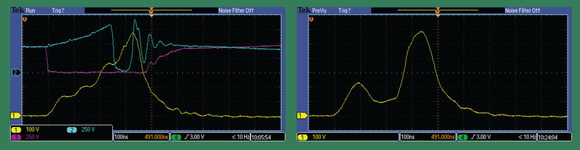
High voltage nanosecond pulser test setup to demonstrate high voltage 100 kHz frequency



50 kV, 60 ns pulse (left). 60 kV, 360 ns pulse (right).



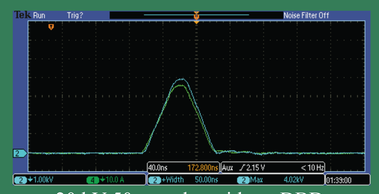
50 kV into 3 kΩ single pulse (left) and 100 kHz pulse train (right).



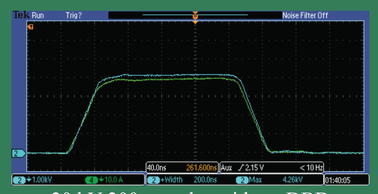
Pulse waveform shaping: Yellow trace is output voltage.

Dielectric Barrier Discharge Waveform

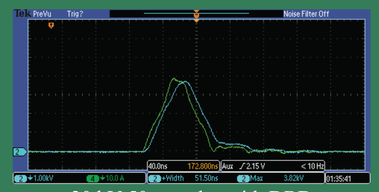
Many DBD applications require voltages up to 20 kV. An ideal pulser would produce an output that would not change significantly in the presence of a DBD. The traces below show the output voltage (blue) and output current (green) with and without a DBD at two different pulse widths. The load resistor was 550 Ω and the DBD was 12 pF. At this higher voltage, the pulser can still operate at 100 kHz CW and be burst to higher frequency.



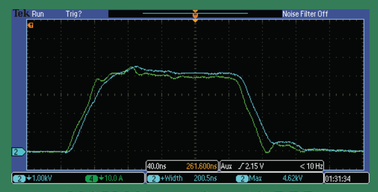
20 kV 50 ns pulse without DBD



20 kV 200 ns pulse without DBD



20 kV 50 ns pulse with DBD

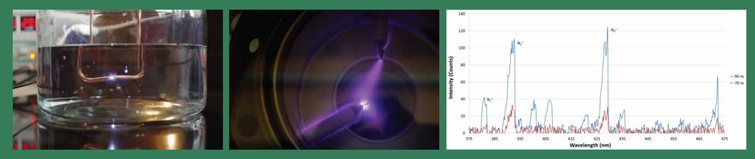


20 kV 200 ns pulse with DBD

Nanosecond Pulser Driving Non-equilibrium Plasma

EHT has used the EHT Nanosecond Puslers to drive non-equilibrium plasmas including dielectric barrier discharges, pseudosparks, capillary discharges, and atmospheric pressure plasma jets (APPJ).

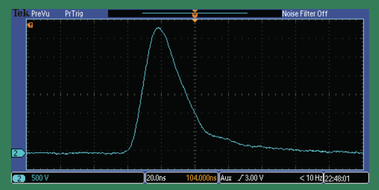
Dielectric barrier discharge jet into low pressure background (left), large area APPJ - 3 cm diameter (middle), and small APPJ 0.625 cm diameter (right)



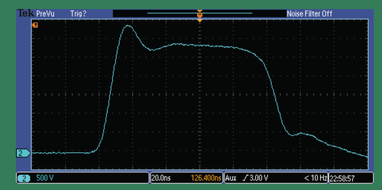
Underwater discharge (left). Pseudospark in low pressure xenon (middle). APPJ plume spectra demonstrating the effect of varying the pulse width (right)

Rise Time Improvements

The goal of this test was to evaluate the output of the upgraded nanosecond pulser to identify the shortest rise time. The output voltage was 20 kV into a floating 1.7 kΩ load. The 10% - 90% (of waveform flat top) rise time ≈ 9 ns. Waveforms: Blue = V_{Out}, Purple = I_{Out}



T_{rise} ≈ 9 ns, Pulse width ≈ 40 ns FWHM



T_{rise} ≈ 9 ns, Pulse width ≈ 200 ns FWHM

Conclusion

Eagle Harbor Technologies, Inc. has developed a customizable, high voltage nanosecond pulser specifically designed to produce non-equilibrium plasmas like pseudosparks, dielectric barrier discharges, atmospheric pressure plasma jets, and other cold atmospheric plasmas. Unlike other nanosecond pulsers on the market, EHT pulsers give the user the ability to independently adjust the output voltage, pulse width, and pulse repetition frequency using front panel controls. With this control researchers can carefully optimize the specific plasma parameters needed for their application.

- Output voltage: 0 - 20 kV
- Pulse width: 20 - 500 ns
- Pulse repetition frequency:
  - CW: Single Pulse - 100 kHz
  - Burst: Up to 1 MHz
- Rise time: 20 ns (load dependent)
- Power: 30 W - 5 kW
- Integrated front panel control
- DC power supply included

EHT Nanosecond Pulser product line

Acknowledgment

This work was supported by the U.S. Navy SBIR (N00014-14-P-1055)

Further Information

For a copy of this poster please visit http://www.eagleharbortech.com.