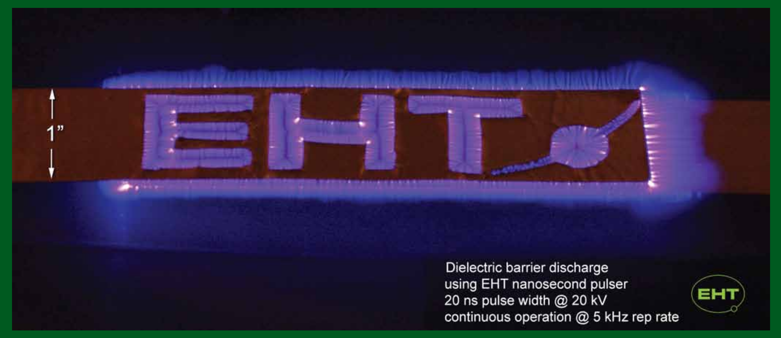
A high voltage nanosecond pulser with variable pulse width and pulse repetition frequency control for non-equilibrium plasma applications

T. M. Ziemba; K. E. Miller; J. R. Prager; J. G. Carscadden; and I. Slobodov
prager@eagleharbortech.com
EAGLE HARBOR TECHNOLOGIES

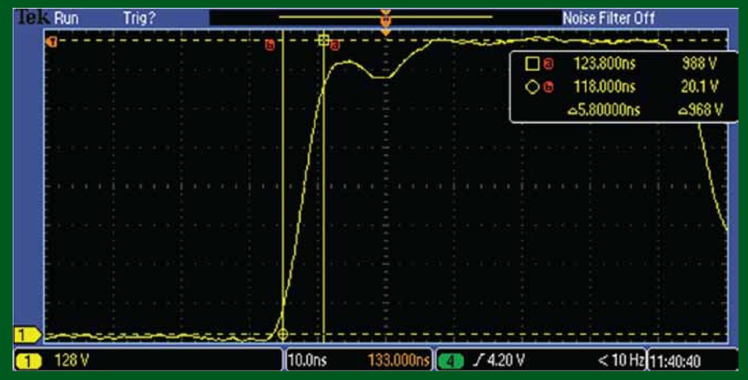
Introduction:



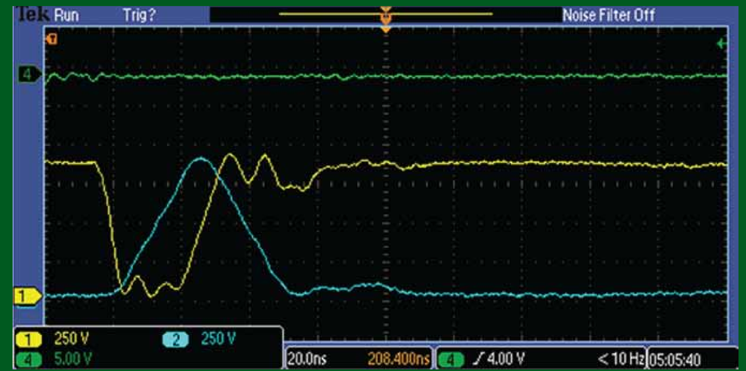
Eagle Harbor Technologies (EHT) is developing a high voltage nanosecond pulser capable of generating non-equilibrium plasmas, including dielectric barrier discharges, pseudospark discharges, and liquid plasma discharges for plasma medicine, material science, enhanced combustion, drag reduction, and other research applications. The EHT nanosecond pulser technology is capable of producing high voltage (up to 60 kV) pulses (width 20 – 500 ns) with fast rise times (< 10 ns) at high pulse repetition frequency (adjustable up to 100 kHz) for CW operation. The pulser does not require the use of saturable core magnetics, which allows for the output voltage, pulse width, and pulse repetition frequency to be fully adjustable, enabling researchers to explore non-equilibrium plasmas over a wide range of parameters. A magnetic compression stage can be added to improve the rise time and drive lower impedance loads without sacrificing high pulse repetition frequency operation.

Nanosecond Pulser Hardware:

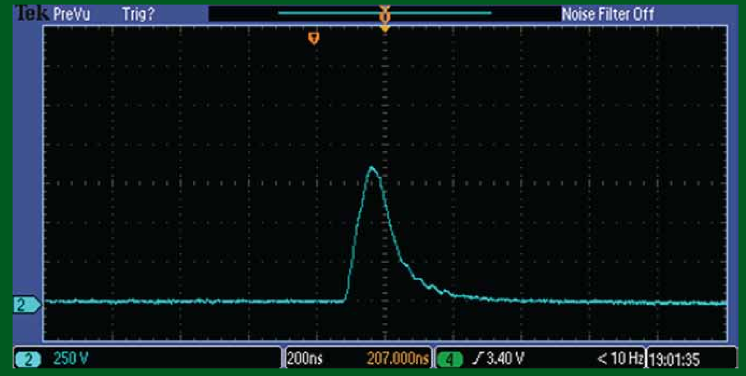
The EHT nanosecond pulser is based on IGBT switching technology that allows for extremely fast IGBT transititions. Two test boards have been constructed. A low power board was designed to enable rapid transformer prototyping and IGBT testing (right). A high power version was designed for use in plasma applications that require higher input power and for directly driving lower impedance loads (not shown).



10 kV, 70 ns pulse with 6 ns rise.



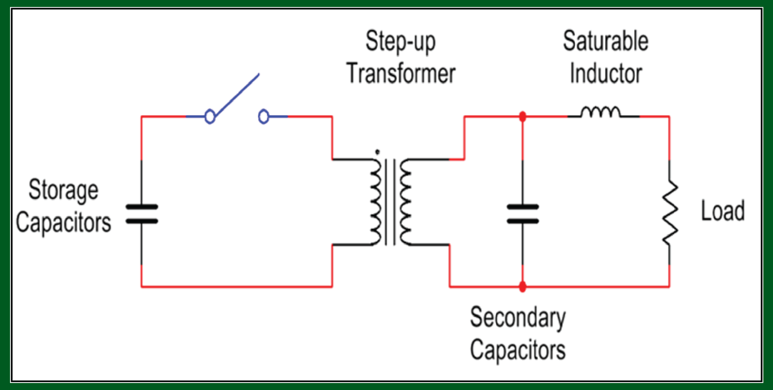

Variable pulse width demonstration with a single transformer: 18 kV pulse with 30 ns (Left, Blue Trace) and 500 ns (Right) pulse width measured at the FWHM.



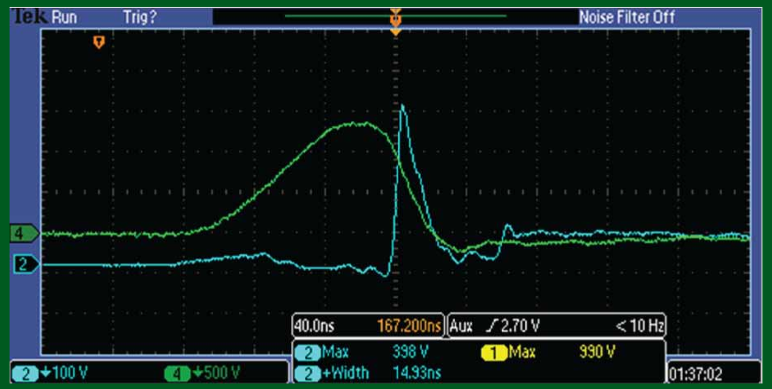

High voltage demonstration with different pulse widths: (Left) 50 kV pulse with 60 ns FWHM. (Right) 60 kV (flat section) 360 ns pulse.

Magnetic Compression Stage Testing:

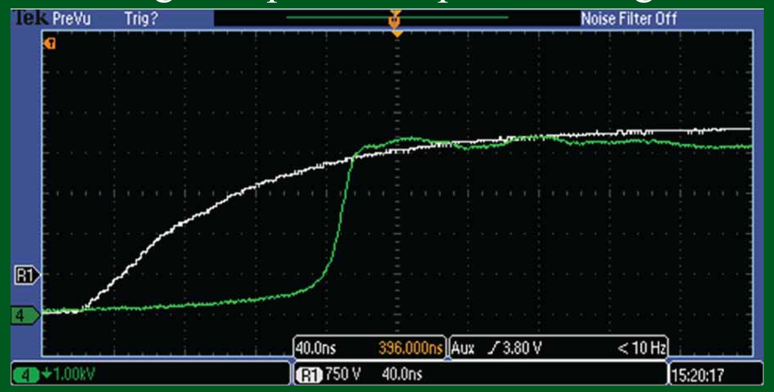
Adding a magnetic compression stage allows for faster rise times, shorter pulse widths, and low impedance load driving but is not required for many applications.



Simplified circuit with a single magnetic pulse compression stage.



Compressed pulse (Ch2) into 50 Ohms at 12 kV.

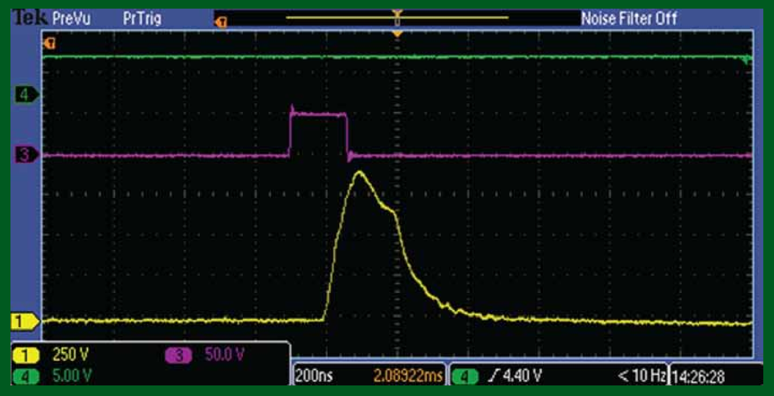


Comparison of rise time for non-compressed and compressed pulses

Compressed 12 kV pulses with variable pulse widths.

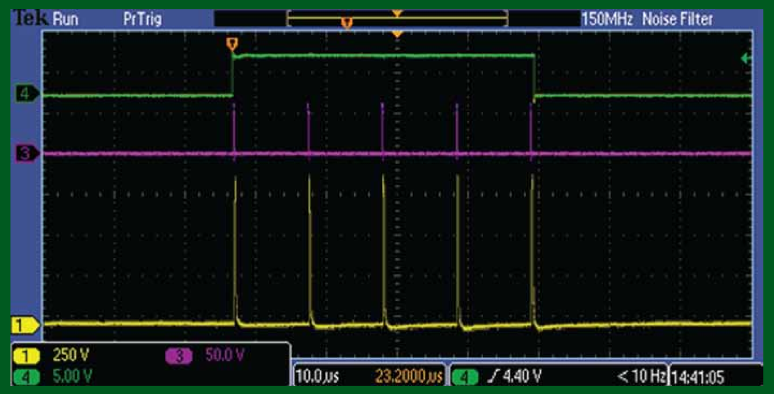
High Pulse Repetion Frequency Testing:

High PRF is difficult to obtain with multi-stage magnetic reactor pulsers, which are not required for the EHT pulser. This allows for PRF > 100 kHz and a frequency that can be changed on the fly. Even with a single stage saturable element, the nanosecond pulser is capble of switching at 100 kHz.

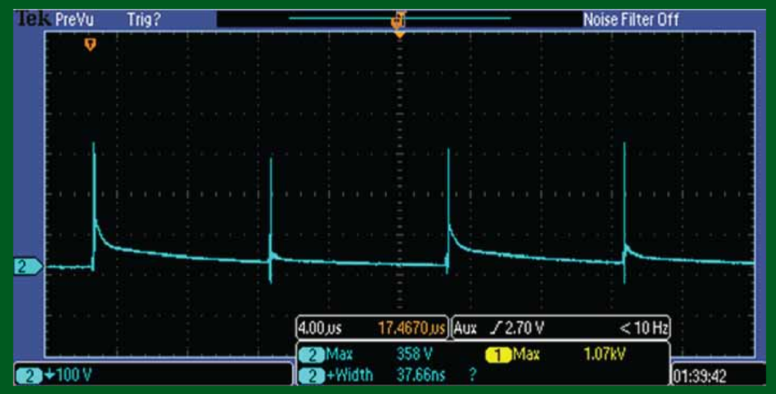


50 kV single pulse into 3000 Ohm load

50 kV into 3000 Ohm load at 10 kHz



50 kV into 3000 Ohm load at 100 kHz without magnetic compression



10 kV 15 ns pulses at 100 kHz into 50 Ohm load using magnetic compression

Acknowledgments:

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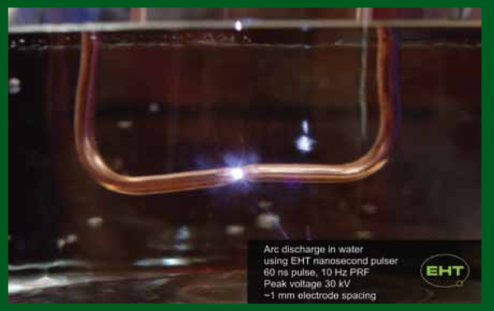
Plasma Physics Applications:

The EHT nanosecond pulser has been utilized to generate a wide variety of non-equilibirum plasmas.

EHT nanosecond pulser driving dielectric barrier discharges (DBD). The DBD driver for EP Technologies operated at 20 kV at 100 Hz (left) and 10 kHz (middle) for plasma medicine applications. At right, a 1 m long DBD-based plasma wand for atmospheric drag reduction demonstrating the capability of driving high capacitance DBDs.


Left: EHT nanosecond pulser driving an atmospheric DBD-based plasma pencil made with flowing helium gas. Middle: Water plasma discharge driven by EHT nanosecond pulser. Right: Pseudospark generated in low pressure argon background (~200 mTorr). To create the pseudospark, the pulser produced 30 kV, 80 ns pulses at 200 Hz during CW operation.

Conclusions

This research builds on the first generation EHT nanosecond pulser (NSP-1000). EHT has successfully demonstrated the following capabilities:

- Operation with variable pulse widths (20 – 500 ns)
- Fast rise times (< 10 ns)
- Wave shape flexibility
- Adjustable, high peak voltage (60 kV) at high power (10s MW)
- Adjustable, high repetition frequency operation > 100 kHz

Future pulsers in this family will have improved thermal management, deliver more energy per pulse, produce pulses with faster rise times, and be able to drive lower impedance loads. These improved capabilities of these pulsers will enable them to drive non-linear transmission lines and produce unique non-equilibrium plasmas.

First generation EHT nanosecond pulser

Further Information:

For more information on nanosecond pulsers or other switching power supplies please visit our website (http://www.eagleharbortech.com) or email me.