Spectroscopic Investigation of a DBD Over a Wide Range of Pulse Parameters

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EAGLE HARBOR TECHNOLOGIES

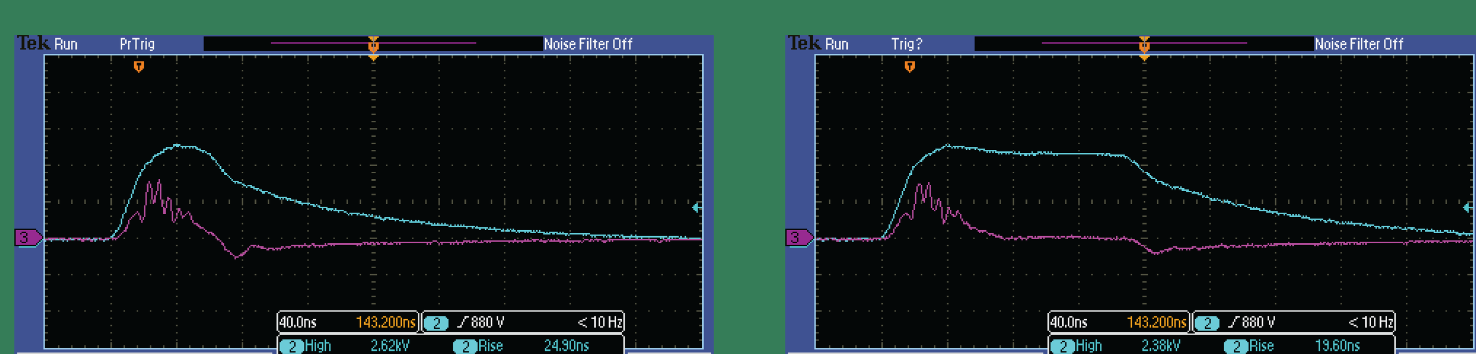
Introduction

Most high voltage pulsers used to drive dielectric barrier discharges (DBDs), produce a single pulse shape (width and voltage), making it challenging to assess the effect of pulse shape on the production of different chemical species during a discharge. Eagle Harbor Technologies (EHT), Inc. has developed a nanosecond pulser that allows for independent control of the output voltage, pulse width, and pulse repetition frequency. Through the utilization of this technology, presented here is a characterization of reactive species generated by the DBD under the independent variation of voltage (0-20 kV), frequency (0-10 kHz) and pulse width (20-180ns). A better understanding of this parameter dependency can allow for more targeted and effective application of plasma in medical, environmental, industrial, and other applications.

EHT Nanosecond Pulser

EHT has developed a customizable, high voltage nanosecond pulser with independently adjustable output voltage, pulse width, and pulse repetition frequency for producing non-equilibrium plasmas like pseudosparks, dielectric barrier discharges, atmospheric pressure plasma jets, and other cold atmospheric plasmas. The pulser used for this experiment had the following parameters:

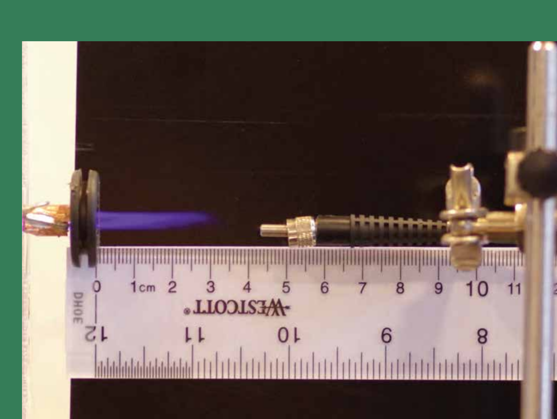
- Output voltage: 0 - 20 kV
- Pulse width: 20 - 260 ns
- Pulse repetition frequency: Single Pulse - 10 kHz (CW)
- Rise time: 20 ns (load dependent)
- Power: 120 W



Output voltage (blue) and output current (pink) measured with 1:4.5 voltage divider and current transformer for a 10 kV pulse of 80 ns (left) and 184 ns (right) into a DBD

Expermintal Setup

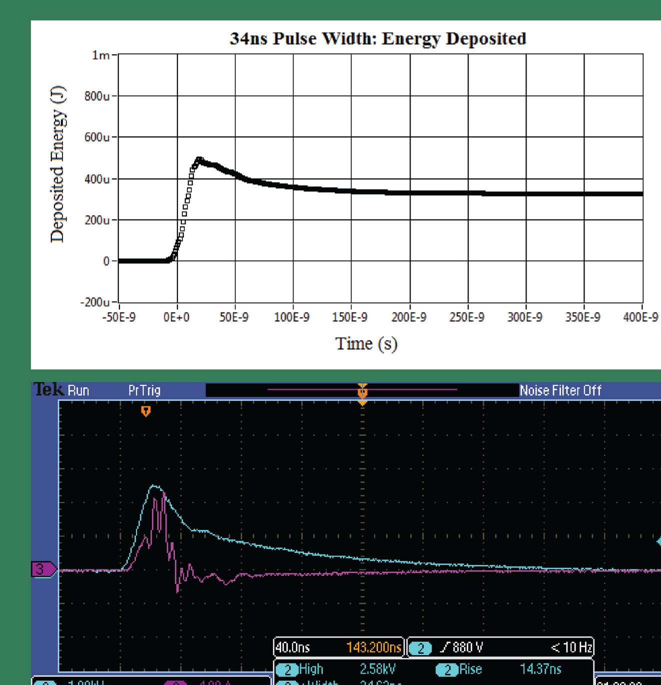
EHT constructed several DBD and DBD-like electrode configuration. These included a helium plasma-pencil jet, a high-pressure Xenon-Bromine DBD, and an arc in air. In all cases, the two electrodes were driven with the EHT NSP-120-20-F Nanosecond Pulser. Using an oscilloscope and high-frequency current and voltage probes, the NSP output current and voltage were measured. A Thor Labs CCS200 spectrometer was used to obtain the spectral data.



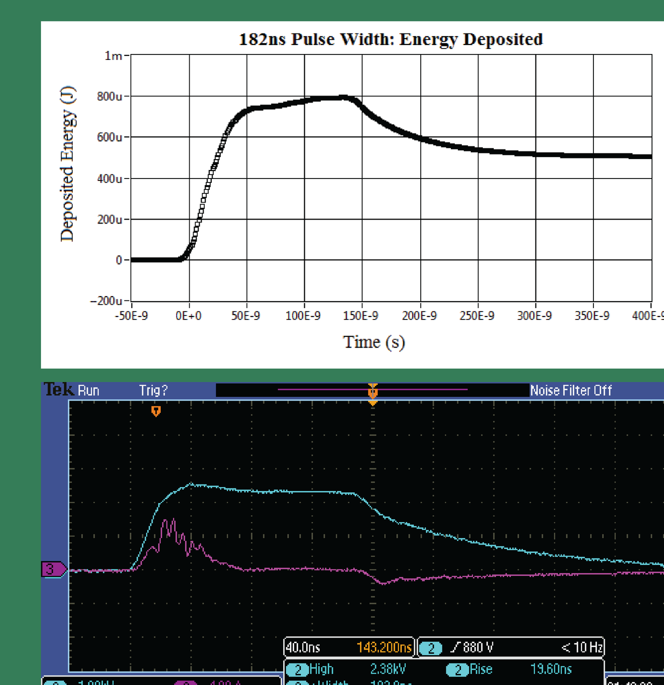
Plasma plume and spectrometer fiber.

Atmospheric Plasma Pencil DBD-like Jet

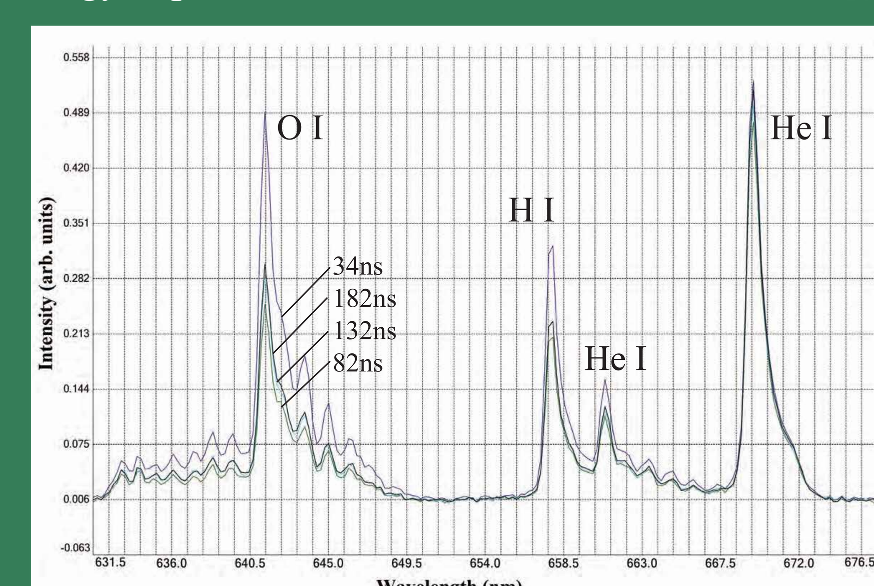
A DBD-like 'plasma pencil' consisted of an outer band electrode around a 0.25" quartz tube and a copper pin inner electrode. Helium gas flowed thtough the quartz was ionized with 12kV nanosecond pulses at a variety of PRFs and pulse widths, interacting with neutrals to produce spectra.



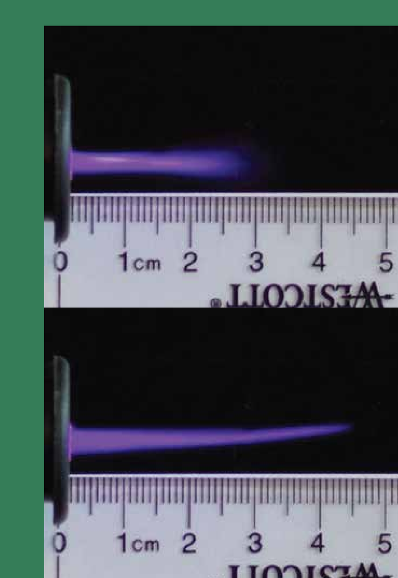
Energy deposition and waveform at 34ns



Energy deposition and waveform at 182ns



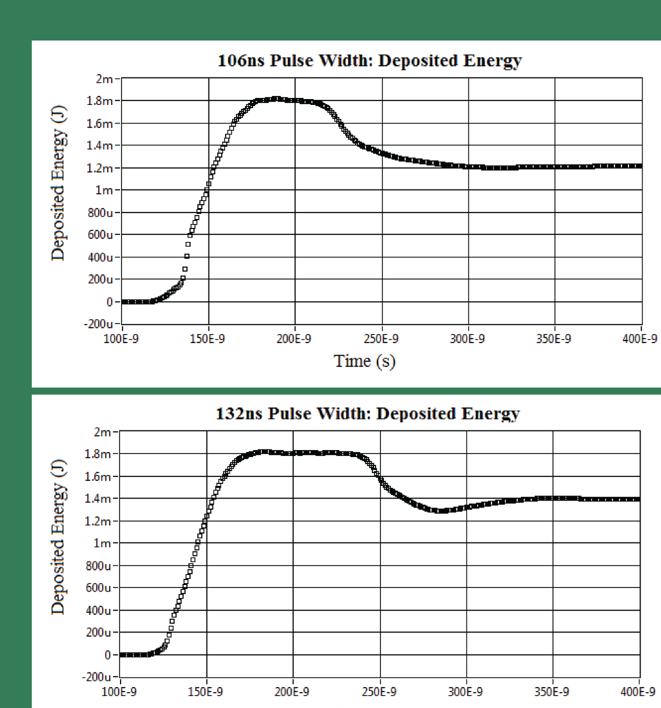
Operation at different pulse widths clearly shows intensity variation of O and H lines, but not He lines



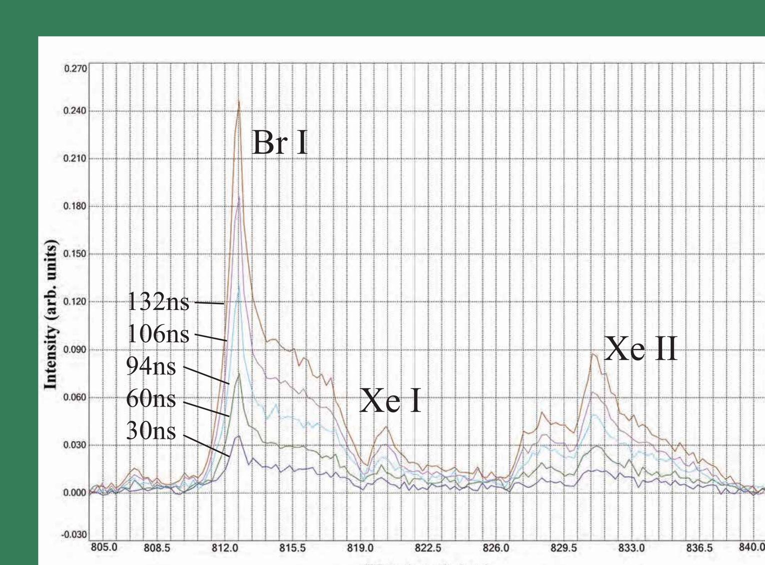
Gas flow decreased from 7.4 - 1.5 sL/min. Maximum jet length was at 2.4 sL/min

High Pressure Xenon-Bromine DBD

The DBD consisted of a sealed mixture of xenon and bromine at 7 atm inside a 1cm diameter quartz tube. 20kV nanosecond pulses were applied at 1kHz between an internal tungsten electrode and an external copper electrode. Varying pulse width yielded changes in both spectral line intensity and total energy deposited in the plasma.



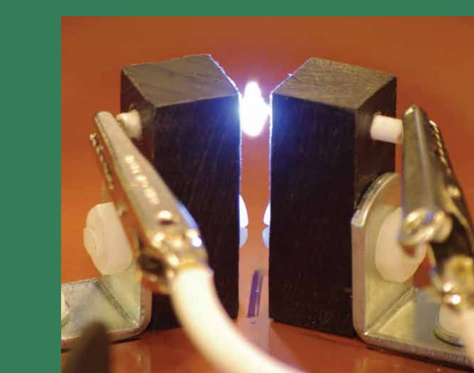
106ns and 132ns pulses deposited 1.2mJ and 1.4mJ into the plasma, respectively.

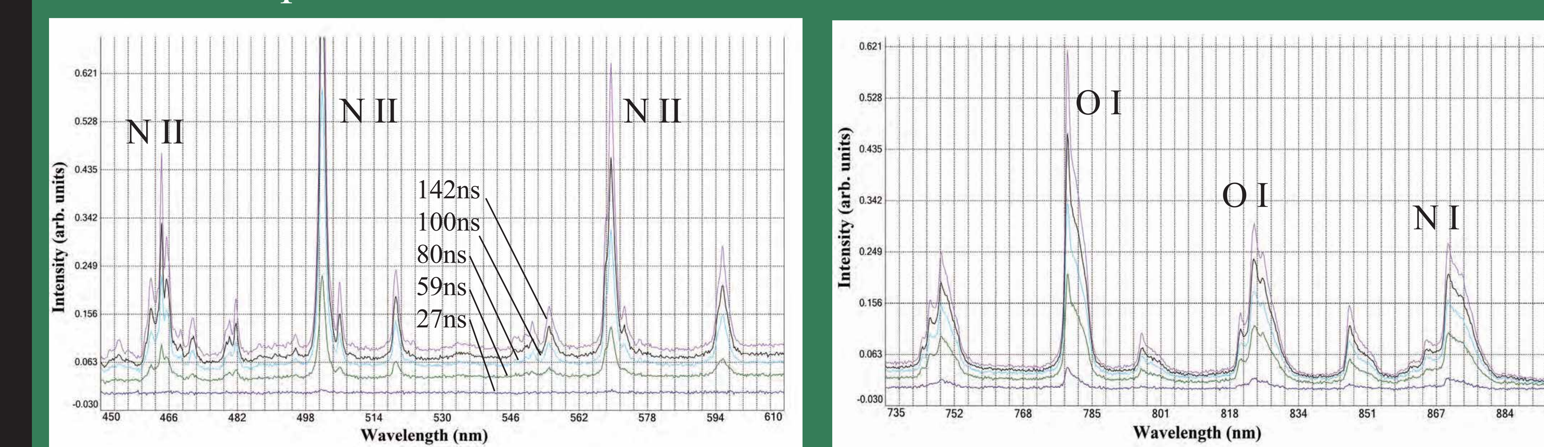


While increases in the blackbody radiation were modest, Br I, Xe I, and Xe II spectral lines increased dramatically with pulse width. This indicates potential utility of nanosecond pulsers in exomer production

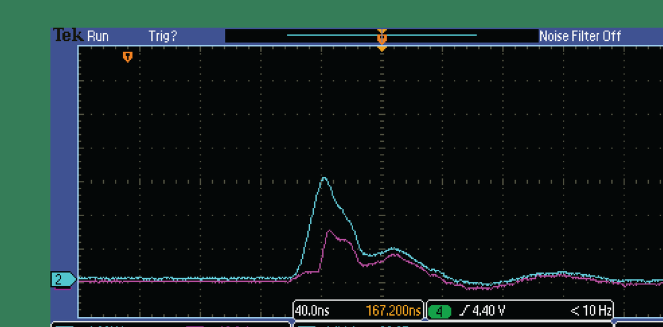
Atmospheric Arc

An arc was created between copper electrodes with a 1mm spacing with 15kV nanosecond pulses 1kHz and a variety of pulse widths. The results indicated that varying the pulse width allows for isolation of various arc phases, and therefore selecting for relative intensities of different spectral lines.

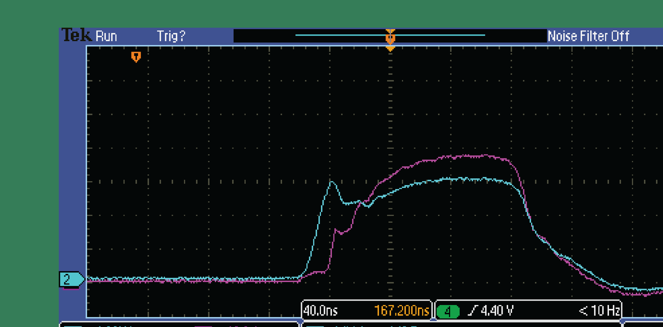




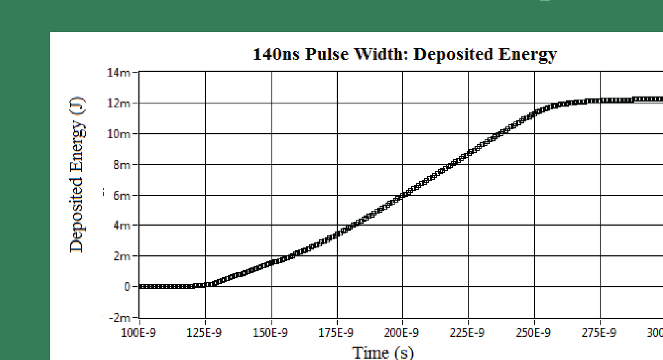
Some high intensity lines are only visible at pulse widths >27ns (left plot), while other lines of similar intensity are represented at all pulse widths (right plot).



Voltage (blue) and current (purple) waveforms of 27ns 15kV pulse



Voltage (blue) and current (purple) waveforms of 142ns 15kV pulse



A plot of energy deposited into the arc with respect to time (left) is consistent with the expectation of a constant power, and helps validate other power measurements

Conclusion

Under each of the discharge conditions investigated, variation of pulse parameters was shown to affect the spectral signature of the plasma. In particular, the ratio and intensity of different reactive species can be altered by the manipulation of pulse width within the tested range of ~20ns-180ns. Increasing PRF in the regime investigated (1-10kHz) was seen to increase the intensity of the spectral data, and altering voltage allowed breakdown to be achieved without damaging the experimental setup. The degree of independent parameter variability inherent to the EHTs NSP pulsers is key for applications that benefit from control of reactive species creation or experimal parameters.

Further Information

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