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A thyratron-based pulse generator for the investigation of the removal of NO_x from engine exhaust streams using nonthermal plasmas (NTPs) is described. Our near-term experiments will focus on measuring temperature distributions and reactive species concentrations in electric-discharge NTP reactors using laser induced fluorescence (LIF) and tunable diode laser absorption spectoscopy (TDLAS), with first experiments on LIF measurements of [OH] in a pulsed dielectric-barrier discharge.

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A Fast-Pulse, Electrical-Drive Circuit for Fundamental Studies of NO_x Removal in Nonthermal Plasmas

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A thyratron-based pulse generator for the investigation of the removal of NO_x from engine exhaust streams using nonthermal plasmas (NTPs) is described. Our near-term experiments will focus on measuring temperature distributions and reactive species concentrations in electric-discharge NTP reactors using laser induced fluorescence (LIF) and tunable diode laser absorption spectroscopy (TDLAS), with first experiments on LIF measurements of [OH] in a pulsed dielectric-barrier discharge.

Because the self-extinguishing microdischarges in a conventional (low frequency driven) barrier discharge are both short lived (a few to a few tens of nanoseconds) and randomly distributed in the process volume, it is difficult to measure the time-varying properties of the species produced by the plasma. To synchronize the plasma ignition with the optical diagnostics, a thyratron-switched, high-voltage pulse generator has been constructed to drive a small dielectric-barrier plasma cell (diagram in Fig 1). The output voltage pulse has a rise time of 6.5 ns, a peak voltage of up to 40 kV, and a repetition rate of up to 10 Hz. A microdischarge streamer occurs between the pin electrode and the glass barrier during the rise time of the voltage pulse. The delay between the input signal and the microdischarge is 250 ns with an uncertainty of 4 ns, thus allowing repetitive initiation of a microdischarge with low temporal jitter.

The high-voltage pulse circuit utilizes fast switching and series resonant energy transfer from the storage capacitance to the load capacitance producing an inverted voltage pulse with a peak value of approximately twice the charging voltage. The storage capacitor, $C_s = 1.2$ nF, is charged through R_c by a positive 20 kV dc power supply. With appropriate grid biasing and triggering, a fast rise time thyratron tube (CX-1588, EEV Inc.) is used in a low-inductance geometry (where L_s is the corresponding stray inductance) to switch the positively charged side of C_s to ground. Voltage doubling occurs when C_s is much greater than the parallel combination of the high-voltage cable capacitance, C_c, and the cell capacitance. In this case $C_c = 150$ pF which is much greater than the cell capacitance (few 10's of picofarads). When $L_r >> L_s$, L_r represents a high impedance during the fast rising pulse allowing the pulse to be delivered to the cell. After the fast rising pulse produces the microdischarge, the residual energy left in the combined system capacitance is slowly dissipated in R_r through L_r. This allows another negative pulse to be applied to the cell after an appropriate switch recovery period which is 100 ms at the maximum repetition rate of 10 Hz.

The energy deposited in the microdischarge per pulse is obtained from the voltage and current versus time, v(t) and i(t), measured at the cell. The voltage waveform (Fig. 2a) and current waveform (Fig. 2b) are plotted for a 2 mm barrier/pin gap spacing, with a small flow of humid air. The energy dissipated in the microdischarge is found by integrating the product of the voltage and current waveforms over the pulse length, which was 3.5 mJ under these conditions. The dissipated energy per pulse is dependent on many factors such as the gap spacing and the properties of the gas (i.e. composition, pressure, and temperature) and must therefore be continuously measured using this technique.

Apart from the ability to diagnose the properties of the plasma and resulting chemistry both temporally and spatially, the pulsed dielectric-barrier system provides opportunities to investigate other properties of NTPs. The fast-rising pulse also produces a higher E/N in the discharge than in conventional dielectric-barrier cells, which affects the destruction and removal efficiency (DRE) of pollutants. Therefore, the differences in the DRE of a conventional dielectric-barrier cell versus a pulsed cell can be investigated.

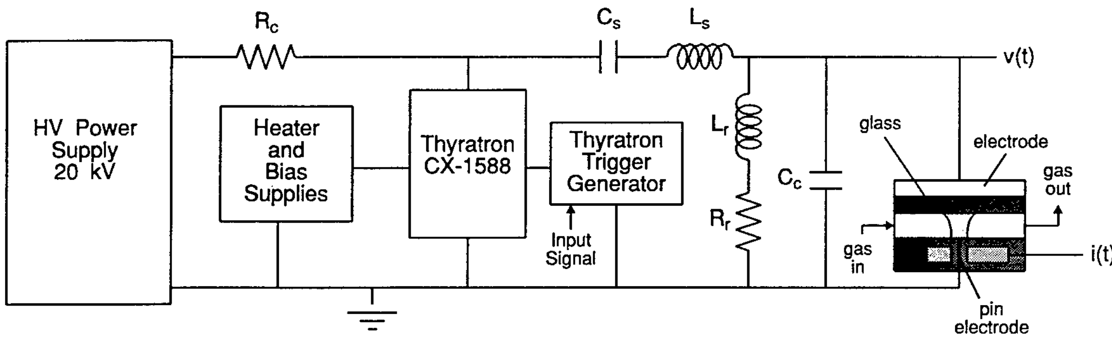


Figure 1. Diagram of the thyratron-based pulse generator with the relevant circuit elements, the thyratron switch (with associated biasing and triggering), and the dielectric-barrier cell.

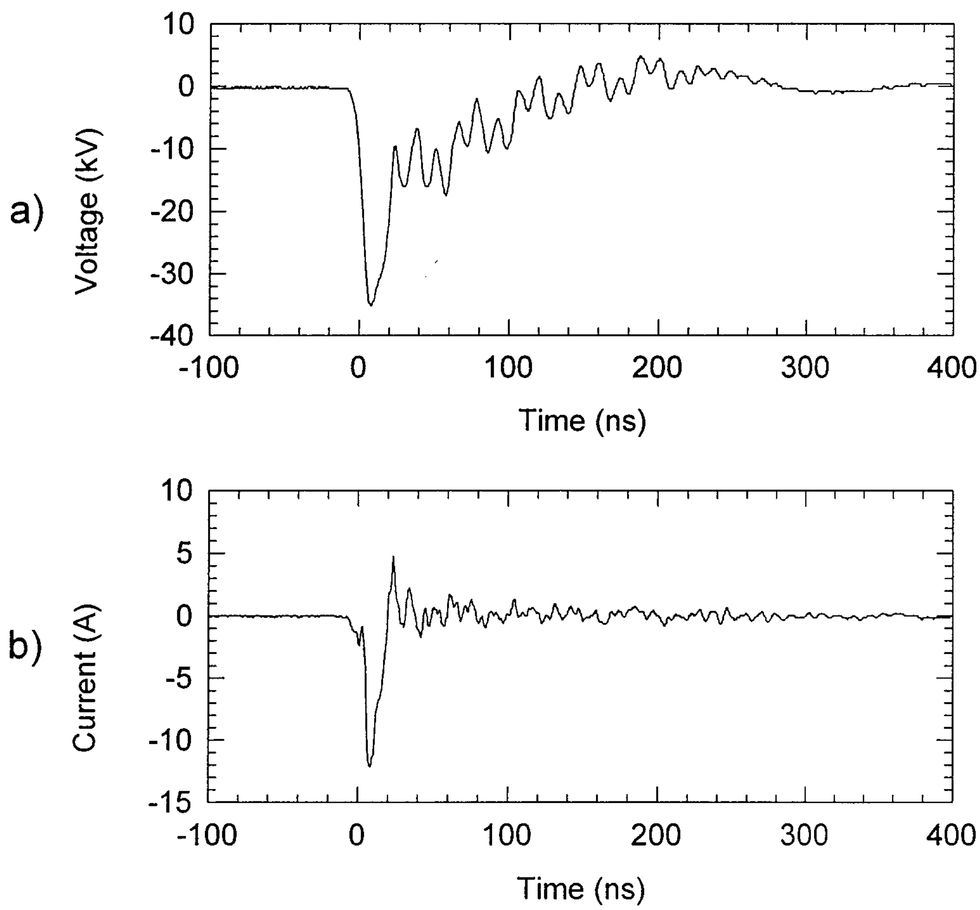
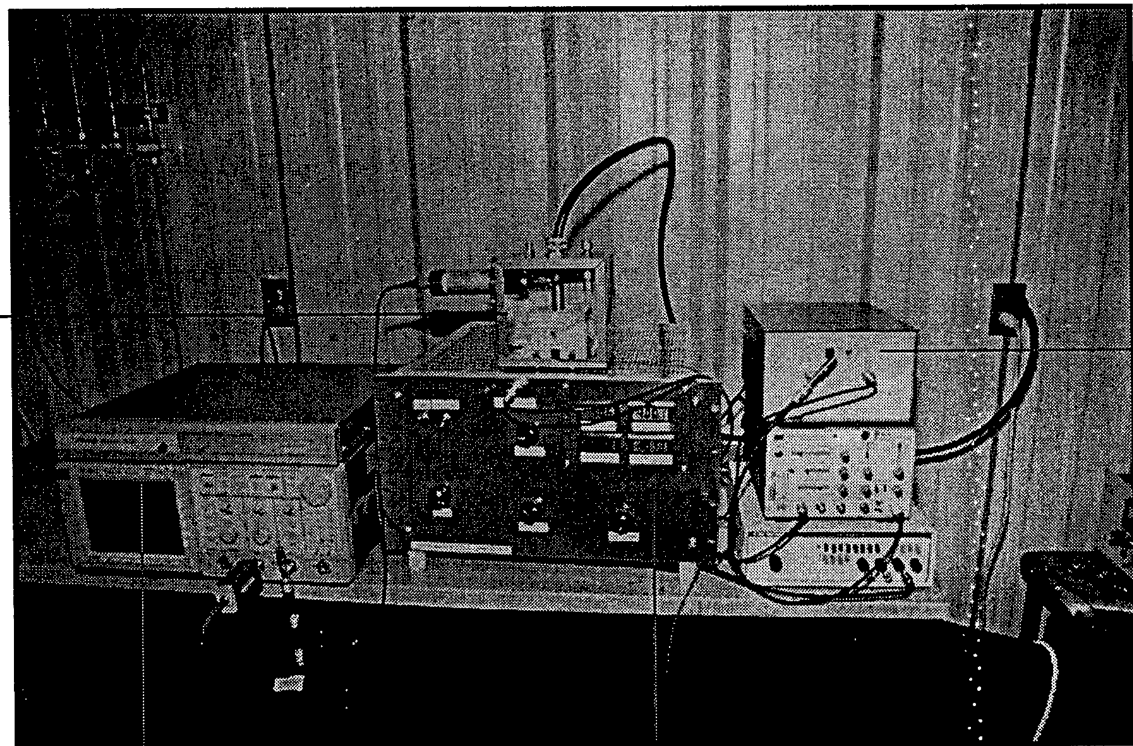


Figure 2. The voltage and current versus time waveforms of the single-barrier/pin dielectric-barrier cell with a gap spacing of 2 mm in humid air where a) is the voltage waveform and b) is the current waveform.

Fast-Pulse Nonthermal Plasma Reactor for Fundamental Investigations



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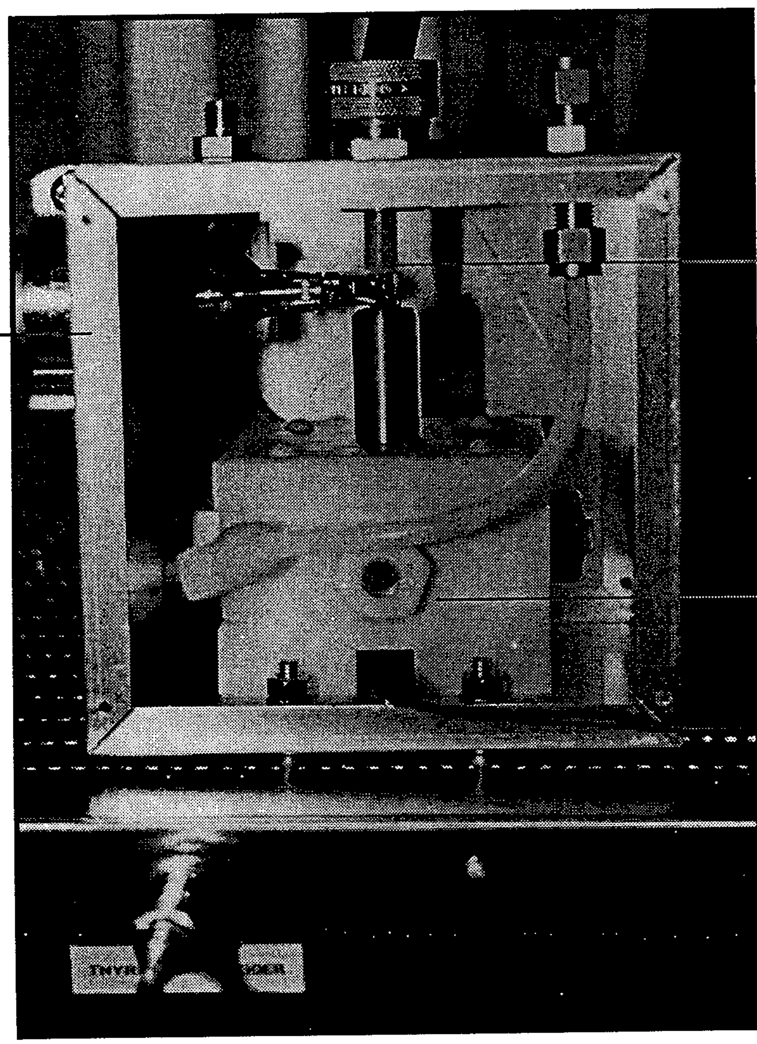
Dielectric-Barrier Cell for Fundamental Nonthermal Plasma Processing Investigations (Side View)



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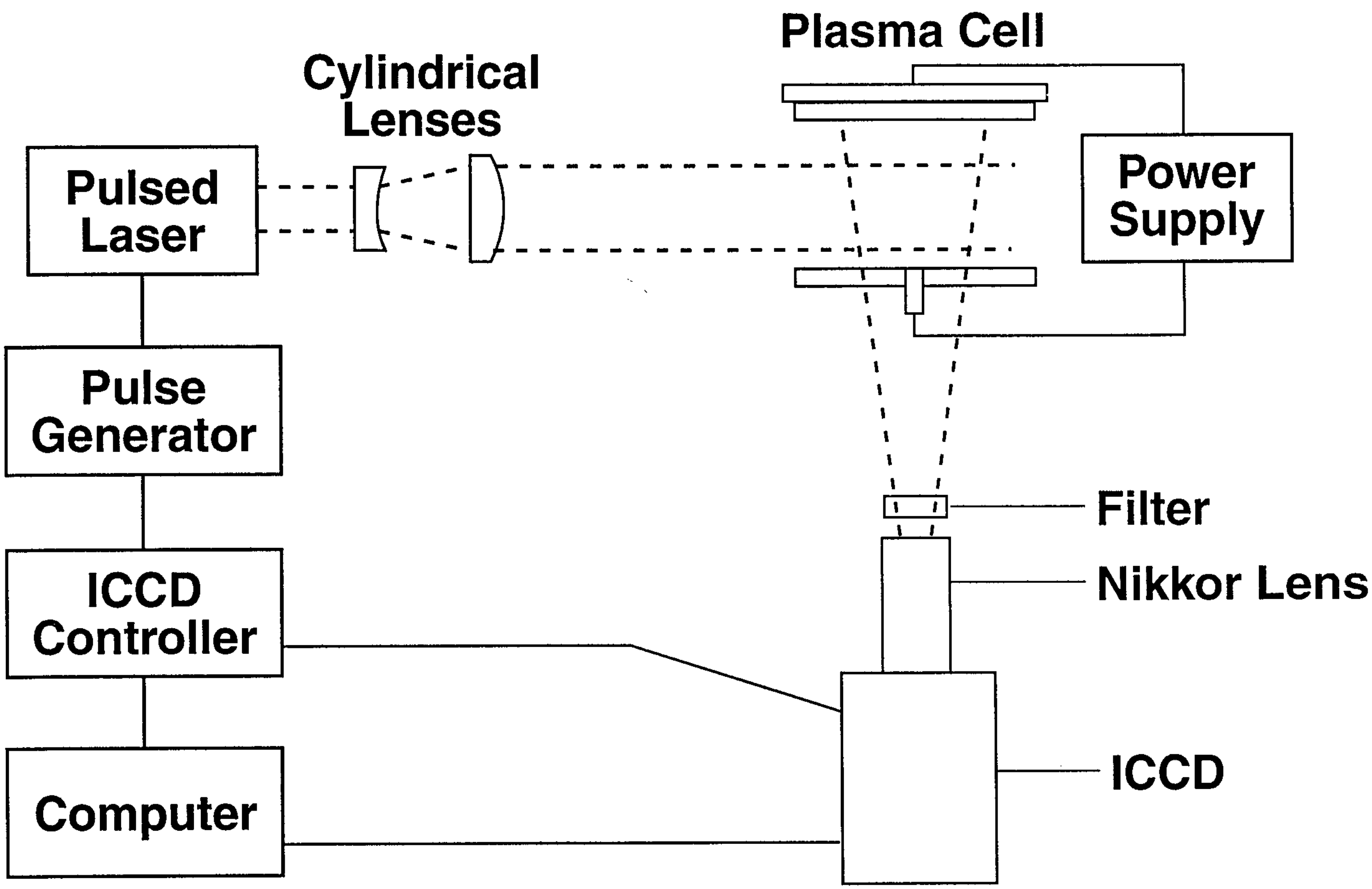
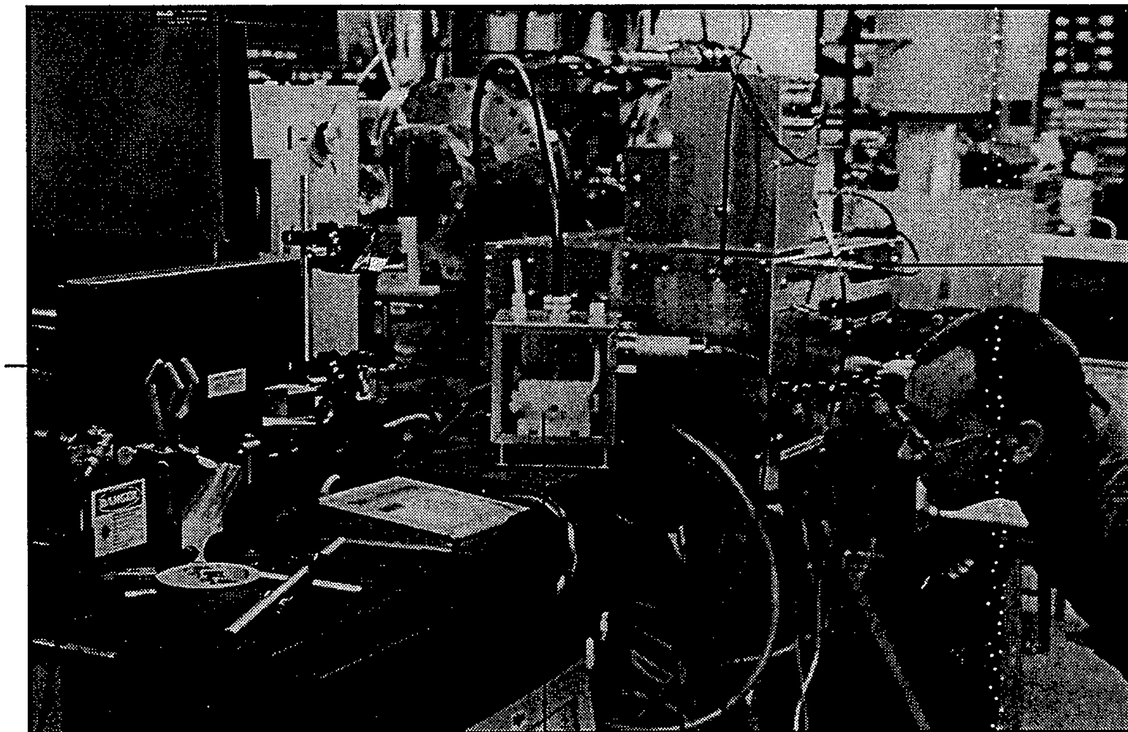
Schematic Diagram of Planar Laser-Induced Fluorescence Setup



Nonthermal Plasma Reactor and Probe-Laser Setup at the Army Research Laboratory



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