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LASER DISCHARGES IN ATTACHING GASES

Progress Report

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DISCLAIMER

ABSTRACT

Both experimental and theoretical efforts are well underway in this study of the maintenance and stability of glow discharges in attaching gas mixtures. The discharge test apparatus for establishing UV-preionized, self-sustained, diffuse discharges in halogen-containing mixtures has been assembled and operated. Initial tests and measurements have been made with gas mixtures containing SF_6.

I. INTRODUCTION

A significant problem in the development of high-power gas discharge lasers is the glow-to-arc transition, which limits the electrical energy that can be deposited in the diffuse glow plasma. In general, this instability occurs more readily as electron attachment increases in importance as an electron loss process, and it will likely be an important deleterious effect in, for example, rare gas-halogen excimer lasers. This research program is a combined experimental and theoretical study of the maintenance and stability characteristics of glow discharges in attaching gas mixtures involving processes similar to those in laser discharges, e.g., KrF. The emphasis is on the formation of filaments during the initial development of the glow-to-arc instability, with the goal of identifying the dominant physical mechanisms responsible for the onset of the instability.

II. STATUS

A. Theory

Prior to the initiation of this contract, theoretical models were developed at the Westinghouse Research Laboratories for the quasi-steady properties of diffuse laser discharges and for the initiation of filament formation at the onset of the glow-to-arc transition. These computer models are being modified for application to laser discharges in attaching gases and for comparison with experimental measurements in the present study. The modifications have been described earlier. In particular, during this reporting period, voltage-current characteristics have been calculated for specific quasi-steady diffuse glow discharges established in the present experimental apparatus. These characteristics are being compared directly with initial experimental results.

B. Experiment

A discharge test facility is being prepared for establishing UV-preionized, self-sustained discharges in a uniform electric field region and for associated optical diagnostics. The goal of this effort is to develop a well-controlled experiment for examining the development of the instability in an established diffuse glow plasma. The stable diffuse-glow conditions and the initial axial growth of filaments will be characterized primarily by variation of discharge parameters and by streak and framing photography.

During the present reporting period the experimental discharge test facility was assembled and initial experimental studies are now underway. The photograph of Fig. 1 shows a general view of the experimental system. The gas mixing and handling system is housed in the closed rack shown at the left side of the photograph. Plexiglas front and rear panels are installed on the rack to prevent exposure of personnel to an accidental release of F_2. A vent system, not shown in the

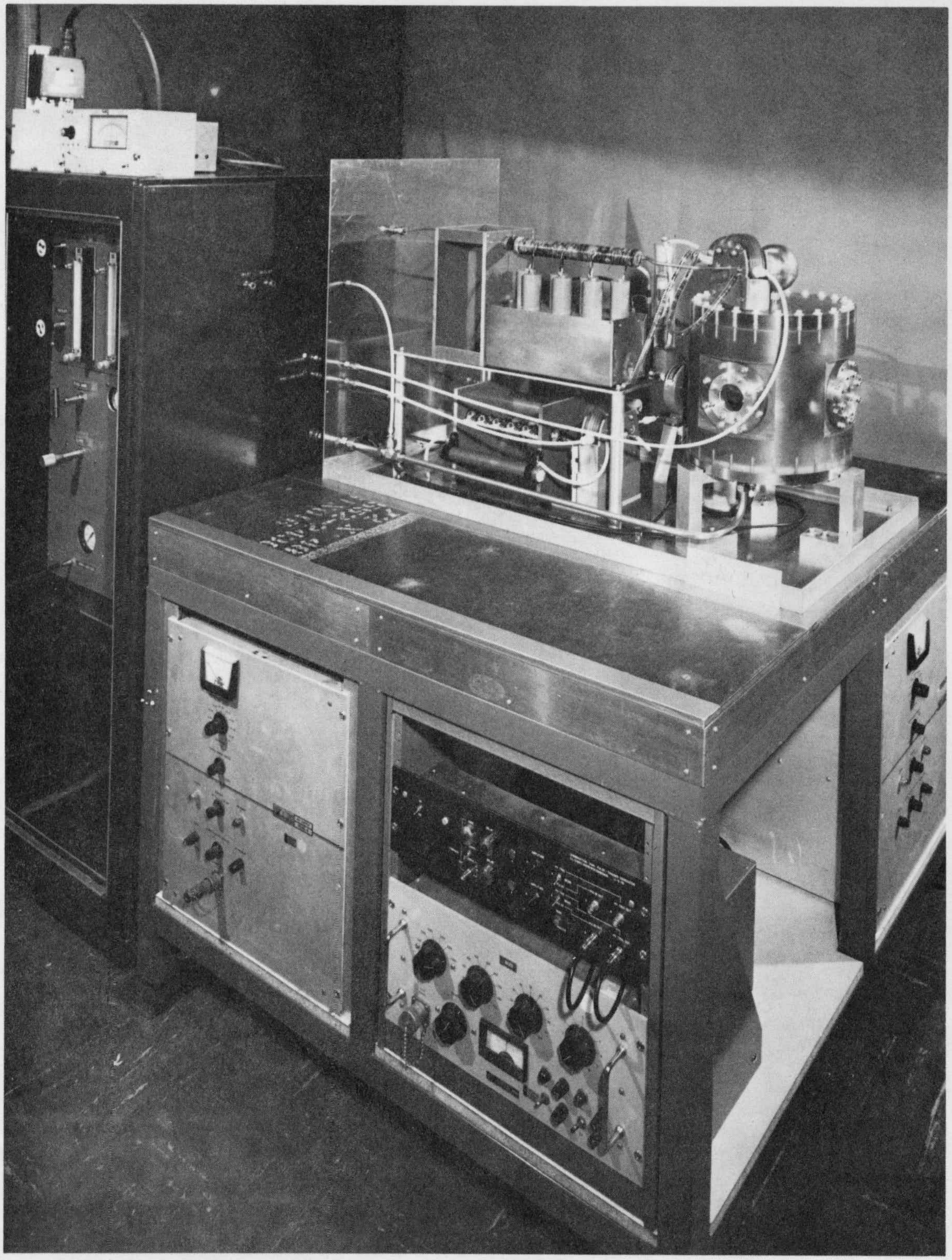

Fig. 1. Photograph of the experimental system.

photograph, would remove any F_2 released inside the rack. The high voltage power supplies and electronic timing circuitry are located under the table. The discharge chamber and its associated electronic components, i.e., pulse forming network, trigger generators, spark gaps, etc., are located on the central portion of the table. A large rectangular metal box is available for covering these components. This box provides electrical shielding for scopes and other diagnostic facilities and acts as a fume hood to prevent escape of F_2.

Figure 2 shows a schematic view of the discharge chamber and the associated electronic components. The cathode C, screen anode A, preionizer P, and one of the three viewing windows W on the discharge chamber are shown.

In most of our tests the energy storage capacitor C for the preionizer spark array is charged to 5 to 10 kV. Current and voltage wave forms for the preionizer, obtained using current transformer CT_p and a high voltage probe, yield currents of $\sim$100 A with a duration of $\sim$200 nsec. Under these conditions the energy in the preionizer discharge is about 0.1 joule/pulse. In the operation of the preionizer some problems of arcing between adjacent rows of spark gaps and arcing to the underside of the anode structure have been solved by moving the spark array and by using dielectric barriers. Various other techniques for overcoming these problems are under consideration.

The pulse forming network, PFN, presently being used is a seven-stage network which produces a 1 μsec pulse and has a characteristic impedance of 70 Ω. With a charging voltage of 10 kV, the stored energy in the PFN is about 0.35 joules. The delay between the firing of the preionizer discharge and the main discharge can be varied. Trigger generators provide the high voltage pulses required to actuate the spark gap switches SG_p and SG_d.

Preliminary measurements of discharge current and voltage, using current transformer CT_d and a high voltage probe, have been conducted in a variety of gases and gas mixtures. These mixtures include binary mixtures of He and SF_6. SF_6 was chosen rather than F_2 so that

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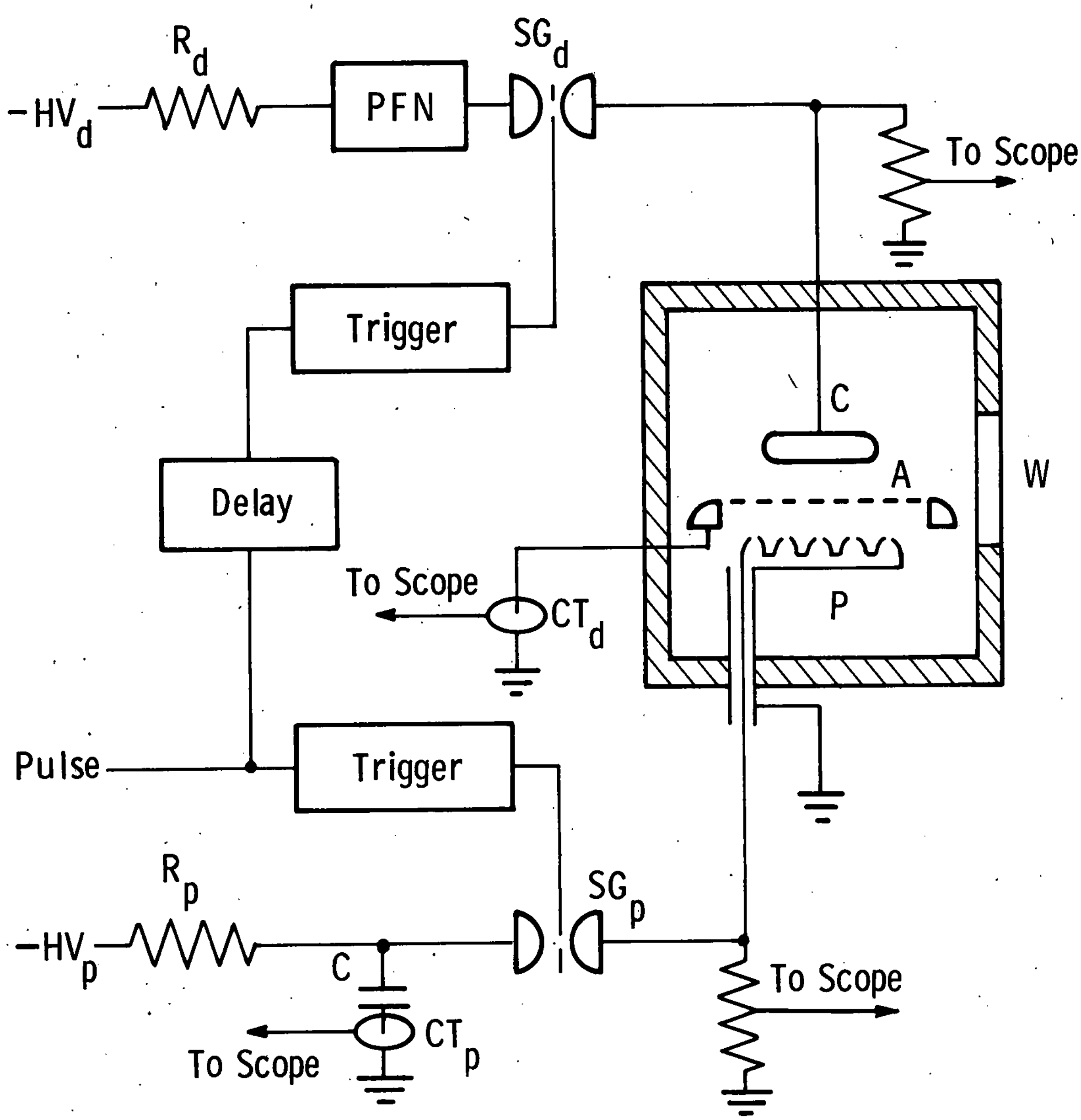

Fig. 2. Schematic diagram of the discharge chamber and circuitry.

stringent safety requirements for gas handling could be set aside during the initial operation of the experimental apparatus.

Figure 3 shows a dual beam oscilloscope trace of discharge voltage (upper curve) and current (lower trace) obtained in a glow discharge in a binary mixture of 0.5% SF_6 and He at a total gas pressure of 400 torr. The discharge gap was 1.5 cm, and the diameter of the discharge column was approximately 3.5 cm. In this case the quasi-steady diffuse discharge is maintained for about 1 μsec, with the duration limited by the pulse-forming network rather than by filamentary arc formation. Under other (controllable) conditions, arc formation terminates the diffuse glow. (For the data shown in Fig. 3, shunt and series resistors were included with the discharge in the circuit. The observed ringing effect resulted from a mismatch between the effective load impedance and the PFN.)

Some tests and modifications of the system are continuing. For example, the question of gas mixing is being examined. However, as indicated by the results described, the experimental system is close to being ready for optical diagnostics of the filament formation in various gas mixtures with the image converter camera.

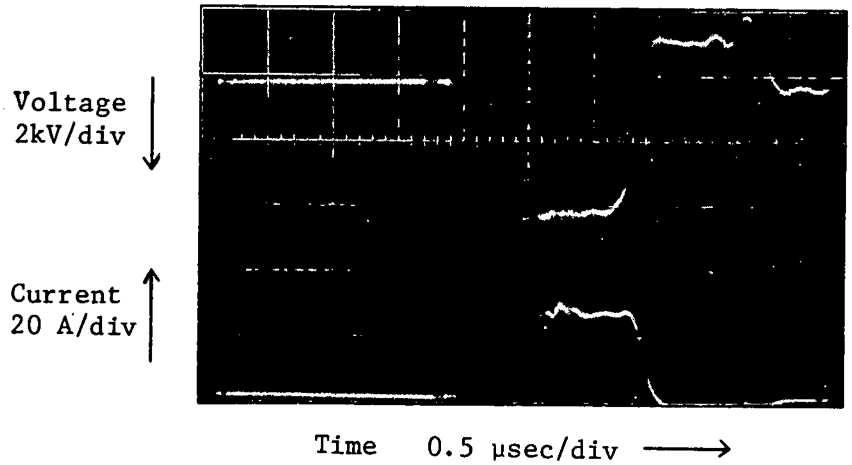

Fig. 3. Oscillograms showing temporal variation of discharge voltage and current for a mixture of SF_6 (0.5%) + He at 400 Torr.

III. CONTRACT REQUIREMENTS AND EFFORT

The work reported herein is in compliance with the contract requirements. During the third quarter the principal investigator has devoted nearly one-half of his time to this project.