Technical Progress Report
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Excitation Efficiency and Energy
Storage Capabilities of High-Pressure
Rare Gas ~ Metal Vapor Mixtures

Prepared for

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Administration

by

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ABSTRACT

Experiments have been performed to produce uniform glow discharges in high pressure alkali vapor - rare gas discharges. Experiments in mixtures of 50 Torr Hg and 100 Torr He have shown strong recombination pumping of the excited states and the possibility of gain on the $5461 \text{ \AA } \text{Hg } 7^3\text{S} - 6^3\text{P}_2$ transition. Uniform glow discharges have also been produced in mixtures of 1 Torr Cs and 1000 Torr Ar at 600° K .

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I. Introduction

The aim of this series of experiments have been to investigate the feasibility of pumping a metal vapor - rare gas dissociation laser by an electrical discharge. Some of the important questions associated with this aim are:

- 1) Can a "diffuse" glow discharge be created in a high pressure rare gas - metallic vapor mixture?
- 2) What fraction of the electrical energy is utilized in producing the excited states?
- 3) How much energy can be stored in the excimer states and what is the time scale for pumping?
- 4) Is the impedance level suitable for efficient transfer of electrical energy into the system?

Our efforts to answer these questions and progress made to date on Mercury and Cesium - rare gas mixtures are covered in the next two sections.

In addition to the discharge studies, we have also undertaken the fabrication and testing of super-thin silicon windows for E-beam transmission and current amplification. A detailed report on their construction was mailed to Dr. Carbone in March.

II. High Pressure Mercury-Rare Gas Mixtures

Most of our studies in the past have been performed in mixtures of mercury with Argon, although recently we have used Helium as the rare gas. Inasmuch as up-to-date results with Argon have been communicated to Dr. Carbone in a separate letter outline, let us concentrate here on the most recent ideas with Helium. The most exciting result is that we think we have observed "gain" on the 5461 Å line in the afterglow of a discharge in Hg (~ 50 TORR) + Helium (~ 100 TORR). Let us explain the experiments leading to this result.

First it should be noted that "age" and electrode sputtering finally caught up with the "old" discharge tube. It was replaced by a tube, designed with the same basic ideas, but with more careful attention to symmetry and the diagnostic problem. This is sketched below.

FIG 1.

The cathode is again perforated with holes placed opposite the tips of the preionization electrodes, which, in turn, are spaced around the circumference of the cathode. These five electrodes and the cathode lead were brought out of the vacuum container wall with a circular press, a most difficult task. Note, too, that the windows are adjacent to the discharge volume through the use of the re-entrant window design.

The preionization electrodes are still driven by either a simple A-C power transformer or by a pulse from a hard tube modulator. In the recent studies with Helium, the main discharge is very uniform and quite repeatable even if the preionization circuitry is disabled.

Figure 2 below shows some raw data indicating gain at 5461 Å in the afterglow of a pulsed discharge.

Traces A and B represent respectively the reference line for the experiment and the amplitude of source. Trace C represents the amplitude of the spontaneous light emitted at 5461 Å by the afterglow and Trace D is the light from the source "amplified" in the afterglow.

plus the spontaneous plasma light. In a very crude sense we may write:

$$I_C = \hat{I}_{(\text{plasma})}$$

$$I_D = G I_{(\text{SOURCE})} + I_{(\text{plasma})}$$

where $I_{(\text{SOURCE})} = I_B - I_A$.

Notice the amplitude at the sixth major division. The source is 2 divisions, the plasma light is also 2 divisions, but the source plus the plasma is ~ 4.2 division, or $G \sim 1.1$. While this gain is not overwhelming, it is significant. The numbers indicated above the photograph are the values of the gain at various times in the afterglow.

We have attempted to make this system into a laser, but without success. But in doing so, we obtained another indication of gain. In this experiment, we reflected the spontaneous light back on to itself in the manner shown in Fig. 3 below.

Here the ratio of the blocked to unblocked intensities is at least equal to or greater than 2 over the times 2 - 7 μ sec in the after-glow. Obviously the part passing through the plasma twice also suffers from the insertion loss of the tube windows. However, the fact that one can still obtain the factor of ≥ 2 enhancement with the far mirror is another indication of gain. Unfortunately the gain is not high enough to reach threshold with our present cavities.

III. High Pressure Cesium - Rare Gas Mixtures

Our work here has concentrated on the establishment of the glow in high pressure Cs-Ar mixtures and on the measurement of the basic electrical characteristics. Our main results have been reported in a letter to Dr. Robert Carbone, however, the main points are as follows:

- (1) Uniform glow discharges have been created in Cs-Ar discharges at 600° K (1 Torr Cs) for argon pressures of up to 1000 Torr (at 300° K). Higher pressures are desirable and should be readily achieved, however we are at the explosion limit of our glass tube, so a higher pressure vessel will be necessary and is now being designed.
- (2) The discharge voltage in our present tube established an impedance level which is satisfactory for efficient electrical pumping.
- (3) The optical emission on the resonance lines follows exactly the type of lineshape expected at these pressures due to excimer formation as has been previously observed in absorption studies.
- (4) Even though we have been working at low currents, fairly reasonable electron densities of around $10^{12}/\text{cm}^3$ have been estimated from microwave absorption measurements.

Our present experiments are directed towards answering points 2) and 3) of the introduction. We intend to examine these questions by increasing the power into the gas discharge and by using optical emission and absorption to monitor the densities of the excited states of interest. At the moment we are concen-

trating on increasing the current and the corresponding electron density. By improving our discharge pulse shaping and by going to a 3 μ sec pulse, we have managed to increase our current to 8 amps prior to arc formation. Our desire is to go considerably higher yet. The sharper current pulse is also helpful in allowing us to observe the time dependent processes in the afterglow in more detail.

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