Final 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

J.K. Crane
J.T. Verdeyen
B.E. Cherrington
Gaseous Electronics Laboratory
Department of Electrical Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

MASTER

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ABSTRACT

Gain has been observed on the $5461\text{\AA}$ ($7^3\text{S}_1 - 6^3\text{P}_2$) and $3650\text{\AA}$ ($6^3\text{D}_3 - 6^3\text{P}_2$) transitions in atomic Hg. The media consists of 50-150 torr and He and 20-50 torr of Hg excited by a 1 μs , pulsed, $0.5-4 \text{ a/cm}^2$ discharge. Gain as high as 10% has been measured with an OSRAM spectral lamp. Gain appears in the afterglow from 2-10 μsec after the termination of the discharge pulse. The upper state appears to be pumped by recombination, during which time the lower state is being depopulated by collisions with electrons or Helium atoms.

Final ReportI. Introduction

A rather complete report on the status of the contract effort was submitted to ERDA for a renewal request for this contract in June, 1976. When word was received in August, 1976 that the contract would not be renewed, we requested, and received a no-cost extension to 1 January 1977. At the same time, we limited the scope of the research to the examination of gain on the Neutral Mercury transition. Thus this final report will cover only that subject.

II. Gain on Neutral Transitions

Gain is observed on the 5461 Å and 3650 Å transitions in neutral mercury. This gain occurs in the afterglow of a pulsed discharge in mixtures consisting of 20-50 torr Hg and 50-150 torr He. The gain is observed from 2-10 μs after a 0.5 μs square pulse of current density from 0.4-2.0 amp/cm².

Figure 1 shows an energy level diagram for neutral Hg with some of the key transitions. The 3650 Å transition is from the $6^3D_3-6^3P_2$ and the 5461 Å transition is from $7^3S_1-6^3P_2$. Both gain transitions end on a common level.

Figure 2 shows the experimental apparatus with which gain is observed and measured. Light from an Osram Spectral Lamp (Hg) is chopped and collimated, then sent through the discharge inside the oven. Light from the discharge along with the amplified signal from the Spectral Lamp is focused onto the slits of a $\frac{1}{2}$ M. monochromator and detected using a 1P28 photomultiplier.

Figure 3 shows a plot made of spontaneous emission in the afterglow for the three transitions occurring from the 7^3S_1 to $6^3P_{0,1,2}$ levels in Hg. Even though these three transitions have a common origin (the 7^3S_1 level of Hg), they show remarkably different time behaviors in the afterglow. The 5461 Å emission appears to decay most rapidly while the 4358 Å and 4047 Å emissions show longer time behaviors. A tentative explanation for this behavior is trapping on the 4358 Å and 4047 Å transitions thus effectively prolonging their decay rate.

Figure 4 shows a typical photograph of the 5461 Å emission taken using the apparatus in Fig. 2. The top trace shows zero light; the second trace, light from the source alone (S); the third trace shows the light from the discharge (P); and the lowest trace represents the source light

amplified in the discharge S (1 + G) along with the plasma light (P).

Using this method gains of 10% have been measured.

Although the discharge tube was not designed for lasing due to its short gain length (5 cm.) and lack of brewster angle windows, an attempt was made. The results are shown in Fig. 5. The photograph shows light from the coupling mirror with the back mirror blocked and unblocked. The ratio of this light is on the order of 6. This result is encouraging and further indicates the presence of amplification although threshold has not been reached.

Further work was done to explore the origin of the gain. The initial hypothesis was that gain occurs from recombination pumping of the upper levels of the 5461 Å and 3650 Å transitions. To test this theory an experiment was performed in which a perturbing pulse was applied in the afterglow to heat the electrons and thus quench recombination. The results of this experiment are shown in Fig. 6. The upper photograph shows a 6% value for the gain at 7 μs in the afterglow. The second photograph shows the results of applying a perturbing pulse. The gain is reduced to zero. This experiment indicates that recombination may be responsible for pumping the upper levels (7^3S_1 and 6^3D_3) of the two gain transitions.

Figure 7 shows a tentative model for the excitation and afterglow of the Hg-He discharge under study. Hg ions are created by two-step ionization. These ions are likely to form Hg_2^+ by the following reaction:

where M represents a third body. Subsequently the 7^3S_1 and 6^3D_3 are populated via dissociative recombination, either directly or by cascading down from higher levels. The 6^3P_2 state is believed to be rapidly depopulated by collisions (with He atoms or electrons). Energy finally leaves the system via broad band emission from the Hg_2 excimer.

Figure 8 shows the original tube with which gain was observed and measured. It consisted of two 5 cm. diameter circular electrodes. One of the electrodes was perforated and a series of pin electrodes placed behind it for use as preionization or perturbation diagnostics. In order to utilize a longer gain path length, a tube was constructed with rectangular electrodes, 15 cm. in length. Subsequent experiments failed to reproduce the previous results. A study was made of the characteristics of this tube and it was found that at the required Hg densities for gain (20-50 torr), the electron density in the tube, as measured by microwave absorption, fell to a much lower value than measured at lower pressures. Along with this decrease in electron density, the discharge was observed to display a constrictive nature, much different than the uniform discharge observed in the first tube. These constrictions occurred at the four corners of the rectangular electrodes. The inability to observe gain in this tube was believed to be the result of the reduced electron density and constrictive nature of the discharge found in this tube.

With the failure of this second tube, it was decided to return to the original tube with the addition of brewster angle windows. Subsequent experiments on this tube failed to produce the gain observed in the first series of experiments. A careful study showed that the spontaneous emission in the afterglow for the $7^3S_1 - 6^3P_{0,1,2}$ transitions was different than in the first series of experiments (Fig. 3). Strong N_2^+ emission at 3914 Å gradually grew to dominate the other discharge lines. The presence of the N_2 is thought to be the result of cleaning the discharge tube with HNO_3 , thus forming nitride compounds on the electrodes. These compounds appear as a brown film on the electrode surface. The damaging nature of N_2 in the discharge is a matter of speculation at this point, but no other explanation is presently available for the observed results.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8