METAL VAPOR EXCIMER LASER

QUARTERLY PROGRESS REPORT
for Period February 1, 1978 - April 30, 1979

MASTER

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June 1979

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ABSTRACT

A new alignment procedure has resulted in Febetron pre-ionized current pulses up to 400 A (500 kV, 30 ns) with a consequent increase in the discharge current to $\sim 100 \text{ A/cm}^2$ at 10-20 kV. Under these conditions spectra for Cd/Hg/Ne mixtures have indicated large HgCd* continuum emission with densities $\sim 3 \times 10^{16} \text{ cm}^{-3}$ and a lifetime $\sim 3 \text{ } \mu\text{s}$.

A major technology problem still remaining which has considerably slowed the research is the unreliability of the quartz to metal seals at high temperature (550°C). Work on this problem is described.

The apparatus is presently being set up to make gain/absorption measurements over the HgCd* emission band.

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I. INTRODUCTION

A major problem which has had considerable impact on this project is the unreliability at high temperature (550°C) of the quartz to metal seals. Despite this handicap, significant progress has been made during this quarter.

Ferbertron preionization current pulses up to 400 A (500 kV, 30 ns) have been magnetically guided along the entire length of the discharge tube. These high preionization current pulses have allowed a large increase in discharge current. Discharges with currents greater than 100 A/cm^2 at 10-20 kV have been achieved. Under these conditions emission spectra for Cd/Hg/Ne mixtures have clearly shown large HgCd* emission and absolute fluorescence intensity measurements have indicated substantial HgCd* formation with densities $\sim 3 \times 10^{16} \text{ cm}^{-3}$ and a lifetime $\sim 3 \text{ } \mu\text{s}$. The apparatus is presently being set up to make gain/absorption measurements over the entire HgCd* emission band.

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II. EXPERIMENTAL APPARATUS

A. QUARTZ TO METAL SEALS

The weakest point in the experimental apparatus continues to be the quartz to metal seals supplied by Bomco Corporation (Gloucester, MA). The seal is a quartz to molybdenum housekeeper seal which uses very thin walled molybdenum. Nitrogen gas is used to keep the molybdenum surface from exposure to oxygen; however, after a short time the seals appear to corrode and fail.

A high temperature silica adhesive was used successfully on the smaller 1/2 in. seal and greatly extended their life but the larger 1 in. and 1 1/2 in. seals have cracked after being heated to high temperature. Attempts are currently underway to anneal these seals at a high temperature in an inert atmosphere to see if we can relieve the strain and prevent cracking of the seals. A secondary approach which is being taken is to directly seal the quartz to the stainless using a copper gasket. Some limited success has been achieved but a reliable seal at the highest temperature (~ 550°C) has not yet been developed.

B. DISCHARGES

Calculations indicate that in order to achieve a gain of ~ 10 percent per pass in this apparatus, discharge currents in excess of 50 A/cm (at 20 kV) are necessary. To achieve these discharge conditions requires large Febetron preionization current pulses. These large Febetron current pulses have been achieved

using a new alignment procedure for the magnetic field coils in which the Febetron current transmitted down the discharge tube is directly measured by a Pearson transformer as shown schematically in the bottom of Figure 1. Febetron current pulses up to 400 A have been measured to date. A typical Febetron current pulse (~ 30 ns) is shown at the top of Figure 1. A side-view open shutter photograph of the magnets showing visible emission from the discharge tube filled with 400 Torr of He with a magnetic field used to guide the Febetron pulse along the tube is shown in Figure 2. These large preionization pulses have allowed us to achieve discharge currents of greater than 100 A/cm^2 in Cd/He/Ne mixtures.

The discharge circuit has been improved and is shown schematically in Figure 3. Because of the lower impedance of the discharge the ballast resistance has been lowered. The 10Ω resistor in the crowbar circuit was installed as a damping resistor to reducing ringing as shown in the oscilloscope traces of Figure 4. The top trace where no damping resistor was used shows significant ringing in both the current and voltage. The large voltage swings which are greater than the voltage rating of the capacitor would greatly reduce its lifetime. The lower trace of Figure 4 shows how the ringing is damped by the 10Ω resistor. The capacitance has been increased from $0.01 \mu\text{f}$ because of the larger discharge currents being produced.

H 9165

Figure 1 Lower: Schematic Showing Measurement of Febetron Preionization Current.
Upper: Measured Febetron Current Pulse with 400 Torr of He in Tube.

H9I60

Figure 2 Visible Emission in HgCd* Laser Tube from Magnetically Guided Febetron Pulse in 400 Torr He.

H8882

Figure 3 Schematic of Improved Discharge Circuit

H9162

Figure 4 Effect of Damping Resistor in Reducing Ringing in Crowbar Circuit. Lower Trace with 10 Ω Damping resistor shows significant reduction in ringing.

The discharge circuit works very well when no Febetron preionization pulse is fired. The reliability is not as good with the Febetron fired since the large pulse can cause the crowbar to prefire. We are presently trying to use high-voltage diodes in the crowbar circuit to prevent prefire and thereby increase the reliability of the circuit.

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III. MEASUREMENTS AND DISCUSSION

Since the quartz to molybdenum seals deteriorate rapidly at high temperature, the circuits have been tested using a dummy load or for more realistic tests the apparatus was run at lower temperatures ($\sim 300^\circ\text{C}$). At these temperatures, Hg/Ne mixtures were tested. Typical I/V characteristics for a Hg/Ne mix 92 Torr/754 Torr (270°C) as a function of Febetron to discharge delay is shown in Figure 5. For a crowbar delay of $\sim 2 \mu\text{s}$ or greater the discharge current is small. As the Febetron to discharge delay is decrease the discharge current increases to a maximum of 400 A for no delay. The crowbar can be observed at $2 \mu\text{s}$ after the discharge is turned on.

Once one is able to produce a discharge of energy sufficient to pump large densities of these metal excimers, it is important to observe their fluorescence spectrum to see where the energy has been channeled. Fluorescence spectra were made of He/Ne, Cd/Ne and Cd/Hg/Ne mixtures using an optical multichannel analyzer (Trainor, Northam). Typical spectra are shown in Figures 6, 7 and 8.

In the pure Hg case (Figure 6) ($[\text{Hg}] = 72 \text{ Torr/Ne} = 700 \text{ Torr}$) only Hg emission lines were observed with no apparent continuum Hg_2^* emission. It could be that in the presence of electrons, Hg_2^* is either not formed or rapidly quenched. For pure Cd (Figure 7) ($[\text{Cd}] = 10 \text{ Torr/Ne} = 700 \text{ Torr}$) all the line emission has been

H9I76

Figure 5 I/V Characteristics in Hg = 92 Torr/Ne = 754 Torr Mixture at $T = 270^\circ\text{C}$ as a Function of Febetron/Discharge Delay.

DUG- 436.7 CNT- 2923
[]

Figure 6 Measured Mercury Fluorescence for Hg = 72 Torr/
Ne = 700 Torr Mixture

WV-4363.2 CNT= 36872

43.2 T= 1 P= 128 ET= 0.00516 131072P3 71345.6

Cd 267 -
Cd 288 -
Cd 298 -
Cd 326 -
Cd 347 -
Cd 361 -

Cd 441 -
Cd 468 -
Cd 480 -
Cd 509 -

Cd 644 -

H9357

Figure 7 Measured Cadmium Fluorescence from Cd = 10 Torr/
Ne = 700 Torr Mixture

BUG= 475.0 CNT= 18885

97.7 T= 1 #= 10 ET= 0.00516 63536FS 820.3

Cd 267 -	Hg 407 -	Hg 436 -	Cd 509 -	Hg 546 -	Hg 579 -	Cd 644 -
Cd 288 -	Hg 441 -	Cd 468 -				
Cd 298 -		Cd 480 -				
Hg 313 -						
Cd 326 -						
Cd 347 -						
Cd 361 -						

H9356

Figure 8 Measured Mercury/Cadmium Fluorescence from a Cd = 10 Torr/
Hg = 62 Torr/Ne = 676 Torr Mixture

identified as due to Cd* (i.e., no significant impurities) and a rather broad continuum possibly due to Cd₂* was observed. The Cd/Hg/Ne mixture (Figure 8) ([Cd] = 10 Torr, [Hg] = 62 Torr, [Ne] = 676 Torr) shows both Hg and Cd line emission together with the clear HgCd* continuum peaked at ~ 475 nm.

Absolute fluorescence intensity measurements of this band have been made using a filter centered at 475 nm and a photodiode. The setup is shown schematically in Figure 9. It can be shown that the fluorescence, $P_v(\text{W/cm}^3)$ is related to the measured signal, W (watts) as

$$P_v(\text{W/cm}^3) = \frac{W(\text{watts})}{\pi/4 \frac{r_1^2 r_2^2}{S^2} L F T} \quad (1)$$

where $r_1 = 0.32$ cm, $r_2 = 0.4$ cm, $S = 30$ cm, $L = 1.25$ cm, $f = 0.3$ (filter transmission) and $T = 0.78$ (transmission through 3 quartz windows).

The HgCd* fluorescence is related to the HgCd* density as follows

$$P_v = \frac{[\text{HgCd}^*] \epsilon_{\text{HgCd}^*}}{\tau_{\text{HgCd}^*}} \quad (2)$$

where ϵ_{HgCd^*} is the energy of an HgCd* emitted photon (= 2.6 eV) and τ_{HgCd^*} is the lifetime of the HgCd* excited state (~ 3 μs).

A typical photodiode fluorescence signal is shown in Figure 10. The dashed curve gives the background signal (tube evacuated). The measured signal translates [using Eqs. (1) and

J1234

Figure 9 Schematic Diagram of Setup for Measuring Absolute HgCd* Fluorescence

J1211

Figure 10 Typical HgCd* Fluorescence Signal

(2)] to a HgCd* density $\sim 3 \times 10^{16} \text{ cm}^{-3}$ with an observed lifetime $\sim 3 \text{ } \mu\text{s}$. This large density and long lifetime are consistent with an electron quenching rate

of $k_e \leq 10^{-9} \text{ cm}^3/\text{s}$.

The apparatus is presently being set up to perform gain measurements over the entire HgCd* emission band.

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