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Resonance radiation trapping effects in CuCl laser

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The effects of resonance radiation trapping of 3248 and 3274 Å upon the corresponding laser fluorescent lines of 5106, 5700 and 5782 Å of copper have been investigated as a function of temperature in a CuCl laser with and without helium buffer gas. The experimental values of the laser starting temperature at 315 °C and the dissociation level at about 10% in CuCl at resonance radiation trapping threshold are found to be in good agreement with the reported values from calculations.

INTRODUCTION

Experimental investigations of resonance radiation trapping effects upon the laser transitions starting from the same resonant levels in self-terminating laser systems have not been found in the literature, except in the copper iodide (CuI) laser by Weaver, Liu, and Sucov.[1] The conditions for resonance radiation trapping in these systems are discussed briefly by Walter *et al.*[2]

Theoretical values of resonance radiation trapping threshold parameters and the trapping effects upon the fluorescent lines (laser lines) for the lasants Cu, CuCl, CuBr, CuI, Mn, and $MnCl_2$ have been reported recently by Srigouri, Ramaprabhu, and Prasada Rao.[3] Laser starting temperatures in pure metals and their halides and dissociation levels in metal halides have been estimated at resonance radiation trapping threshold conditions by these authors using Holstein's theory[4,5] of resonance radiation trapping. These threshold parameters were found to be consistent with the experimental observations reported earlier. In order to give experimental support to the theoretical calculations reported by Srigouri and co-workers,[3] a double-pulse CuCl laser has seen fabricated to investigate the effects of resonance radiation trapping upon fluorescent lines (laser lines).

In this paper we present the experimental investigations of the effects of resonance radiation trapping of 3248 and 3274 Å at threshold, upon the corresponding fluorescent lines of 5106, 5700, and 5782 Å as a function of tube temperature in copper using a CuCl laser, with and without helium buffer gas.

EXPERIMENT AND RESULTS

A double-pulse CuCl laser has been designed and fabricated following the details given by Chakrapani *et al.*[6] Purified dry cuprous chloride powder is spread alone the length of the quartz plasma tube to form an active length of about 30 cm. The plasma tube is provided with a furnace and a Chromel-Alumel thermocouple with all the necessary controls for temperatures up to 700 °C. Dielectric coated broadband (400–600 nm) mirrors of 99.9% and 70% reflectives obtained from Tec-optics (U.K.) are used to form the cavity of the system.

The two capacitor banks with 45 and 5 nF in the low inductance discharge circuits are charged up to 15 kV dc and discharged through the plasma tube using high-voltage spark gaps triggered by a high-voltage double-pulse generator provided with silicon-controlled rectifier circuits. A low-voltage double-pulse generator with a variable delay between the pulses controls the system. The first pulse dissociates the copper chloride in the vapor state into copper atoms and chlorine and their ionic species. The delayed second pulse is an excitation pulse to pump the ground-state atoms to the upper laser level to create transient population inversion. The minimum delay corresponds to the relaxation time of the metastable state to the ground state after dissociation. A pumping current pulse lifetime of about 150–200 ns is found to be adequate for pumping the ground-state atoms in order to have sufficient transient population inversion.

The main object of the experiment is to compare the intensities of the resonance radiative transitions with the laser fluorescent lines as a function of tube temperature. To observe this, it was found convenient to record the resonance radiative transitions and the fluorescent lines using a quartz spectrograph for different tube temperatures. The spectra were recorded using ORWO NP27 photographic films of ASA400. The intensities of the resonance radiative transitions (3248 and 3274 Å) and the laser fluorescent lines (5106, 5700, and 5782 Å) were measured using a Joyce Loebel double-beam microdensitometer.

Laser action upon the 5106-Å line alone in the presence of helium gas at a pressure of 3 Torr has been observed starting from 315 °C. The optimum delay between the pulses and the optimum temperature have been determined to be 350 μs and 350 °C, respectively. All the following experiments were conducted at the optimum delay.

The experiment to investigate resonance radiation trapping effects was conducted in two parts, one without helium gas and the other with helium gas at a pressure of about 3 Torr. In the first part of the experiment the intensities of the resonance and the fluorescence lines were recorded in the absence of helium. Laser action was not observed in any of these fluorescent lines in the absence of helium, irrespective of their gains. The values of intensity ratios and temperatures are given in Table I.

The second part of the experiment in the presence of helium gas reveals the results with laser radiation only from the 5106-Å transition. The 5700- and 5782-Å lines are not found to be lasing except for 5782 Å, very inconsistently. All the measurements are made upon the 5106-Å line in the presence of helium under lasing conditions. The values of the

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TABLE I. Temperature variation of experimental intensity ratios ($I_F|I_R$) without helium (fluorescence case).

Temperature (K)	$I_{\text{fluorescence}}/I_{\text{resonance}}$		
	I_{5106}/I_{3248}	I_{5700}/I_{3248}	I_{5782}/I_{3274}
525	0.03	···	···
550	0.09	0.03	···
575	0.5	0.07	0.59
580	0.73	0.3	0.61
590	1	0.6	0.89
600	1.02	0.9	···
605	1.08	···	···
612	1.37	···	1.4
620	1.9	···	···

intensity ratios and the temperatures are given in Table II.

The experimental intensity ratios between fluorescence and resonance transitions in both the cases with and without helium gas have been computed as shown in Tables I and II following the microdensitometer curves for different temperatures. These curves are to be compared with the theoretical curves obtained to confirm the effects of resonance radiation trapping upon fluorescent lines.

THEORETICAL INTENSITY RATIOS

The ratio of the intensities of fluorescence and resonance lines given by Weaver and co-workers[1] is written as

$$I_F/I_R = \lambda_R A_F/\lambda_F A_R,$$

where I_F and I_R are the intensities of the fluorescent and resonance lines with the wavelengths λ_F and λ_R, respectively. A_F and A_R are the spontaneous emission rates for the corresponding transitions.

From the theory of resonance radiation trapping, the calculated values of A (trapped) upon 3248 and 3274 Å already discussed by Srigouri and co-workers,[3] have been taken into account to compute the intensity ratios I_F/I_R for various temperatures. For λ_R, λ_F, and A_F being constant, the theoretical intensity ratios using the formula for different A_R values corresponding to different temperatures and dissociation levels have been computed. As A_R is dependent on the ground-state atomic density and also on the tube temperature, theoretical intensity ratios have been computed at each temperature for dissociation levels of 100%, 10%, and 1% in CuCl. These calculations have been performed taking all the fluorescent lines (5100, 5700, and 5782 Å) and their

TABLE II. Temperature variation of experimental intensity ratios (I_L/I_R) with helium pressure of 3 Torr (laser case).

Temperature (K)	I_L/I_R
	I_{5106}/I_{3248}
585	1.91
600	3.18
610	4.90
625	6.01

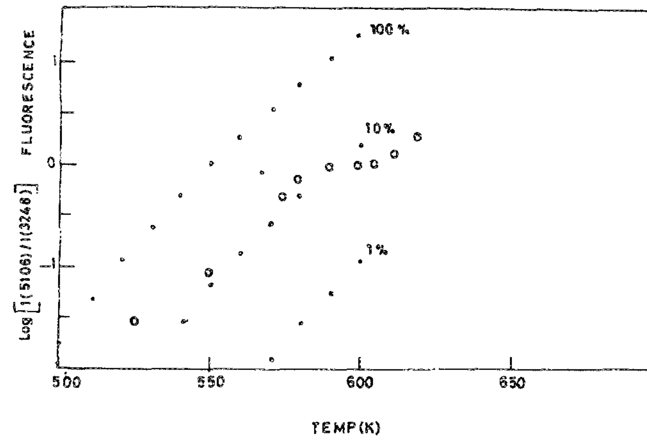

FIG. 1. log [I(5106)/I(3248)] as a function of temperature (fluorescence case). ●, theoretical points; ○, experimental points.

corresponding resonance lines (3248 and 3274 Å) into consideration. Theoretical curves are plotted for I_F/I_R against temperature for these dissociation levels and are shown in Figs. 1–4. Experimental intensity ratios obtained from microdensitometer curves for the same range of temperatures are also plotted on the same graphs. Figures 1, 2, and 3 show the variation of I_F/I_R with temperature for the dissociation levels of 100%, 10%, and 1% along with the experimental points for the fluorescent lines 5106, 5700, and 5782 Å. Figure 4 shows the variation of I_L/I_R with temperature for the same dissociation levels along with the experimental points for the lasing transition 5106 Å (I_L is the intensity of the lasing transition).

In all these plots, both in the fluorescence as well as laser investigation, the experimental points (open circles) are found to fall very close to the theoretical points (solid circles) at a dissociation level of 10% in the present case of CuCl in a temperature range of 550–650 K. The experimental points in the case of fluorescent transitions 5106, 5700, and 5782 Å are found to be in good agreement with the theoretical curve at a dissociation level of 10%. But in the case of laser investigations upon 5106 Å, the experimental points are not in exact agreement with the theoretical curve at the 10% dissociation level but are closer to it.

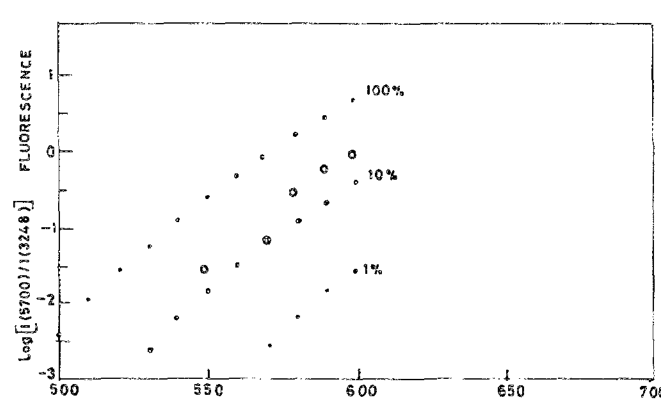

FIG. 2. log [I(5700)/I(3248)] as a function of temperature (fluorescence case). ●, theoretical points; ○, experimental points.

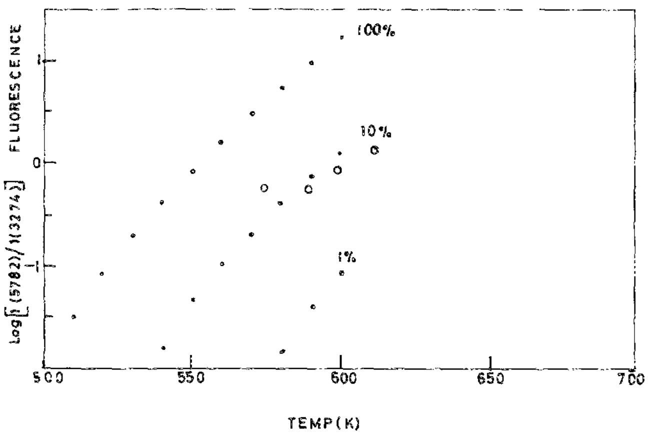

FIG. 3. log [I(5782)/I(3274)] as a function of temperature (fluorescence case). ●, theoretical points; ○, experimental points.

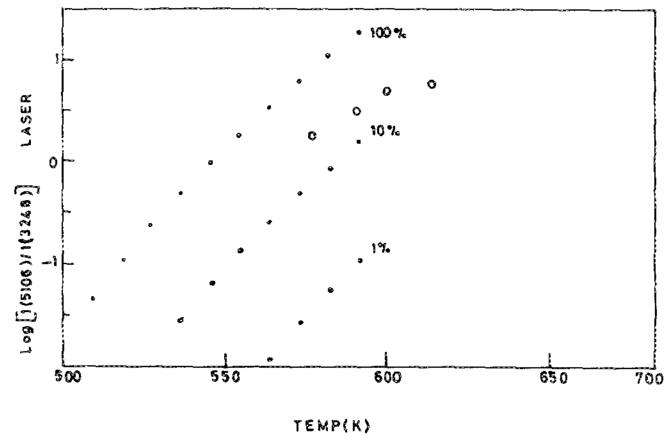

FIG. 4. log [I(5106)/I(3248)] as a function of temperature (laser case). ●, theoretical points; ○, experimental points.

ANALYSIS AND DISCUSSION

From the experiments, it is found that laser action upon the 5106-Å transition starts at 315 °C in the presence of helium at a pressure of 3 Torr. This temperature is found to be in excellent agreement with the theoretically calculated value[3] of 312 °C from the theory of resonance radiation trapping. The laser starting temperature of 315 °C is taken as the temperature at threshold trapping of the 3248-Å resonance line.

The experimental points (open circles) are found to fall very close to the theoretical points (solid circles) in all the figures. This agreement shows the level of dissociation at about 10% near the threshold trapping of resonance radiation. It is also found from the experimental curves that a dissociation level of about 10% is maintained throughout the range of temperatures investigated.

From these investigations, it is realized that the resonance radiation trapping theory will help in understanding the mechanisms involved in the self-terminating metal vapor laser systems to a greater extent and guide the experiments in the most promising directions. This theory may be applicable to any atomic system provided it follows such rules as already given by Walter *et al.*[2]

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[1]L. A. Weaver, C. S. Liu, and E. W. Sucov, IEEE J. Quantum Electron. **QE-10**, 140 (1974).
[2]W. T. Walter, N. Solimene, M. Plitch, and G. Gould, IEEE J. Quantum Electron. **QE-2**, 474 (1966).
[3]K. Srigouri, S. Ramaprabhu, and T. A. Prasada Rao, J. Appl. Phys. **61**, 859 (1987).
[4]T. Holstein, Phys. Rev. **72**, 1212 (1947).
[5]T. Holstein, Phys. Rev. **83**, 1159 (1951).
[6]G. Chakrapani, T. A. Prasada Rao, A. A. N. Murty, and D. Ramachandra Rao, Appl. Phys. Lett. **31**, 832 (1977).