

THE PROBABLE IODINE MOLECULAR LASERS IN THE VIOLET AND ULTRAVIOLET REGIONS

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ABSTRACT

Iodine when excited in the presence of argon shows three band systems in the regions 4420–4000 Å., 3,460–3015 Å. and 2785–2731 Å. all of which involve O_u^+ ($^3\pi_u$) state at 15642 cm.^{-1} as the common lower state. It is pointed out in this article that the transitions involving the first two band systems are suitable for laser action as these transitions are very strong and as their common lower state gets efficiently flushed out due to the crossing or touching of a O_u^- repulsive state while a continued high frequency discharge through a mixture of iodine and argon would keep the upper state populated all the time. Tuning of the interferometer system is expected to make this laser action possible in a wide range of frequencies.

INTRODUCTION

THE fluorescent¹⁻⁴ and electrical⁵⁻⁸ excitations of iodine vapour are known to give a discrete band system in the region 6700–5000 Å, and a number of groups of semi-continuous bands (or diffuse bands) in the region 4800–2500 Å. However, the introduction of a foreign gas changes this spectral pattern completely.

Elliott⁹ reported by fluorescent excitation of a mixture of iodine and nitrogen four band systems in the region 4630–4000 Å, 4321–4041 Å, 3450–3040 Å and 2730–2520 Å. All these band systems except the first one have been later obtained by Waser and Wieland¹⁰ by exciting a mixture of iodine vapour and argon by high frequency discharge. The first band system obtained by Elliott therefore had been attributed to IN molecule while the other three were attributed to the iodine molecule. Venkateswarlu¹¹ later excited the iodine vapour in the presence of argon by transformer and high frequency discharges and obtained the band systems similar to those by Waser and Wieland and in addition also a weak system in the region 2785–2750 Å. These band systems had been reinvestigated a few years ago

by Verma¹² by taking the spectra on a 21-foot grating spectrograph and all the systems were well analysed or reanalysed. The ranges of the band systems as extended by Venkateswarlu¹¹ and by Verma¹² are (i) 4420–4000 Å, (ii) 3460–3015 Å, (iii) 2785–2731 Å and (iv) 2730–2486 Å. Of these the first three systems involve the $\sigma_g^2 \pi_u^4 \pi_g^3 \sigma_u O_u^+ (^3\pi_u)$ as the common lower state of the system while the fourth one involves the ground state of the molecule as the lower state. We will consider in this paper only the first three systems as they are the only ones of interest from the laser point of view. The upper electronic states of these systems lie at 41411, 45937 and 51847 cm^{-1} respectively while the common lower state O_u^+ is at 15642 cm^{-1} .

PRESENTATION AND DISCUSSION

The strong discrete band systems in the region 6700–5000 Å which one gets in the emission of iodine vapour without the presence of a foreign gas, is due to a transition from the upper electronic state $O_u^+ (^3\pi_u)$ at 15642 cm^{-1} to the ground state. Venkateswarlu¹¹ observed that as argon is introduced the intensity of the visible iodine band system decreases. This band system gets completely quenched above a certain argon pressure and in experiments conducted by him, the band system was absent.

When a foreign gas is introduced the excited molecules in the O_u^+ state probably go over to the repulsive O_u^- state¹¹ which either touches or crosses the O_u^+ state and dissociate into $^2P_{3/2} + ^2P_{3/2}$ iodine atoms in the manner suggested by Vanvleck¹³ in magnetic quenching of iodine fluorescence and Turner's¹⁴ fluorescence experiments in a mixture of argon and iodine. The absence of the visible band system in emission of iodine in presence of argon therefore suggests that the molecules soon after reaching O_u^+ state get immediately flushed out or drained out; and this O_u^+ state is the lower state for the band system 4420–4000 Å, 3460–3015 Å and 2785–2730 Å under consideration. This is indeed an ideal criterion for the lower state that one looks for in a laser action. The other criterion that one looks for in a suitable laser action is the intensity of transitions involved. Of the three band systems mentioned, the first two systems 4420–4000 Å and 3460–3015 Å are very intense indicating the use of these transitions for laser action while the band system at 2785–2730 Å is extremely weak and probably need not therefore be further considered at this stage.

Figure 1 shows the potential energy curves of the states under consideration for the iodine molecule. The assignment of electronic terms of various states under consideration are indicated in the figure wherein the assignments for the states marked C, D, F and G are however to be taken

only as tentative. The probable transitions in the regions 4420–4000 Å, and 3460–3015 Å are indicated. The potential energy curves marked F and G at 51528 and 51683 cm^{-1} indicate two of the different electronic states to which iodine molecules in the absence of foreign gas go over by electrical excitation and from which they go down to different repulsive states dissociating into $^2\text{P} + ^2\text{P}$ iodine atoms giving rise to different groups of diffuse bands.⁵⁻⁷ In the presence of argon the collisions take the iodine molecules from the states like F and G to the states like C and D. Transition from C to B gives the system 4420–4000 Å, and transition from D to B gives the system 3460–3015 Å. Soon after the molecules reach the B state $\text{O}_u^+(^3\pi_u)$ the collisions take them over to O_u^- repulsive state which dissociates into $^2\text{P}_{3/2}$ iodine atoms. An extremely large difference in population is thus always maintained between the states C and B as well as between the states D and B thus facilitating the laser action. As the discharge tube is to be operated continuously the states C and D will be steadily populated all the time.

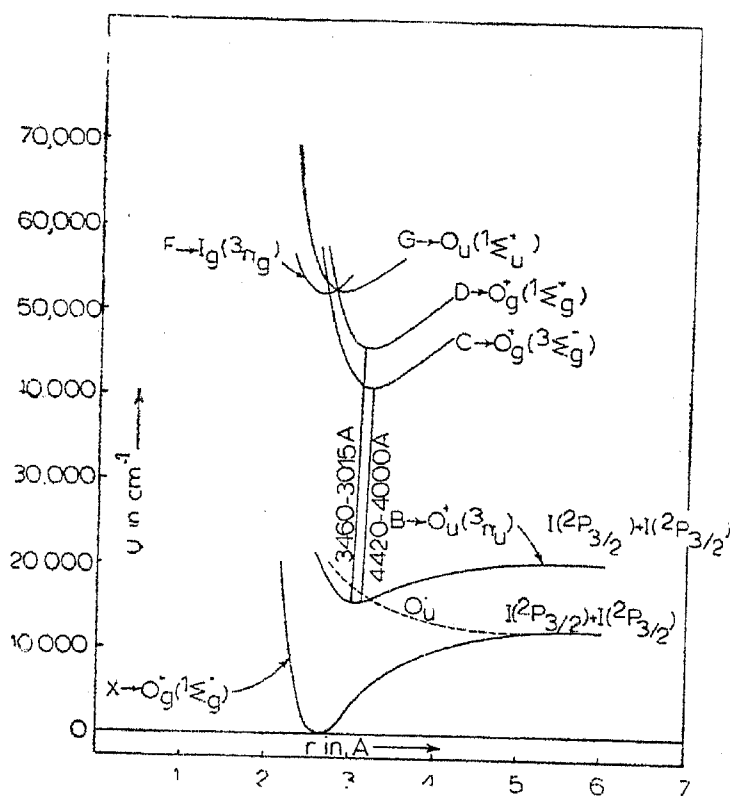


FIG. 1. Potential energy curves for I₂ molecules.

A suitable experimental set-up will probably have to be similar to that of the conventional He-Ne laser apparatus. The discharge tube can be fitted with windows at Brewster angles and with three side stopcocks to pump out

and put in fresh iodine vapour and argon at different intervals if necessary. The pressure of the argon is expected to be about 10 mm. and that of iodine is probably about 10^{-1} to 10^{-2} mm. The discharge tube is to be placed between two reflecting plates, one of which is 100 per cent. reflecting while the other about 95 per cent. reflecting, preferably quartz optics would be suitable for both the regions 4420–4000 Å and 3460–3015 Å, while experiments may of course be conducted with glass optics in the first regions. It is expected that proper tuning of the resonating column results in the change of laser frequency in either of the broad regions 4420 to 4000 Å and 3460 to 3015 Å.

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