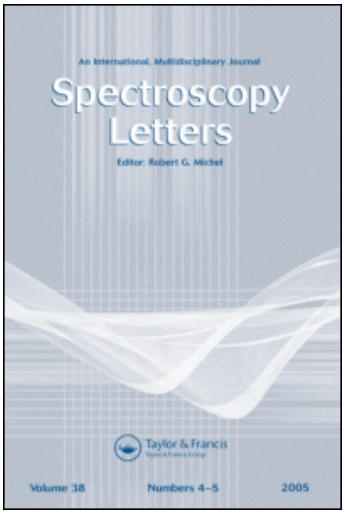

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Rotational Structure in the XeCl Laser Bands at 308 nm

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ROTATIONAL STRUCTURE IN THE XECL LASER BANDS AT 308 nm

Key words : Xenon Chloride Laser, Rotational Structure

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ABSTRACT

The spectrum of XeCl laser emission around 308 nm, photographed and photoelectrically recorded on a 1.5 m monochromator, is presented. The spectrum, recorded at the highest resolution so far, shows partially resolved structure of the violet degraded 0-1 and 0-2 bands of XeCl. The rotational structure of these bands is simulated using estimated rotational constants of XeCl available in literature. Observed and simulated rotational structures are compared. Intracavity absorption is conspicuous in the 0-2 band.

INTRODUCTION

The electronic spectra of rare gas halide molecules were first reported by Kuznetsova et al (1) and from our laboratory by Krishnamachari et al (2). Since then a large number of workers

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have investigated these spectra. Since these spectra involve bound to free (or weakly bound) transitions, rare gas halide molecules were considered potential candidates for laser action, and lasing was soon observed in many of these molecules.

The XeCl molecule has two emission band systems - the B-X system in the 285-310 nm region and the D-X system in the 225-240 nm region. The vibrational structure of these systems obtained in emission has been studied in detail by Abha Sur et al (3) for the isotopic $^{136}Xe^{35}Cl$ molecule. They gave computed rotational structures for the 0-0 and 0-12 bands of the B-X system using estimated splitting and rotational constants.

Lasing action in XeCl was first reported by Ewing and Brau in 1975 (4) in the 308 nm region. The laser emission was studied by Tellinghuisen et al (5) and Iskhchenko et al (6), who have identified the XeCl laser bands as the 0-0, 0-1, 0-2 and 0-3 bands of the B-X system, 0-1 and 0-2 bands being very intense. These investigators, however, could not observe any structure in the lasing bands. In the present studies the 0-1 and 0-2 lasing bands of XeCl have been recorded under high resolution. The partially resolved rotational structure is presented and discussed comparing it with simulated emission spectrum.

EXPERIMENTAL

We have used the Lambda Physik, Model EMG-100 multigas laser. The discharge tube had premixed Xe (60 mbar), Ar (1110 mbar) and 5% and 95% He-HCl mixture (80 mbar). A fast high voltage discharge, initiated by UV preionization, is used for obtaining laser action in XeCl. The spectrum was photographed on the THR-1500 monochromator of M/s. Jobin-Yvon in the first

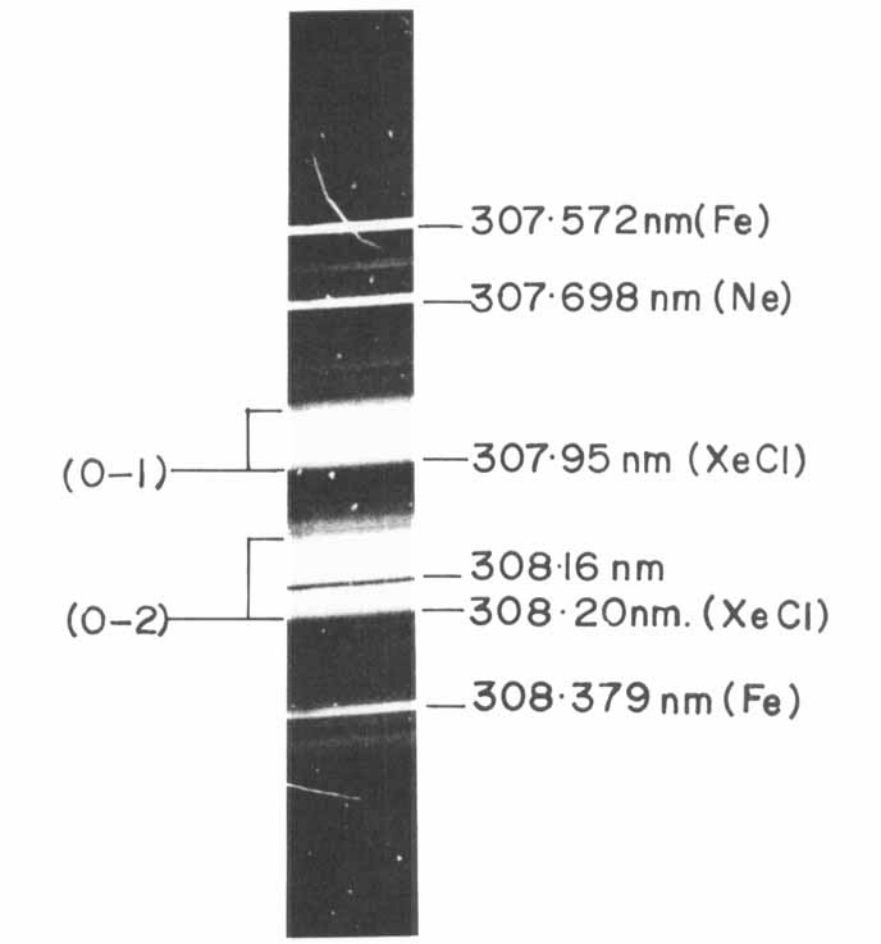
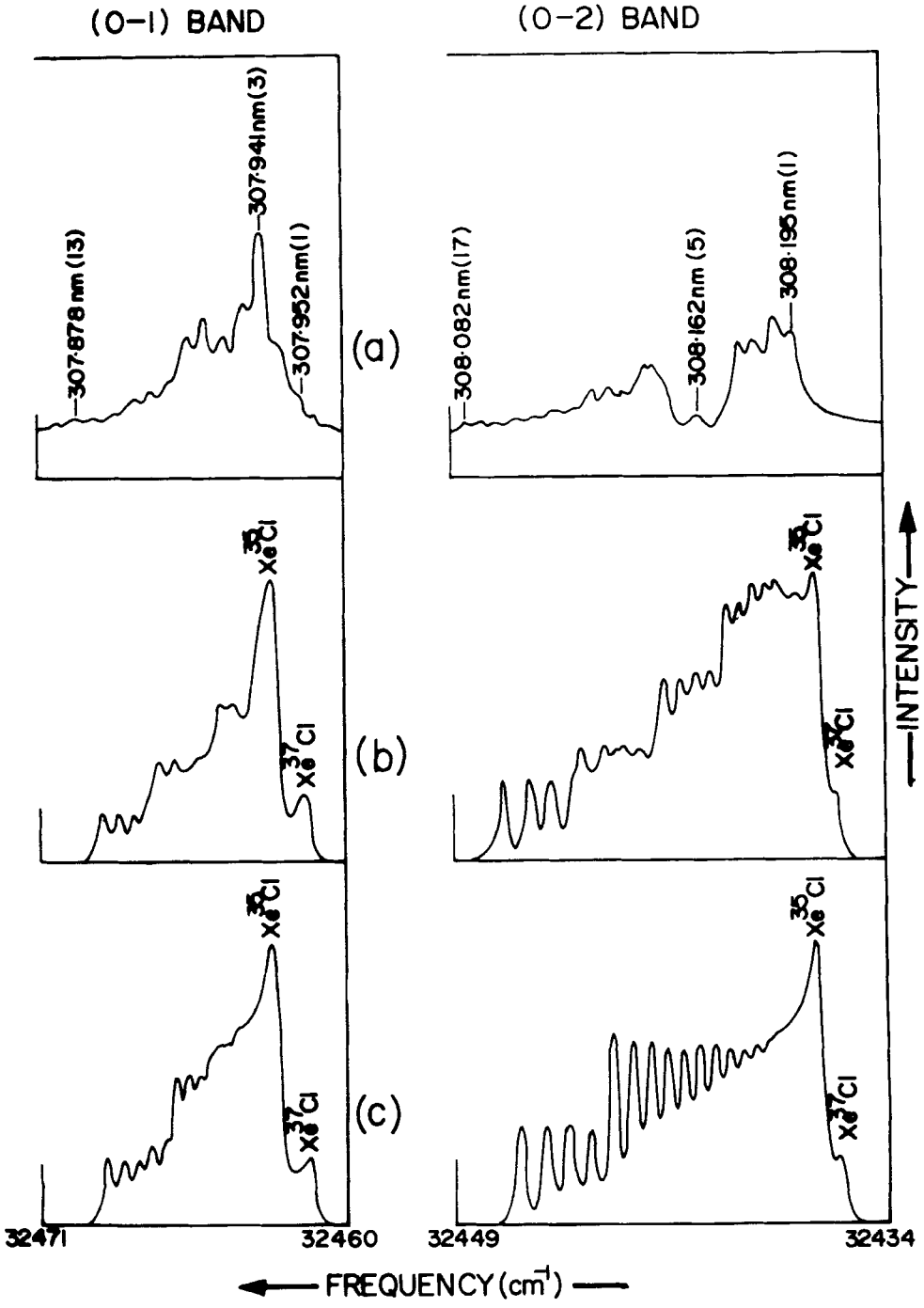


Fig.1 : The spectrum of XeCl laser photographed on the Jobin-Yvon THR-1500 monochromator.

order. The spectrum was also recorded photoelectrically (resolution 0.2 cm^{-1}) using a photodiode and a PAR Model 162 box car averager. Fig.1 shows the photographed spectrum. The photoelectrically recorded spectrum is shown in Fig. 2(a). The relative positions of the peaks in these bands were measured, using the emission lines from an iron hollow cathode lamp as



reference wave lengths. Peak positions (in vac. cm^{-1}) of the rotational structure features of the 0-1 and 0-2 bands are given in Table-1. These are accurate to about 0.1 cm^{-1}.

RESULTS AND DISCUSSION

The 0-1 band shows a prominent peak at 307.941 nm (Fig.2a) very close to the head at 307.95 nm (Fig.1), and has a violet degraded structure consisting of twelve other peaks of smaller intensity, spread over 9 cm^{-1}. The 0-2 band, though it has a violet degraded structure consisting of seventeen peaks spread over 13 cm^{-1}, does not show a pronounced peak, like the 0-1 band. However, the longest wave length peak at 308.195 nm, coincides exactly with the head of this band (Fig.1). Intracavity absorption is very conspicuous in this band, as seen in the pronounced intensity valley at 308.162 nm, Fig.2(a), and a dark line in the spectrogram (Fig.1). Obviously, the observed structure in these bands is too meagre to allow a rotational analysis.

We have therefore simulated the rotational structure of these bands using constants (See Table 2) based on the estimated spin-splitting and rotational constants of ref.3 and the formulae

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Fig.2 :(a) Photoelectrically recorded spectrum of the XeCl laser, the (0-1) and (0-2) bands. The numbers in parentheses correlate with the serial numbers in Table 1.

(b) The simulated spectrum of the (0-1) and (0-2) bands when both P and R lines are considered to lase.

(c) The simulated spectrum of the (0-1) and (0-2) bands when only the P lines are considered to lase.

TABLE-1

Peak positions (in cm^{-1}) of the rotational structure of the 0-1 and 0-2 bands of XeCl

S.No.	(0-1) band at 307.95 nm	0-2 band at 308.20 nm
1	32463.16	32437.57
2	63.76	38.20
3	64.32	39.04
4	64.85	39.57
5	65.59	41.04
6	66.33	42.52
7	66.96	42.94
8	67.59	43.57
9	68.33	44.31
10	68.86	44.94
11	69.60	45.57
12	70.33	46.10
13	70.97	46.94
14		47.57
15		48.10
16		48.73
17		49.47

for the P & R branches used by Tellinghuisen et al (7) and the simulated spectrum is shown in Fig.2(b). Since lasing action is more likely to occur through P-branch transitions, we have also considered only the P-branches in simulating the structure

TABLE-2

Constants (in cm^{-1}) used in simulating the rotational structure of the 0-1 band & 0-2 band (for the isotopic molecule $^{136}Xe\ ^{35}Cl$)

$\nu_{(0-1)}$	=	32463.0
B'_0	=	0.0669
D'_0	=	3.2×10^{-8}
B''_1	=	0.0536
D''_1	=	1.01×10^{-6}
H''_1	=	-3.3×10^{-11}
α	=	-0.4
δ	=	2.0
$\nu_{(0-2)}$	=	32436.7
B''_2	=	0.0512
D''_2	=	1.09×10^{-6}
H''_2	=	-4.6×10^{-11}

and it is shown in Fig.2(c). For simulation, we have assumed a spectral resolution of 0.2 cm^{-1}, a temperature of 325°K and have taken into account eight (out of a total of eighteen) isotopic species of XeCl, whose total abundance in natural XeCl is about 90%. Further, the simulation is carried out to such J values that the simulated spectrum covered about 9 cm^{-1} for the 0-1 band (J = 13.5 in Fig.2(b), J = 22.5 in Fig. 2c) and

13 cm^{-1} for the 0-2 band (J = 19.5 in Fig. 2b, J = 26.5 in Fig. 2c). The head is formed in the 0-1 and 0-2 bands by the p_e branch at J = 6.5 and 5.5 respectively in the simulated spectrum.

While comparing the observed and simulated spectra, we look forward only to a broad agreement and not to a peak to peak correspondence in the structures. This is due to several reasons. Firstly, we have used estimated rotational constants, in the absence of constants derived experimentally from an analysis of these bands in absorption/emission. Secondly, the intensity distribution in the simulated spectrum corresponds to Boltzmann distribution of rotational levels at 325°K, whereas the intensity distribution in the laser spectrum will be weighted much more (than given by Boltzmann distribution) in favour of lines with a higher gain. Thirdly, effects due to intracavity absorption are not considered in the simulated spectrum. In the light of the above considerations, one may say that the comparison is satisfactory for the 0-1 band and poorer for the 0-2 band. Finally, it is emphasised that the main purpose of this note is to present the high resolution spectra of the partially resolved lasing 0-1 and 0-2 bands of XeCl and also point out the occurrence of intracavity absorption in the 0-2 band due to an excited species significantly populated in the discharge. Similar intracavity absorption effects have been observed in the spectra of the $C \rightarrow A$ transition of XeF and Xe_2Cl lasers (8,9 and 10).

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