Spectroscopic Investigation of Foreign Gas Effect upon CO_2 Laser Frequencies

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(Received August 6, 1968)

Under CW (continuous wave) operating conditions in a CO_2 laser, the laser action normally occurs on a few P-branch transitions of the 10.6 μ band of CO_2. Wood and Schwarz[1] observed that introduction of sulfur hexachloride gas to a cell placed within the cavity causes the laser oscillations to shift to a few R-branch transitions. We have found that similar phenomena occur in a wide variety of organic and inorganic gases as well as in SF_6. Not only were the frequencies of the laser transitions dependent upon the foreign gases employed, but they were found very sensitive to the pressures of given gases. With some foreign gases of appropriate pressures within the cavity we have also observed the CW laser oscillations in a few P-branch lines of the 9.6 μ band: a Fermi resonance partner of the 10.6 μ band.

The experimental setup is similar to that reported by Wood and Schwarz[1] and will be described in detail elsewhere.[2] The gases were introduced to a 10 cm cell with KCl windows which was placed inside the cavity. The spectroscopic studies were made with a Perkin-Elmer 112G grating spectrophotometer with a KBr foreprism.[3] Part of our results is shown in Table 1 and in Fig. 1.

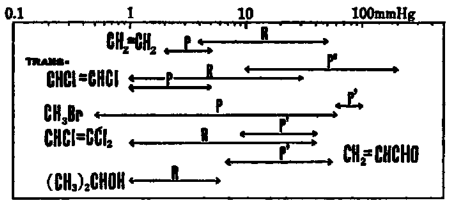

Fig. 1. Dependence of laser frequencies on the vapour pressures of foreign gases. (P′ refers to the P-branch of the 9.6 μ band.)

In most cases, our results can be interpreted simply from the absorbances of given gases in this region. A good example is sulfur hexafluoride shown in Table 1. This molecule absorbs strongly in the P-branch region of the 10.6 μ band, much less strongly in the R-branch region, and it has practically no absorption in the P-branch region of the 9.6 μ band. This explains rather remarkable changes in its oscillation frequencies with the gas pressures. This interpretation seems to hold for the most gases observed. Similar results were also obtained when some liquids were introduced in a liquid cell inside the cavity. However, ammonia and methyl bromide seem to be exceptions. In the case of NH_3 gas (85 mmHg), the usually strong P(20) line was completely missing from the emmis on spectrum, whereas no strong absorption seems to be present at the corresponding frequency. Even when the pressure of NH_3 was reduced to 7 mmHg, the P(20) line was the weakest among the transitions in the P-branch region. This result may be related to a near coincidence of the laser line with one of vibration-rotation transitions of NH_3. The 2sQ(4,2) line which Garing *et al.* reported at 944.14 cm^{-1} is most likely to coincide with the P(20) line at 944.18 cm^{-1}. This band is very weak in intensity, however, a close matching in frequency may suppress the laser oscillation of the particular line involved. It may also be the case with methyl bromide.

TABLE 1. THE EFFECT OF FOREIGN GASES ON THE OSCILLATION OF CO_2 LASER (in approximate order of intensisties)

(a) NH_3 Pressure (mmHg)	10.6 μ band P-branch	10.6 μ band R-branch	(b) SF_6 Pressure (mmHg)	10.6 μ band P-branch	10.6 μ band R-branch	9.6 μ band P-branch
170		20, 22	13			20, 22, 24, 18, 16
50	22, 18	20, 22, 18	5.3		16, 18, 14	
20	22, 18, 24, 16		0.5		18, 20, 16	
7	22, 18, 20		0.0_3	20, 18, 22	18	
3	20, 22, 18					

1) O. R. Wood and S. E. Schwarz, *Appl. Phys. Letters*, **11**, 88 (1967).
2) I. Suzuki and S. Suzuki, to be published.
3) S. Mizushima *et al.*, A Report on the Perkin-Elmer Grating Spectrophotometer Model 112G, The Perkin-Elmer Corp., 1959.
4) J. S. Garing, H. H. Nielsen and K. N. Rao, *J. Mol. Spectry.*, **3**, 496 (1959).