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Laser action in methyl fluoride (CH_3F) was first reported by Chang and Bridges [1] who found that when CH_3F gas at a pressure near 1 torr was optically pumped by 9.55μm radiation from a CO_2 laser, stimulated emission occurred at 452, 496 and 541μm. Both super-radiant [2] and optical cavity [3] forms of CH_3F laser have been operated in our laboratory and this paper discusses the spectral composition of the laser radiation measured in each case.

In the super-radiant assembly, CH_3F gas was contained in a 3.3 m length of glass pipe fitted with a KCl window at one end to admit the 200 MW, 60 nsec half-width, 9.55μm pumping pulse, and a TPX window at the other through which FIR radiation emerged. The FIR pulse was ragged, lasted some tens of nsecs, and was characterized by 4 or 5 nsec peaks rising to powers of 1 MW. The spectral content of this radiation was analysed by means of a variable spacing Fabry-Perot interferometer fitted with copper mesh plates, having an overall measured finesse of 14. Figure 1 shows a sequence of etalon scans made by displacing one plate by 20μm between successive laser discharges. The fsr = 15 GHz and the three traces correspond to 2, 4 and 5 torr pressures of CH_3F. The absolute wavelength of the lines was identified from the frequency of repetition of the fringes as the plate separation was increased by many wavelengths. At 2 torr, laser

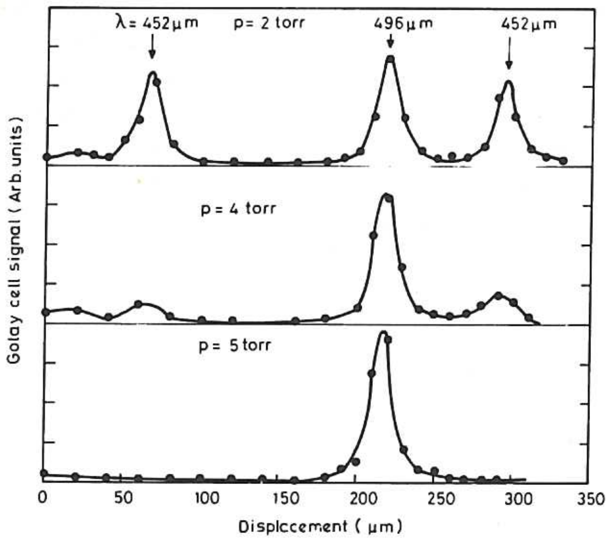

Fig. 1 Low resolution Fabry-Perot spectrum of super-radiant emission. Free spectral range = 15 GHz; p is CH_3F pressure.

output was equally divided between 452 and 496μm lines, but the 541μm line did not appear. Increasing gas pressure towards 5 torr reduced the 452μm line and beyond 5 torr it vanished entirely. Since it arises from population inversion between V=0 J=13 and V=0 J=12 levels when V=0 J=12 population is removed by absorbing the pumping radiation to V=1 J=12, the cessation of laser action at 452μm appears to imply that about 5 torr, repopulation of V=0 J=12 by collisions compensates for depletion of the level by pumping.

The fine structure of the 496μm line at 5 torr was investigated with the etalon fsr = 800 MHz (instrumental width = 55 MHz). Figure 2 shows the spectrum we measured, which is seen to consist of three components of which the central one is considerably more intense than its neighbours. The spacing of these components in terms of etalon plate displacement, reading from the left, is 45μm between the first and second, and 37μm between the second and third. This corresponds to 145 MHz and 119 MHz respectively. The frequencies of the fine structure of the 496μm transition for different values of the projected angular momentum quantum number K were calculated using the equation given by Smith and Mills [4] in terms of K, J, and the appropriate molecular rotational constants given by Chang and Bridges [1]:

$$\nu = (B_1 - K^2 D_{JK1})\left[J_1(J_1+1) - J_2(J_2+1) \right] - D_{J1}\left[J_1^2(J_1+1)^2 - J_2^2(J_2+1)^2 \right]$$

with

B_1=25197.7 MHz, D_{JK1}=0.54 MHz and D_{J1}=0.058 MHz.

By comparing the interline frequency intervals measured in our experiment with those calculated for J_1=12 and J_2=11, it was possible to identify the three observed components of the 496μm transition with the K=6, 5, and 4 levels in the CH_3F molecular spectrum fine structure. We note that Chang and Bridges [1] found laser action only in K=1, 2 whereas Brown and coworkers [5] studying super-radiant emission, found K=1, 2, 3, 4, 5, 6, 7 excited.

Laser action in CH_3F at 496μm has also been

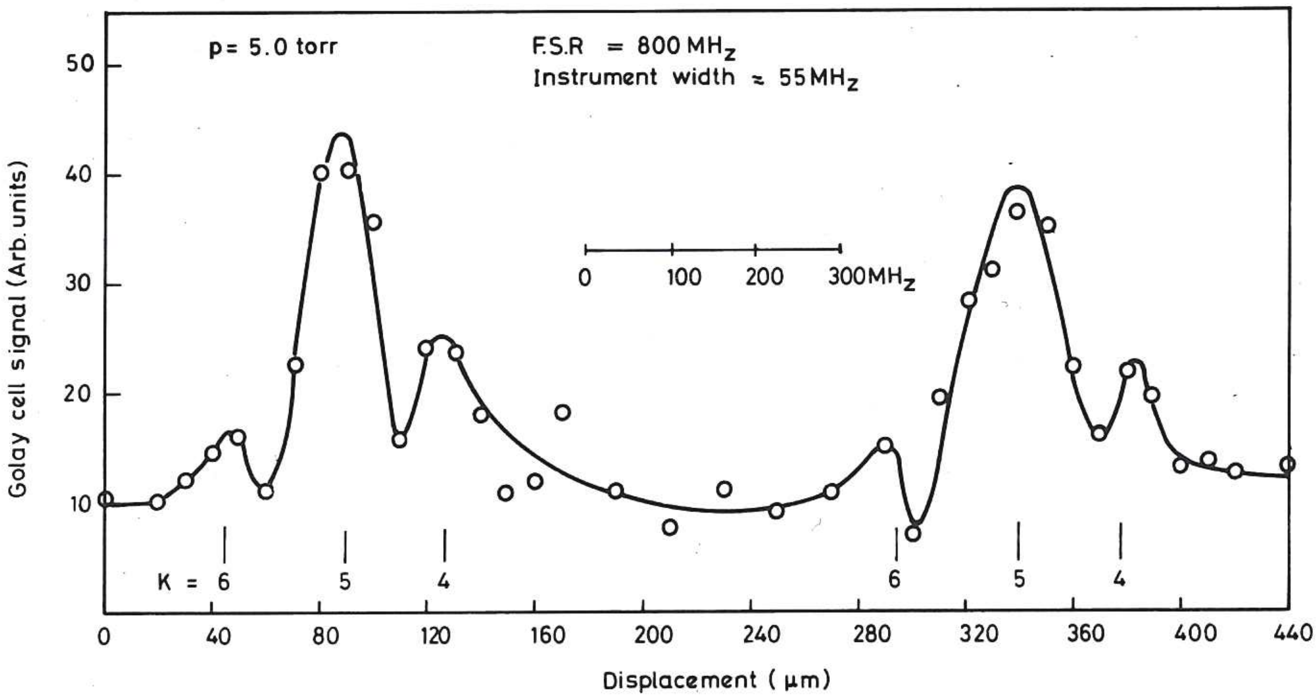

Fig. 2 High resolution spectrum of super-radiant emission showing fine structure identified with K = 4, 5, 6 CH_3F molecular levels.

obtained in a hemispherical optical cavity [2] pumped by 42J of 9.55μm CO_2 TEA laser radiation, and highly modulated 1 μsec pulses delivering 6 mJ at peak powers of 10 kW have been recorded. Laser action in this case is confined to fundamental cavity modes spaced 40 MHz apart, and can only occur when a cavity mode coincides with a molecular K level (broadened by gain saturation).

The spectrum measured by the copper mesh etalon set so that fsr = 360 MHz (instrumental width = 28 MHz) is shown in Figure 3. At pressure up to 0.4 torr the overall width was between 50 and 100 MHz, and this is increased to and appeared to remain constant at 150 MHz beyond 0.8 torr.

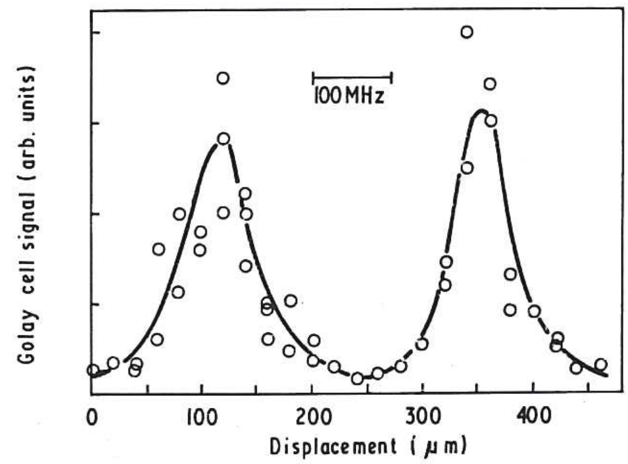

Fig. 3 High resolution spectrum of optical cavity laser emission.

Its observed width and shape suggest that the spectrum is composed of a sequence of neighbouring cavity modes, perhaps as many as 4 or 5 at higher pressures. Oscillograms made with a point-contact diode showed by their 40 MHz modulation that even at pressures as low as 0.1 torr at least 2 neighbouring cavity modes were excited. This could be explained by assuming either the closely-spaced K = 0,1,2,3 levels are operating, or else some single gain saturation broadened level among the more widely spaced higher K values is being pumped. In view of our conclusion that K = 4,5 and 6 were active in the super-radiant configuration, with K=5 being the most intense, it is consistent to expect that this single level is responsible for the laser action observed in the optical cavity case.

These Fabry-Perot spectra lack time resolution and it is possible that their apparent width may be due to the onset and decay of different modes at different times during the pulse. Point contact diode oscillograms support this interpretation.

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