FOUR-MILLIMETER MOLECULAR BEAM GENERATOR BASED ON THE $1_{01}-0_{00}$ *TRANSITION IN THE* CH_2O *MOLECULE*

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Generation of a frequency of 72,838 Mc due to the $1_{01}-0_{00}$ transition in the CH_2O molecule is obtained. The absence of a fine structure and the presence of an upper level Stark energy maximum in the $1_{01}-0_{00}$ line favor the frequency stability of the molecular generator. The power of the molecular generator is 3×10^{-11} W. An emission line at 72,409 Mc due to the $5_{14}-5_{15}$ transition was also observed. The observed Stark effect and fine structure of the line are in agreement with the theoretical predictions. An absorption line in the beam was observed in the $1_{01}-0_{00}$ transition.

An increase in the number of substances utilized in beam masers and continuous extension of the development of beam maser techniques into the short wavelength portion of the spectrum are of interest. Our efforts toward that goal have led to the construction of a formaldehyde molecular generator operating in the four-millimeter frequency band [1,2]. Formaldehyde $C^{12}H_2O^{16}$ is a light elongated and a slightly asymmetric-top molecule with a rather large dipole moment, $\mu = 2.31$ D. The 72,838 Mc rotational $1_{01}-0_{00}$ transition was utilized. The slight asymmetry of the molecule allows us to consider with good accuracy the Stark effect in the above transition to be of the form of the Stark effect for the $J = 1$ and $K = 0$ transition for the symmetric top. The Stark effect for the $K = 0$ levels of a symmetric top is in turn identical with the Stark effect of a linear molecule.[3]

The form of the Stark effect favors level sorting of the beam molecules. The energy of molecules of the lower level decreases in the field E and the energy of molecules in the upper level with $M = 0$ increases and has a maximum for $E = 150$ kV/cm (the sorting system breaks down at $E \approx 200$ kV/cm). Apparently, the presence of the point $dw/dE = 0$ sharply reduces the influence of changes in the sorting voltage on the number of the active molecules appearing at the exit of the separation system; this should favor the frequency stability of the molecular generator. The capture angle was determined, as usually, from the equality of the radial-motion energy to the Stark energy and was found to be $\alpha_C \approx 3°$. The active molecules are sorted uniformly by the field since there is no spread in the M-numbers. The square of the matrix element of the dipole moment is $|\mu_{ij}|^2 = 1.77$ D^2. The population of the level 1_{01} is $\delta = 0.09\%$, and $\delta_0 = 0.03\%$ molecules are in the state $M = 0$. In the CH_2O molecule, only the H nuclei possess spin. Their spin is $1/2$ and the molecule does not have a quadrupole fine structure. In the case of the $1_{01}-0_{00}$ transition, the spins of the H nuclei are oppositely directed and the resulting spin of the molecule is zero. In this case the magnetic fine structure is also absent. Therefore, the $1_{01}-0_{00}$ line does not have any fine structure, which should also favor the frequency stability of a molecular generator operating on that line.

The beam maser had the usual construction with a E_{010} mode resonator. Owing to the good sensitivity of the apparatus, the absorption line in the beam was observed (with the sorting po-

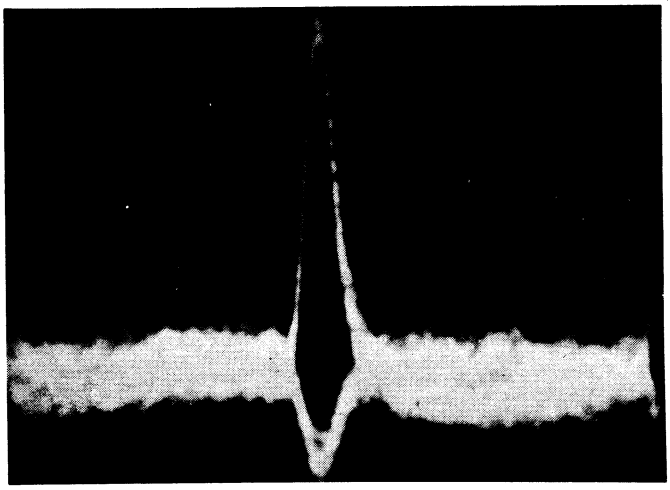

FIG. 1. Photograph of the emission line (positive large pulse) and the absorption line in the beam.

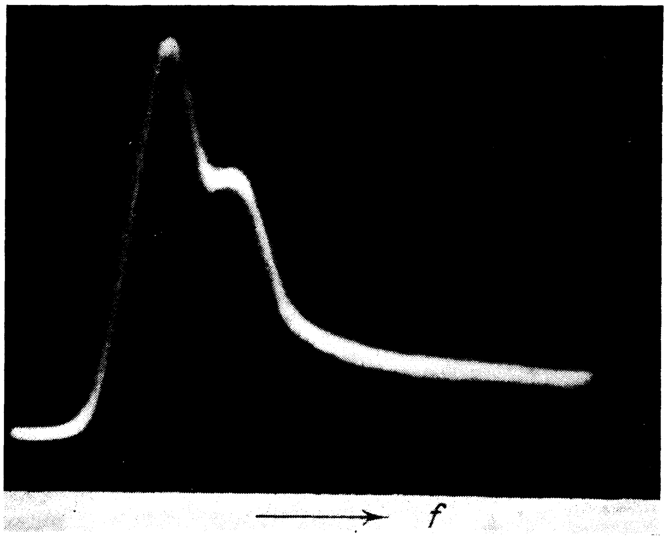

FIG. 2. Photograph of the emission line of the 5_{14}–5_{15} transition.

tential turned off). This was photographed together with the emission line (Fig. 1). The lines have the same width (of the order of 15—20 kc), which is in agreement with calculations based on the transit time. Generation was obtained for the 1_{01}—0_{00} transition starting with a sorting voltage of 6 kV. In the 13—16 kV sorting-voltage region the amplitude of the generated signal remained essentially constant, which confirms the deductions drawn with respect to the Stark effect. The power fed to the receiver was compared to the power radiated from a standard noise tube, which in turn was checked with a thermally calibrated radiometer and was found to be 3×10^{-12} W. The coupling coefficient was ~ 0.1 and the tank-circuit power was 3×10^{-11} W. The generator was operating without any cooling membranes and without any time limit.

The 5_{14}—5_{15} transition was also investigated at 72,409 Mc. An examination of the rotational levels of the CH_2O molecule shows that the 5_{14}—5_{15} levels experience a Stark effect comparable to the Stark effect of a pair of isolated levels. Application of a field E produces "repulsion" of the levels, i.e., conditions for sorting exist. The square of the matrix element of the transition dipole moment is $|\mu_{ij}|^2 = 0.066D^2$. The population of the 5_{14} level, taking into account the nuclear weight $g_{nuc} = 3$, is 0.9%. The capture angle, computed for a field $E = 200$ kV/cm, is 1.7°. For the 5_{14}—5_{15} states, the spin of the molecule is $I = 1$ and the line has a hyperfine structure which can be resolved with the aid of the maser. The theory of the hyperfine structure of the CH_2O molecule is given in [4]. The line splits into three components corresponding to the values $F = 6$, 5, and 4; $F = I + J$; $J = 5$. The shifts of the components $F = 6$, 5, and 4 from the frequency of the unperturbed line are respectively -5.6; -12.6; $+23.6$ kc, with intensities (in % of the total) 40, 33, and 27%. The computed shape of the line (as a function of frequency f) for a component width of 20 kc is in good agreement with the experimental shape shown in Fig. 2. The components $F = 6$ and $F = 5$ cannot be resolved and thus do not permit more exact evaluation of the constants corresponding to the interaction between the electronic states and rotation of the molecule and the spin-spin interaction of the H nuclei. When the field E is increased, the 5_{14}—5_{15} line, unlike the 1_{01}—0_{00} line, does not saturate, and the increase in the sorting voltage increases the number of active molecules. In order to obtain self excitation on the 5_{14}—5_{15} line it would be necessary to approximately double either the number of active molecules or the quality factor of the resonator.

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