REORIENTING OF MOLECULES IN A FORMALDEHYDE BEAM MASER

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Basov et al. [1] have observed the effect of constant electric and magnetic fields on a state-selected molecular beam, leading to frequency and amplitude changes in the oscillations of an ammonia maser. The effect was attributed to the reorienting (in space) of molecules "marshalled" in a determinate order by the state-selector field. It is of interest in this connection to measure the characteristics of the reorienting process in a formaldehyde maser.

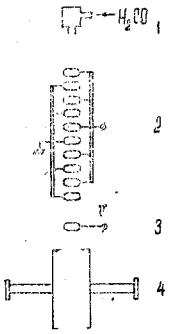

Fig. 1. Schematic of experimental setup: 1) beam source; 2) ring-type state selector; 3) additional elec-electrode; 4) cavity.

The reorienting processes were investigated in a molecular oscillator using the $1_{01}-0_{00}$ transition in formaldehyde CH_2O. From experiments on a formaldehyde maser with a Fabry-Perot-type interferometer [2], it had already been established that the molecules emerging from the state selector are molecules with M = 0 and M = ±1 with a 3 : 1 intensity ratio (the quantization axis coincides with the beam axis). In entering the cavity the only molecules interacting with the E_{010} field are those with M = 0. When a reorienting field is superimposed, there is equal probability of the transitions (M = 0 → M = = ±1) and (M = ±1 → M = 0) and the excitation parameter must decrease. With 100% reorienting the excitation parameter should be reduced to 1/3 of its initial value. With a further increase in the perturbation, the variations of the excitation parameter will be in the nature of oscillations, decaying as a result of molecule-velocity spread.

The experimental setup is shown diagrammatically in Fig. 1. The electrode generating a weak field is a little ring surrounding the molecular beam between the ring-type state selector and the E_{010}-mode cavity at distances of 14 and 4 mm respectively. The maser operated under amplification conditions; the excitation parameter (i.e., the probability of the transition of molecules for a constant beam and state-selector voltage) was measured as a function of the ring-electrode voltage. This is the primary effect; it is this effect that causes oscillation-frequency and amplitude changes in the oscillator. The measurements obtained are shown in Fig. 2. [Curves obtained with a quadrupole system had a similar but less regular behavior owing to asymmetry of the scatter field]. It was found that the excitation parameter decreased even in the case of a noncharged ring electrode. With the ring-electrode voltage of a different sign from the state-selector voltage (one half of the state selector was earthed) the dependence of the excitation parameter upon the ring-electrode voltage agreed with the expected dependence. The excitation voltage variations covered a 1 : 3 range, which is evidence of nearly 100% reorientation. For a ring-electrode voltage of the same sign as the state-selector voltage the excitation-parameter variations were less marked and monotonic, which may be attributed to the considerably less marked change in field configuration near the ring electrode in this case. In fact, the reorienting effect of the ring may even be completely removed by applying to it a potential equal to the potential that was generated by the scatter field at the point where the ring is placed.

Using the same state selector, beam source, and reorienting electrode, experiments were carried out with an ammonia maser using the J = 3, K = 3 transition $^{14}H_3$. To retain the field character, a diaphragm with an aperture of the same diameter as the limit waveguides of the 4-mm cavity was placed before the cavity. Then the ammonia oscillator was easily triggered. However, in the ammonia oscillator the dependence of the excitation parameter on the reorienting-electrode voltage was not very pronounced (~1%) and did not contain a series of oscillations. Subsequently, experiments were carried out on an apparatus similar as in [1], and the results obtained were in good agreement with results of [1]. At the same time we measured the value, not given in [1], of the maximum variation of the excitation parameter in ammonia. It was found to be of the order of 20%, which is considerably less than in the case of formaldehyde. It is interesting to note that a scale model of the capacitor used for reorienting in [1] did not practically affect, in a formaldehyde maser, the transition probability of formaldehyde molecules.

In an ammonia maser the reorientation could also be obtained by means of a magnetic field of the order of 1 Oe. Similar experiments on a formaldehyde maser gave no reorientation for magnetic fields of up to 50 Oe.

Control experiments were carried out with the state-selector voltage switched off, when the line observed in the maser cavity was the absorption line of molecules of the beam. In this case, the presence of voltage at the ring electrode had no effect on the intensity of the absorption line, just as one would expect from the equiprobable M-distribution of the molecules in the nonselected beam. This is a further confirmation that no spurious effects were present in the experiment and that the observed effects were just reorientation of molecules.

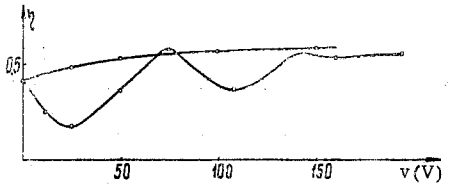

Fig. 2

During the experiments with the formaldehyde maser it was observed that the solid-formaldehyde layer covering the frozen components was strongly electrified. The additional noncontrollable fields thus arising modified the reorientation of molecules and resulted in slow amplitude and frequency variations of the maser oscillations. Apparently such an effect may also be observed in an ammonia maser.

To improve the long-term frequency stability of a molecular oscillator, measures should be taken to prevent the fields of the frozen operating substance from penetrating the space between the state selector and the cavity.

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RADIATION ADMITTANCE OF LONGITUDINAL SLOTS IN A CYLINDER

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Known results on the admittance of longitudinal slots on a conducting-cylinder surface are mainly concerned with the conductance component for half-wave slots [1, 2] and were obtained by integrating the Poynting vector in the wave region.

Below, formulas and results are given for both components of the admittance of a slot on a conducting circular cylinder surface, obtained by the induced MMF method. If, in the well-known mathematical formulation of the induced MMF method, the magnetic-field intensity is expressed in terms of the Green function, the self-admittance of a longitudinal slot S, having an electric-field strength distribution E(**r**), may be written in the form of a functional as follows:

$$Y = \int_S E(r)\left(k^2 + \frac{\partial^2}{\partial z^2}\right)\int_S G(r, r')E(r')\,dS'dS, \qquad (1)$$

where

$$G = -\frac{j}{\pi^3 a^2 \omega\mu}\sum_{m=0}^{\infty}\varepsilon_m \cos[m(\varphi-\varphi')]\int_0^{\infty}\frac{1}{\varkappa\left|H_m'(\varkappa a)\right|^2}\times$$
$$\times \exp\left(-\sqrt{\varkappa^2-k^2}\,|z-z'|\right)(\varkappa^2-k^2)^{-1/2}\,d\varkappa, \qquad (2)$$

a is the cylinder radius, $k = 2\pi/\lambda$, $\varkappa$ is the wave number, and $H_m'(\varkappa a)$ is the derivative of the Hankel function.

Calculations were carried out for a sinusoidal field distribution along the slot

$$E(z) = \frac{1}{t}\sin\left(\frac{\pi}{l}z\right), \qquad (3)$$

where z is the running coordinate along the slot, l is the slot length, and t is the slot width.

After substituting (2) and (3) in (1) and integrating with respect to φ and z, we obtain

$$Y = j\frac{2}{\pi^3 a^2\omega\mu}\sum_{m=0}^{\infty}\varepsilon_m\left[\frac{\sin(mt/2a)}{(mt/2a)}\right]^2\int_0^{\infty}\left[\varkappa\left|H_m'(\varkappa a)\right|^2\right]^{-1}\times$$
$$\times\left[\frac{1}{2}l\,\frac{k^2-(\pi/l)^2}{(\pi/l)^2+\varkappa^2-k^2}+\frac{\varkappa^2(\pi/l)^2}{[(\pi/l)^2+\varkappa^2-k^2]^2}\times\right.$$
$$\left.\times\frac{1+\exp\left(-\sqrt{\varkappa^2-k^2}\,l\right)}{\sqrt{\varkappa^2-k^2}}\right]d\varkappa. \qquad (4)$$

Expression (4) is conveniently resolved into its real and imaginary parts, and it is convenient to introduce the new dimensionless integration variable $\alpha = \varkappa/k$

$$G = \frac{2}{\pi^3(ka)^2}\sqrt{\frac{\varepsilon}{\mu}}\sum_{m=0}^{\infty}\varepsilon_m\left[\frac{\sin(mt/2a)}{mt/2a}\right]^2\int_0^1\frac{1}{\alpha\left|H_m'(ka\alpha)\right|^2}\times$$
$$\times\alpha^2(\pi/kl)^2\left[(\pi/kl)^2-1+\alpha^2\right]^{-2}\left[1+\right.$$
$$\left.+\cos\left(\sqrt{1-\alpha^2}\,kl\right)\right](1-\alpha^2)^{-1/2}\,d\alpha; \qquad (5)$$

$$B = \frac{2}{\pi^3(ka)^2}\sqrt{\frac{\varepsilon}{\mu}}\sum_{m=0}^{\infty}\varepsilon_m\left[\frac{\sin(mt/2a)}{mt/2a}\right]^2$$
$$\times\left\{-\int_0^1\left|\alpha\left|H_m'(ka\alpha)\right|^2\right|^{-1}\times\right.$$
$$\times\left\langle\alpha^2(\pi/kl)^2\left[(\pi/kl)^2-\right.\right.$$
$$\left.-1+\alpha^2\right]^{-2}\sin\left(\sqrt{1-\alpha^2}\,kl\right)(1-\alpha^2)^{-1/2}-$$
$$\left.-\frac{kl}{2}\,\frac{1-(\pi/kl)^2}{(\pi/kl)^2-1+\alpha^2}\right\rangle d\alpha+$$
$$\left.+\int_1^{\infty}\left|\alpha\left|H_m'(ka\alpha)\right|^2\right|^{-1}\left\langle\alpha^2(\pi/kl)^2\times\right.\right.$$
$$\times\left[(\pi/kl)^2-1+\alpha^2\right]^{-2}\left[1+\exp\left(-\sqrt{\alpha^2-1}\,kl\right)\right](\alpha^2-1)^{-1/2}+$$
$$\left.+\frac{kl}{2}\,\frac{1-(\pi/kl)^2}{(\pi/kl)^2-1+\alpha^2}\right\rangle d\alpha\Bigg\}. \qquad (6)$$

Concrete results were obtained by numerical integration and by retaining a finite number of terms in (5) and (6). The expressions obtained were somewhat modified by isolating the singularity of the integrands for $\alpha = 1$, and by splitting the second integral in (6) into two with integration limits from 1 to A and from A to ∞. To evaluate the last integral, asymptotic forms of the Hankel functions were used. The quantity A was suitably chosen, depending on ka and m.

Results of numerical calculations were summarized in graphical