Kolomeitsev for help with the work.

[1] G. A. Askar'yan, M. S. Rabinovich, M. M. Savchenko, A. D. Smirnova, and V. P. Studenov, JETP Letters 1, No. 6, 18 (1965), transl. 1, 162 (1965).

[2] G. A. Askar'yan, M. S. Rabinovcih, A. D. Smirnova, and V. B. Studenov, JETP Letters 2, 503 (1965), transl. p. 314.

TWO-CAVITY LASER AS HIGH-RESOLUTION SPECTROSCOPE

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It is customarily assumed that the resolving power of a spectroscope is limited by the width of the spectral line. Feld et al. [1] have shown that it is possible to resolve spectral components inside a Doppler (inhomogeneously broadened) line, so that the limit of resolution is determined by the homogeneous broadening. It will be shown below that in a laser it is possible to resolve spectral components within the limits of a homogeneously broadened line, so that the resolution limit of such a spectroscope is apparently determined by the width connected with the monochromaticity and stability of the radiation source.

To resolve the components within a homogeneously broadened spectral line it is expedient to use a laser with two cavities in tandem.

The idea of the spectroscope consists in the following. As is well known, a beam of active molecules passing through the first cavity is polarized there under the influence of the monochromatic signal. The polarized beam, on entering the second cavity, produces there "molecular ringing" (coherent spontaneous emission) having the same frequency as the signal frequency in the first cavity. The phase of the signal in the second cavity depends on the frequency difference between the signal and the peak (center of gravity) of the spectral line and on the distance between cavities [2]. If this distance is modulated, the phase of the signal in the second cavity is also modulated, but if the signal frequency coincides exactly with the peak of the line, then the modulation of the distance between resonators does not cause phase modulation.

On the other hand, owing to the saturation effect, the position of the line peak changes with the magnitude of the signal in the first cavity. By measuring the generation frequency at which the phase in the second cavity does not depend on the modulation of the distance between the resonators, at different values of the signal in the first cavity, we can obtain as many independent relations as there are hyperfine structure components in the line. Simultaneous solution of these relations makes it possible to determine the position of the hyperfine structure components.

The calculation was carried out for illustrative purposes in the case of a line with two spectral components, although it can be readily generalized to include an arbitrary number

of components. To calculate the amplitude and the phase we used the formulas of [3] for a laser with two resonators in tandem. The calculation was made for the case when $\Delta\omega_j(L + l_2)/l_1 \ll \tau_1$, where $\Delta\omega_j$ (j = 1, 2) is the difference between the frequency of the j-th spectral component and the signal frequency, L is the distance between cavities, l_2 is the length of the second cavity, and τ_1 is the time of flight through the first cavity. For components lying within the spectral line width this condition can always be readily satisfied.

At low saturation in the first cavity we obtain three points for which the phase in the second resonator did not change when the distance between cavities was modulated. These points are determined by the following relations:

$$\begin{aligned} &|\mu_1|^2 N_1\Delta\omega_1 + |\mu_2|^2 N_2\Delta\omega_2 = 0,\\ &|\mu_1|^2 N_1\Delta\omega_1\{[(3l_2 + 6L)/l_1] - 6\} + 6|\mu_2|^2 N_2\Delta\omega_2 = 0,\\ &6|\mu_1|^2 N_1\Delta\omega_1 + \{[(3l_2 + 6L)/l_1] - 6\}|\mu_2|^2 N_2\Delta\omega_2 = 0, \end{aligned} \qquad (1)$$

where μ_1 and N_1 are the dipole moment and the number of particles in the second resonator, corresponding to the first spectral component, μ_2 and N_2 are the same for the second spectral component, and l_1 is the length of the first resonator.

Simultaneous solution of (1) yields ω_1, ω_2, and $|\mu_1|^2 N_1/|\mu_2|^2 N_2$ (if N_1 and N_2 are constant). The frequency-measurement error ($\delta\omega$) is determined mostly by the error of measurement of the phase difference between the first and second cavities, and is also connected with technical frequency drift of the first cavity. In the case of synchronous detection

$$\delta\omega = \frac{8\bar{v}}{\Delta L|(3l_2 + 6L)l_1|}\,(T + \tau_1/2 + \tau_2/2)\sqrt{\dot{\chi}^2}\sqrt{2\beta/\theta(\Omega^2 + \beta^2)}. \qquad (2)$$

Here $\bar{v}$ is the mean beam velocity, $T = L/\bar{v}$, $\tau_2 = l_2/\bar{v}$, ΔL is the amplitude and Ω the frequency of modulation of the distance between resonators, $\overline{\dot{\chi}^2}$ is the rms frequency fluctuation of the first resonator, θ the detection time, and β the reciprocal correlation time, if we regard the technical drift as a normal random process. Substituting in (2) $L = l_1 = l_2 = 10$ cm, $\Delta L = 0.1$ cm, $\beta = \Omega = 10$ cps, $\bar{v} = 6 \times 10$ cm/sec, $\theta = 1$ sec, and $(\overline{\dot{\chi}^2})^{1/2} = 1$ cps we get $\delta\omega \sim 20$, i.e., spectral components separated by several cps can be resolved. It must be emphasized that there is still an error connected with the accuracy of the calculations, but it is of no fundamental significance, since the calculation accuracy can always be increased.

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[3] A. N. Oraevskii, Molekulyarnye generatory (Molecular Gnerators), Nauka, 1964.