Here c_{33} and c_{44} are the components of the elastic-constant tensor, a_{14}, a_{13}, and a_{44} the components of the photoelastic-constant tensor, and ε_0 the dielectric constant of the unperturbed crystal.

To estimate the threshold sensitivity in the quartz, we shall assume that the absorption coefficients a_ℓ and a_t are of the same order of magnitude. This does not contradict the experimental data for hupersonic waves [4]. An estimate shows then that for a transverse wave polarized in the same direction as the incident light wave the thrshold intensity is of the same order as for a longitudinal wave. The threshold intensity for a transverse wave polarized in a perpendicular direction is larger by approximately one order of magnitude. Thus, the simultaneous excitation of longitudinal and transverse waves observed in [1] can be explained.

It should be noted at the same time that the growth increment of a longitudinal wave is usually larger than the increment of a transverse wave, and consequently the longitudinal wave is easier to excite. To excite a transverse wave it is necessary that the intensity of the incident light greatly exceed the threshold.

In conclusion, I am grateful to I. L. Fabelinskii for useful discussions.

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SELF-STABILIZATION OF LASER OPTIC-OSCILLATION FREQUENCY BY NONLINEAR ABSORPTION IN GAS

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1. It is known that production of a quantum generator with high frequency stability (frequency standard) calls for a narrow resonance of the active-medium gain with a stable position of the resonance maximum, and a broad loss resonance in the resonator. This is the underlying principle of the frequency standards for the radio [1,2] and optical [3] bands. We propose in this letter a fundamentally different method of laser-frequency stabilization, based on producing in the laser standing-wave field a resonant "dip" in the absorption line of gas placed in the resonator, the gain resonance of the active medium being broad and less stable. The proposed method is of interest for the realization of an optical frequency standard.

2. Let gas at low pressure be situated in the field of a standing light wave $Ee^{i\omega t}\cos kz$ whose frequency coincides with the line of resonant absorption of the gas at the frequency ω_b. In a "weak" light field, which does not cause saturation of the gas absorption, the absorption line retains a Doppler shape. In a "strong" light field, saturation sets occurs in the absorption of the atoms that interact most effectively with the standing-wave field. As a result, the absorption line shape changes appreciable, and if the Doppler line width greatly exceeds the homogeneous width, "holes" are produced at the frequency ω and its reflection

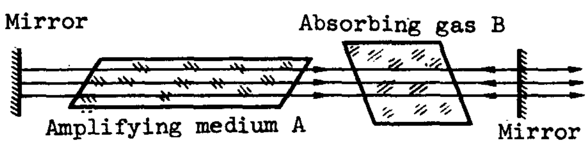
$2\omega_b - \omega$ relative to ω_b. The absorption coefficient of the standing light wave acquires a "dip" at the frequency ω_b, owing to the equality of the mirror-symmetry "holes" at $\omega = \omega_b$. This phenomenon was investigated in detail by Lamb [4] for the case of an amplifying gas medium, and is called the Lamb "dip."

If the gas pressure is low and the radiative transition probability A_{21}^{b} of the absorbing atoms is small, then the "dip" in the absorption line can be quite narrow. Its width $\Delta\omega_b$ is determined by the time of flight of the atoms through the beam, $\tau_0 = d/v_0$ (d = beam diameter, v_0 = average velocity of the atoms) and by the line broadening $\Delta\omega_{col}$ due to the collisions:

$$\Delta\omega_b = 1/\tau_0 + \Delta\omega_{col}, \tag{1}$$

provided $A_{21}^{b} \ll 1/\tau_0$. For example, at a gas pressure of 10^{-2} Torr, when usually $\Delta\omega_{col} \approx 10^4 - 10^5$ Hz, the width of the "dip" for a beam of diameter $d \approx 1$ cm ($v_0 \approx 10^5 - 10^6$ cm/sec) is $\Delta\omega_b$ $2\times10^4 - 2\times10^5$ Hz.

2. Let us place in the laser cavity a cell with absorbing gas, whose absorption line at the frequency ω_b coincides with the gain line of the active medium at the frequency ω_a (see the figure).



At a sufficient excess of pump energy over threshold, when a "dip" is produced in the absorption line, the generation frequency ω is automatically stabilized in the region of the loss minimum at the "dip" frequency ω_b. The transition to the self-stabilization mode is effected if the generation frequency ω is maintained within the limits of the "dip" ($|\omega - \omega_b| \lesssim \Delta\omega_b$). If the laser active medium has a Doppler inhomogeneous broadening line width $\Delta\omega_{Dop}$ and a homogeneous width $\Delta\omega_a \ll \Delta\omega_{Dop}$, then the self-stabilization conditions take the form

$$S_1 = \frac{1}{p_b}\frac{\Delta\omega_b}{kc}, \quad S_2 = \frac{1}{p_b}\frac{a}{k}\frac{\Delta\omega_b}{\Delta\omega_{Dop}}, \quad S_3 = \frac{a a}{k b}\frac{\Delta\omega_b}{\Delta\omega_a} \ll 1, \tag{2}$$

where c is the speed of light, $p_a = aE^2$ and $p_b = bE^2$ the gain and absorption saturation parameters respectively, and a and k are the gain and absorption coefficient per unit length respectively. The generation frequency ω in the self-stabilization mode are determined by the expression

$$\omega = \omega_b + S_1(\Omega - \omega_b) + (S_2 - S_3)(\omega_a - \omega_b), \tag{3}$$

where Ω is the resonator frequency. In the case of an active medium with homogeneous gain line, the expression (3) remains in force if the Doppler width is replaced in S_2 by the homogeneous one $\Delta\omega_a$ and we put $S_3 = 0$. Expression (3) was derived under the assumption that $p_a, p_b \ll 1$, but self-stabilization effects exist also at higher values of the saturation parameters. * From (2) and (3) it follows that the stabilizing action of the absorbing gas is due to the occurrence of a narrow "dip" of width $\Delta\omega_b \ll \Delta\omega_a, kc, \Delta\omega_{Dop}$, as a result of which we get $S_1, S_2, S_3 \ll 1$.

4. To realized the proposed laser it is necessary to choose atoms or molecules having an absorption line at the emission frequency of a cw laser. We point to the two following

possible pairs: 1) the 3.3913-μ line of the He-Ne laser coincides with the 2947.906 cm^{-1} absorption line of CH_4 within 0.003 cm^{-1}, at an absorption coefficient k = 0.17 cm^{-1}/Torr and $\Delta\omega_{col}$ = 5 MHz/Torr [5]; 2) the 3.5070-μ line of the He-Xe laser coincides with the 2850.608 cm^{-1} absorption line of the H_2CO molecule, accurate to 0.007 cm^{-1}, with k ≈ 0.1 cm^{-1}/Torr [6]. At a gas pressure 10^{-2} Torr it is possible to obtain a deep "dip" with width $\Delta\omega_b \approx 5 \times 10^4$ Hz by using a field of intensity 10^{-2} W/cm^2.

In a number of cases the absorbing molecules can be those of the active medium in the absence of excitation, for in this case the condition that the gain and absorption frequencies coincide are automatically satisfied.

The foregoing examples of absorbing molecules are far from optimal, for in their case $A_{21}^b \approx$ sec^{-1}. The most suitable atoms or molecules have $A_{21}^b \approx 10^3 - 10^5$ sec^{-1}. At these values of A_{21}^b it is possible to use very low absorbing-gas pressures ($\sim 10^{-4}$ Torr), which guarantees high stability of the position ω_b of the absorption line. At such low pressures, the mean free path amounts to several times ten centimeters, and consequently, by passing the beam many times through the absorbing gas and maintaining strict parallelism of the beam it is possible to obtain, by having the molecules cross several rays in succession, a narrow "dip" of width $\Delta\omega_b \approx 10^3$ Hz. In addition, with $A_{21}^b \approx 10^3 = 10^5$ sec^{-1}, an appreciable decrease takes place in the power needed for the production of the "dip."

5. Perfectly realistic values are a width $\Delta\omega_b \approx 10^5$ Hz for the absorption "dip" and an accuracy 10^{-9} for the stabilization of the resonator frequency Ω and of the gain line α_a. With $p_b \approx 0.1 - 0.3$ and $\Delta\omega_a$, kc $\lesssim 10^8$ Hz we can expect in this case a stability of the generation frequency ω, relative to ω_b, on the order of 10^{-11}. The absolute stability of the generation frequency will therefore be determined by the stability of the absorption-line frequency ω_b. At low gas pressures ($10^{-3} - 10^{-4}$ Torr) the stability of the center of the absorption line will be determined by the interaction of the molecules with the cell walls, and can apparently be no worse than 10^{-11}.

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*The results for the case of strong saturation, as well as the stability conditions, will be treated in a detailed paper.

ERRATA

In JETP Letters V. 6, No. 4, p. 101, 5th line from top:

read "data for hypersonic waves [4]."

On the same page, 4th line from the bottom:

read "In a strong light field, saturation occurs....