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THEORETICAL CALCULATIONS OF POPULATION INVERSION AND FACTOR OF STRENTHENING OF THE STIMULATED RADION OF TWO-LEVEL ATOM AT VARIOS PRESSURE OF BUFFER GAS

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In offered work results of theoretical calculation of inversion of densities of population and factor of strengthening from detuning frequencies of laser radiation are resulted at various pressure of buffer gas. It is established that the above pressure of buffer gas, the more widely detuning frequencies of exciting radiation. With increase in pressure value of a maximum of inverse density of population and strengthening factor moves towards increase detuning.

Keywords: inversion of population densities, exciting radiation, pressure, population inversion.

Population inversion of the resonance level obtained theoretically by considering the compound - the system "atom + a strong field" ("are dressed atom") [1,2]. A theoretical analysis in [1] shows that for Ω >0, the probability of optical – collision (OS) transition n-m with the impact energy $\hbar\Omega$ quantum translational motion exceeds the probability of OS transition m - n, where the quantum of energy $\hbar\Omega$ borrowed from the translational motion of the atom (Fig.1). Of the total law of thermodynamics as a result of collisions of atoms must be established equilibrium, then bolcman's distribution of energy levels and Einstein coefficients for absorption b_{nm} (Ω) and stimulated emission b_{mn} (Ω) for two-level atoms is determined

$$N_n = N_m \exp(-\hbar\Omega / kT), \tag{1}$$

$$b_{mn}(\Omega) = b_{nm}(\Omega)\exp(-\hbar\Omega / kT), \tag{2}$$

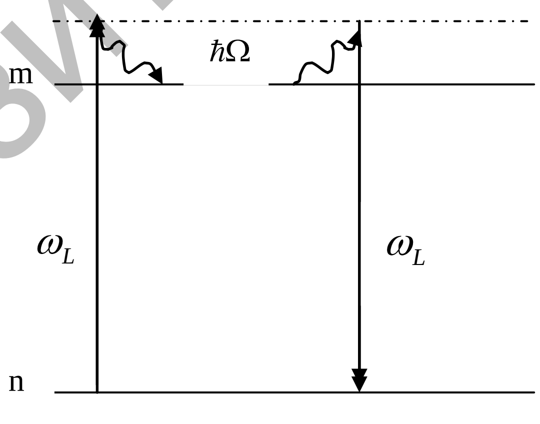

Fig.1. Returns and borrowing photon energy $\hbar\Omega$ of translational motion of the atom

where N_n , N_m – population of the basic n and the raised level m, $\Omega = \omega_L - \omega_{nm}$ the frequency detuning of the laser from the resonance transition of n-m. Hence for $\Omega >$ 0 the population of the upper level more than the lower, i.e. there is a population inversion. With a large collusion line broadening [2] (in the shock area and more) of the balance equation of the population-level m has the form:

$$\frac{dN_m}{dt} + \Gamma_m N_m = I[b_{nm}(\Omega)N_n - b_{mn}(\Omega)N_m], \qquad N_n + N_m = N \quad (3)$$

where N - the concentration of absorbing particles, Γ_m - natural broadening of the m, I - intensity of radiation.

From the theory of quantum kinetic equations for the density matrix of the relation

$$Ib_{nm}(\Omega) = \frac{2|G|^2 \Gamma}{\Gamma^2 + \Omega^2}, \ G = d_{mn}E/2\hbar \tag{4}$$

where G-Rabi frequency, E - amplitude of the electric field radiation, d_{mn} - the matrix element of the transition dipole moment, Γ - width of the shock absorption line.

At large detuning $|\Omega| >> \Gamma$ the shock width can be replaced by the value of Γ_{OS} (Ω), it depends on detuning frequency and proportional to the pressure of buffer gas. In this case the formula (4) has the form

$$Ib_{nm}(\Omega) = \frac{2|G|^2 \Gamma}{\Omega^2}, \quad \Omega > 0,$$

$$Ib_{mn}(\Omega) = \frac{2|G|^2 \Gamma}{\Omega^2}, \qquad \Omega < 0 \tag{5}$$

From the balance equation (3) and with (2), (4) and (5) we obtain:

$$\frac{dN_m}{dt} + \Gamma_m N_m = \chi\Gamma_m[N_n - \xi N_m], \quad \Omega > 0$$

$$\frac{dN_m}{dt} + \Gamma_m N_m = \chi\Gamma_m[\xi N_n - N_m], \qquad \Omega < 0, \tag{6}$$

where, $\xi = \exp(-\frac{\hbar|\Omega|}{kT})$, $\chi = \frac{2|G|^2 \Gamma_{OS}(\Omega)}{\Gamma_m \Omega^2}$ - parameter of saturation for transition m – n, Γ_m -natural line broadening m, E - electric field amplitude of the radiation, d_{mn} - matrix element of the transition dipole moment, Γ_{OC} (Ω) - shock half-width in optical collisions, it depends on detuning frequency and proportional to the pressure of buffer gas.

From formula (3) for the relative population difference of levels m and n get

$$N_m - N_n = N\frac{\chi(1-\xi)sign\Omega - 1}{1 + (1+\xi)\chi} \tag{7}$$

where N - the concentration of rubidium atoms. Amplification of radiation in the center of the line with the difference in the level populations are related:

$$g = \frac{\lambda^2 \Gamma_m}{4\pi\Gamma_{OC}}(N_m - N_n) \tag{8}$$

We estimate the relative population inversion and gain depending on the frequency detuning of the laser radiation at different buffer gas pressure.

We assume the laser intensity I = 10 MW/cm^2, at a temperature T = 480 K the concentration of rubidium atoms N = 1,5 • 10^{15} cm^{-3}, the wavelength at the resonant transition λ = 794.8 nm (fig.2), the characteristic broadening of buffer gas particles of about 10 MHz / Torr, whereas the shock half-width at a pressure of buffer gas 1 and 5 atm. respectively, is approximately (Γ_{OC}) 0,25 and 1,3 cm^{-1}, Γ_m- about ≈ 4 · 10^{-4} cm^{-1}. To calculate the saturation parameter we use the relation:

$$|G|^2 = \frac{I\lambda^3\Gamma_m}{16\pi^2\hbar c} \text{ and } \chi = \frac{2|G|^2\Gamma_{OC}(\Omega)}{\Gamma_{\text{ь}}\Omega^2} = \frac{I\lambda^3\Gamma_{OC}(\Omega)}{8\pi^2\hbar c\Omega^2}$$

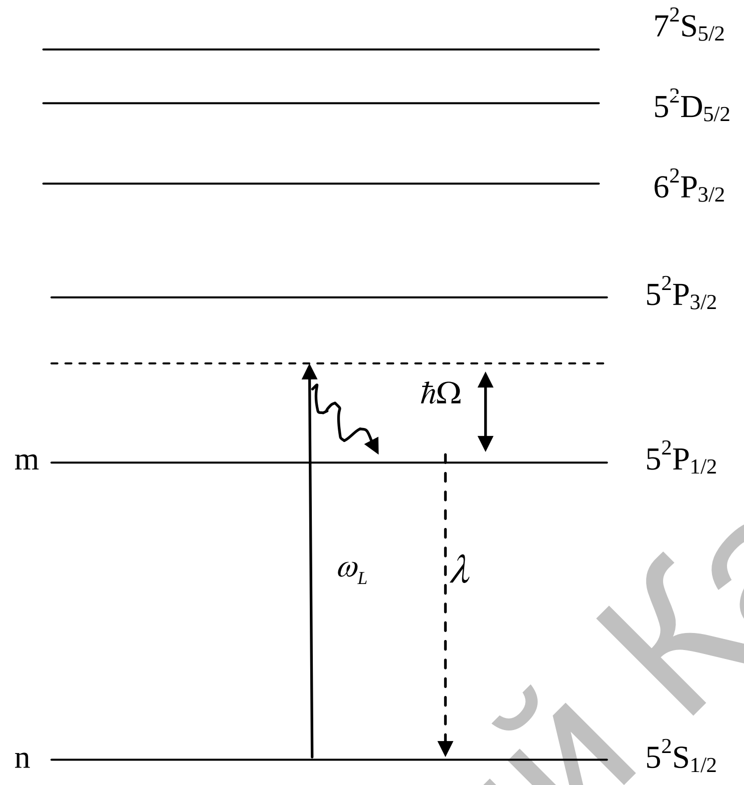

Fig.2. Rb level schema used for the calculation in this paper

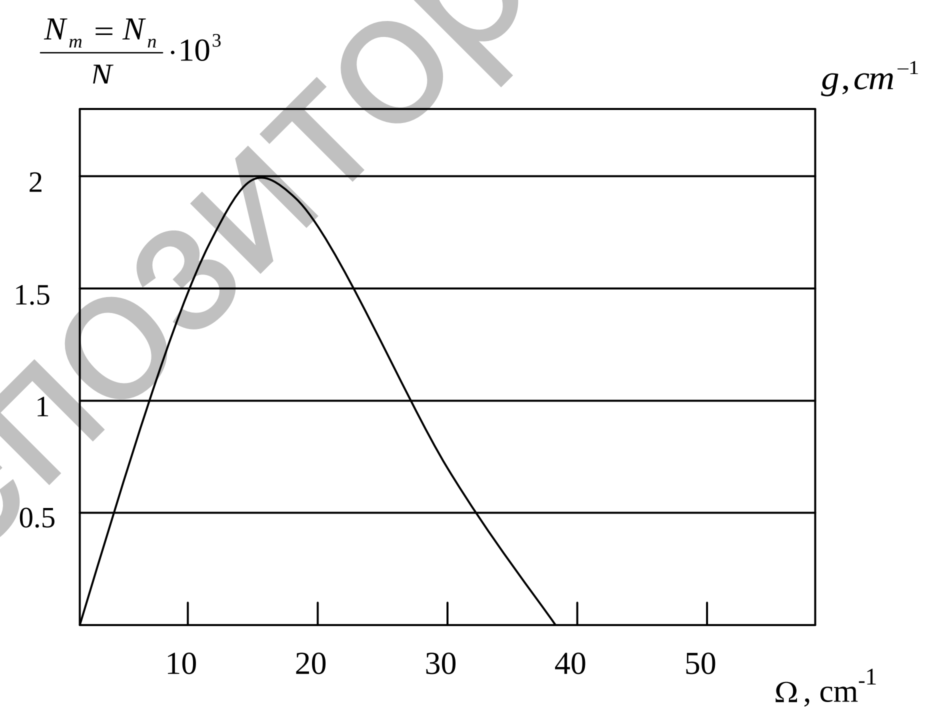

Fig.3. The dependence of the relative population inversion and the gain on the detuning frequency of the laser radiation at a pressure of buffer gas of 1 atm.

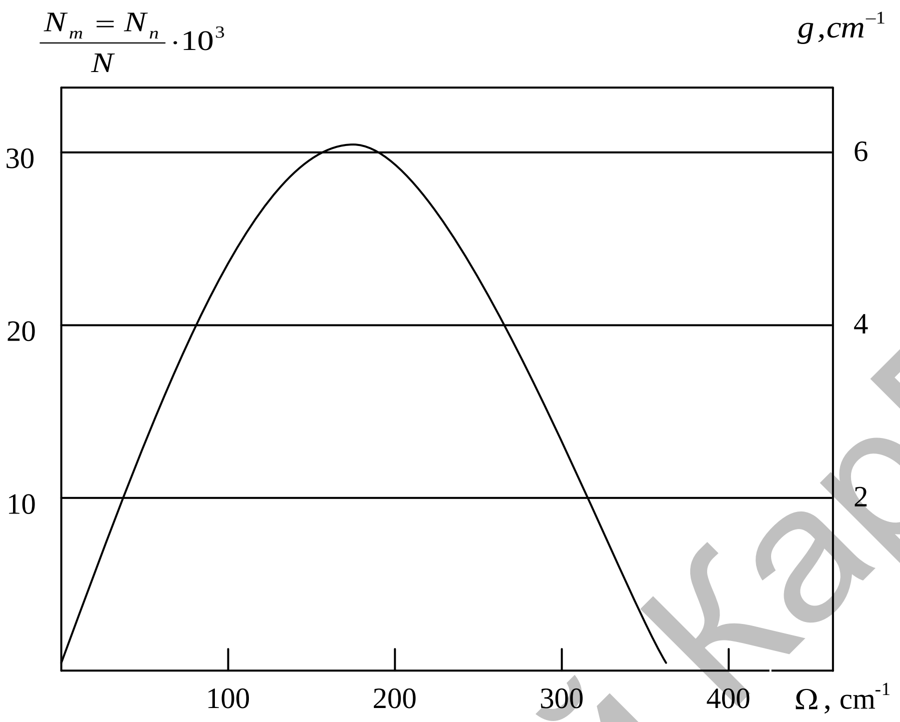

Fig.4. The dependence of the relative population inversion and the gain on the detuning frequency of the laser radiation at a pressure of buffer gas of 5 atm.

Figures 3 and 4 show the relative population inversion and the gain on the detuning frequency of the exciting radiation at different buffer gas pressure. As can be seen with increasing buffer gas pressure region of detuning frequency of the exciting radiation becomes wider and maximum relative population inversion has increased 15 times, and the gain factor of 3. This is due to the fact that Γ_{OC} is proportional to pressure. In the first case to generate a single pass (in the mode super radiance gL ≈ 30) the required length of active medium should be not less than 15 cm, while the second - 5 cm . In this paper, we present the results if theoretical calculation of population inversion and the gain on the detuning frequency of the at different buffer gas pressure. Found that the higher the buffer gas pressure, the greater the frequency detuning of the exciting radiation. With increasing pressure the value of the maximum population inversion and gain is shifted upward detuning.

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