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CONCENTRATION DEPENDENCE OF PHOTON ECHO INTENSITY

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The retarding part of the Coulomb interaction between Cr^{3+} ions is used to calculate the dependence on Cr^{3+} concentration of photon echo intensity in ruby. The result is in quantitative agreement with measurements reported by Compaan and Abella.

In the recent work of Compaan and Abella [1] the intensity dependence of the photon echo (PE) [2, 3] in ruby upon the concentration of the Cr^{3+} impurity centers was investigated. Then for the concentration $n < 0.1\%$ (the weight concentration is taken everywhere) the intensity $I(N)$, is assumed to be proportional to N^2 (N is a number of active centers of sample). However the PE intensity had its maximum at $n \approx 0.1\%$ and then it decreased, but this decrease was not caused by the relaxation process. The authors of the works [4–6] explained such behaviour of $I(N)$ by the influence of the radiation field upon the process of the PE formation just as in the case of a short pulse passing the resonance medium [7, 8]. As can be seen from [1, 4–6], consideration of the experimental data [1] has not lead to the same point of view with regard to the physical nature of the observed phenomenon. In this work it is shown that anomalous behaviour of $I(N)$ is a consequence of a more exact description of the interaction of the atom system with the radiation field including a retarding part of Coulomb interaction between them (RPCI) [9–10]. Considering RPCI, the Hamiltonian of interaction of the N atom system with the external field is written as [9, 10]:

$$\hat{H} = \hat{H}_1 + \hat{H}_2 ; \qquad (1)$$

$$\hat{H}_1 = \sum_i H_{1i} = \sum_{fki} \alpha_1 (\hat{p}_i e_{fk}) [\hat{a}_{fk} \exp(ikr) + \hat{a}^*_{fk} \exp(-ikr_i)]$$

$$\hat{H}_2 = \sum_{fk} \sum_{i \neq j} \beta_1 a_{ij}^{-1} [\hat{p}_i e_{fk}) + (\hat{p}_i n_{ij})(e_{fk} n_{ij})] \qquad (2)$$

$$\times [a_{fk} \exp(ikr_j) + \hat{a}_{fk} \exp(-ikr_j)] .$$

$$\alpha_1 = -(e/m)\sqrt{2\pi\hbar/V\omega_k} , \quad r_i = a_i + \xi_i ,$$

$$\beta_1 = (e^3/2c^2m^2)\sqrt{2\pi\hbar/V\omega_k} , \quad n_{ij} = a_{ij}/a_{ij} . \qquad (3)$$

where r_i, m, e, p_i, are radius-vector, mass, charge and pulse operator of the i-th electron; a_i is the radius-vector of the i-th nucleus, ξ_i is the radius-vector of i-th electron according to its nucleus, ω_k is the frequency of the electro magnetic field, k is the wave vector, e_{fk} is the polarization vector of the corresponding electromagnetic field mode ($f = 1, 2$), a_{fk} and a_{fk} are the creation and annihilation operators of quantums of field mode fk. Using (1)–(3) we get the PE intensity after the system was influenced by two resonance laser pulses with duration Δt_1 and Δt_2 with the interval between them being τ and each Δt_1, Δt_2, τ satisfying the condition of excitation of the PE (see [2–3]). Then at the time moment 2τ the intensity $I(N)$ will be