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COLLECTIVE SPECTRAL PROPERTIES OF RAMAN SCATTERING

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I. INTRODUCTION

During the last years the collective effects in the interaction of atoms and molecules with a laser field and the vacuum of radiation have attracted considerable interest. Many theoretical and experimental studies of superfluorescence[1-10], collective resonance fluorescence[11-16], optical bistability[17-19], etc., were carried out since the early work on superradiance by Dicke[1].

The recent publications deal with collective effects in double optical resonance[20] and the resonant Raman scattering[21,22].

In this paper the theory of collective Raman scattering (Fig.1) has been developed by using the quantum-mechanical master-equation approach and secular approximation[12,22]. In contrast with paper[22], we consider the collective Raman scattering with only one transition strongly driven (Fig.1) and investigate the influence of the frequency detuning of resonance on the collective spectral properties of the Stokes lines.

II. MASTER EQUATION

The N three-level atoms concentrated in a region small compared to the wavelength of all the relevant radiation modes (Dicke model) interact with a monochromatic driving field of a frequency ω and with a field of radiation (Fig.1). Let us label the ground state by $|1\rangle$, the real excited state by $|3\rangle$ and the resonant intermediate state by $|2\rangle$ with energies ω_1, ω_3 and ω_2, respectively (the system of $\hbar = 1$). The real excited state $|3\rangle$ may be a low-lying vibrational or rotational excitation from the ground state. To keep the discussion general, we will not specify these states but say that the intermediate state $|2\rangle$ can be connected via the electromagnetic interation Hamiltonian with both the states $|1\rangle$ and $|3\rangle$ (in the dipole approximation) but the states $|3\rangle$ and $|1\rangle$ are not connected by the dipole Hamiltonian because of parity consideration. The transition $|3\rangle - |1\rangle$ is caused by an atomic reservoir and assumed to be nonradiative[23].

In treating the external field classically and using the Born and Markov approximation with respect to the coupling of the system with the vacuum field and atomic reservoir, one can obtain a master equation for the reduced density matrix ρ for the system alone in the form[2,22]

$$\begin{aligned}\frac{\partial \rho}{\partial t} &= -i\,[H_{coh}, \rho] \\ &- \gamma_{21}(J_{21}J_{12}\rho - J_{12}\rho J_{21} + H.C.) \\ &- \gamma_{23}(J_{23}J_{32}\rho - J_{32}\rho J_{23} + H.C.) \\ &- \nu_{31}(J_{31}J_{13}\rho - J_{13}\rho J_{31} + H.C.) = L\rho,\end{aligned} \tag{1}$$

where $2\gamma_{21}$ and $2\gamma_{23}$ are radiative spontaneous transition probabilities per unit time for a single atom to change from level $|2\rangle$ to $|1\rangle$ and from $|2\rangle$ to $|3\rangle$, respectively; $2\nu_{31}$ is the nonradiative rate for atomic transition from $|3\rangle$ to $|1\rangle$.

The coherence part of hamiltonian H_{coh} in the interaction picture has the form

$$H_{coh} = \frac{\delta}{2}(J_{22} - J_{11}) + G\,(J_{21} + J_{12}) - \Omega_3 J_{33}.$$

Here $\Omega_3 = \omega_{23} - \frac{\omega_{21}}{2}$ (where $\omega_{ij} = \omega_i - \omega_j$); $\delta = \omega_{21} - \omega$ is the frequency detuning of resonance: $G = -d_{21}E_0$ is the matrix element of the driving field and atom interaction;

$$J_{ij} = \sum_{K=1}^{N} |i\rangle_K\,{}_K\langle j| \qquad (i, j = 1,2,3)$$

are the collective angular momenta of the atoms. They satisfy the commutation relation

$$[J_{ij}, J_{i'j'}] = J_{ij'}\delta_{ji'} - J_{i'j}\delta_{ij'}.$$

The atomic coherence phenomena can be illustrated with greater lucidity by introducing the Schwinger representation for angular momentum[24]

$$J_{ij} = C_i^+ C_j \qquad (i, j = 1,2,3),$$

where C_i obey boson commutation relation $[C_i, C_j^+] = \delta_{ij}$.

Further, we investigate only the case of an intense external field or much detuning δ so that

$$\Omega = \frac{1}{2}\left(\frac{1}{4}\delta^2 + G^2\right)^{1/2} \gg N\gamma_{21}; N\gamma_{23}; N\nu_{31}. \tag{2}$$

After performing the canonical transformation

$$\begin{aligned} C_1 &= Q_1 \cos\varphi + Q_2 \sin\varphi \\ C_2 &= -Q_1 \sin\varphi + Q_2 \cos\varphi \\ C_3 &= Q_3, \end{aligned} \tag{3}$$

where $\quad tg\,2\varphi = 2G/\delta,$

one can find that the Liouville operator L appearing in equation (1) splits into two components L_0 and L_1. The component L_0 is slowly varying in time whereas L_1 contains rapidly oscillating terms at frequencies 2Ω and 4Ω. For the case when relation (2) is fulfilled, we make the secular approximation, i.e., retain only a slowly varying part[12,20]. Correction of the results obtained in this fashion will be of an order of

$$(\gamma_{21}N/\Omega)^2 \; ; \; (\gamma_{23}N/\Omega)^2 \quad \text{or} \quad (\nu_{31}N/\Omega)^2.$$

Making the secular approximation, one can find the stationary solution of the master equation

$$\tilde{\rho} = U\rho U^+ = A^{-1}\sum_{R=0}^{N} X^R \sum_{N_1=0}^{R} Z^{N_1} |R, N_1\rangle\langle N_1, R|, \tag{4}$$

where U is the unitary operator representing the canonical transformation (3)

$$X = \frac{\nu_{31}}{\gamma_{23}}\,tg^2\varphi$$

$$Z = ctg^4\varphi$$

$$A = \frac{Z}{Z-1}\,\frac{(XZ)^{N+1} - 1}{XZ - 1} - \frac{1}{Z-1}\,\frac{X^{N+1} - 1}{X - 1},$$

$|R, N_1\rangle$ is an eigenstate of the operator $R = R_{11} + R_{22}$, R_{11} and the operator of number of atoms

$$\hat{N} = R_{11} + R_{22} + R_{33} = J_{11} + J_{22} + J_{33};$$

here $\quad R_{ij} = Q_i^+ Q_j \qquad (i, j = 1,2,3).$

The operators Q_i satisfy the boson communtation relation

$$[\, Q_i \,,\, Q_j^+ \,] = \delta_{ij}. \tag{5}$$

so that

$$[\, R_{ij} \,,\, R_{i'j'} \,] = R_{ij'}\,\delta_{i'j} - R_{i'j}\,\delta_{ij'}\,. \tag{6}$$

For the case of resonance the solution (4) reduces to

$$\tilde{\rho} = B^{-1} \sum_{R=0}^{N} p^R \sum_{N_1=0}^{R} |\, R, N_1 \rangle \langle N_1, R \,| , \tag{7}$$

where $\quad p = \nu_{31} / \gamma_{23}$

$$B = \frac{(N+1)\,p^{N+2} - (N+2)\,p^{N+1} + 1}{(p-1)^2}\,.$$

The solution (7) has the same form as in our previous paper for collective double resonant process /20/ and resonant Raman scattering in intense driving and scattered light /22/. As in ref. /25/, for simplicity we introduce the characteristic function

$$\chi_{R_{11},R}(\zeta, \xi) = \langle e^{i\zeta R_{11} + i\xi R} \rangle_s =$$
$$= A^{-1}\Big[\frac{Y_2}{Y_2 - 1}\, \frac{(Y_1 Y_2)^{N+1} - 1}{Y_1 Y_2 - 1} - \frac{1}{Y_2 - 1}\, \frac{Y_1^{N+1} - 1}{Y_1 - 1} \Big], \tag{8}$$

where

$$Y_1 = x\, e^{i\xi}$$
$$Y_2 = z\, e^{i\zeta}.$$

Here $\langle B \rangle_s$ denotes the expectation value of an operator B in the steady-state (4).

Once the characteristic function is known, it is easy to calculate the statistical moments

$$\langle R^n R_{11}^m \rangle_s = \frac{\partial^n}{\partial(i\xi)^n}\, \frac{\partial^m}{\partial(i\zeta)^m}\, \chi_{R_{11},R}(\zeta,\xi) \Big|_{\substack{i\zeta = 0 \\ i\xi = 0}} . \tag{9}$$

In particular, we have

$$\langle R \rangle_s = A^{-1}\Big[\frac{z}{z-1}\, f_1(x z) - \frac{1}{z-1}\, f_1(x) \Big] \tag{10}$$

$$\langle R^2 \rangle_s = A^{-1}\Big[\frac{z}{z-1}\, f_2(x z) - \frac{1}{z-1}\, f_2(x) \Big] \tag{11}$$

$$\langle R_{11} \rangle_s = A^{-1}\Big[\frac{z}{z-1}\, f_1(x z) - \frac{z}{(z-1)^2}\, f_0(x z) + \frac{z}{(z-1)^2}\, f_0(x) \Big] \tag{12}$$

$$\langle R_{11}^2 \rangle_s = A^{-1}\Big[\frac{z}{z-1}\, f_2(x z) - \frac{2z}{(z-1)^2}\, f_1(x z) + \frac{z^2 + z}{(z-1)^3}\, f_0(x z) - \frac{z^2 + z}{(z-1)^3}\, f_0(x) \Big] \tag{13}$$

$$\langle R R_{11} \rangle_s = A^{-1}\Big[\frac{z}{z-1}\, f_2(x z) - \frac{z}{(z-1)^2}\, f_1(x z) + \frac{z}{(z-1)^2}\, f_1(x) \Big], \tag{14}$$

where $\quad f_0(\alpha) = (\alpha^{N+1} - 1)/(\alpha - 1)$

$$f_1(\alpha) = (N\alpha^{N+2} - (N+1)\alpha^{N+1} + \alpha)/(\alpha - 1)^2$$

$$f_2(\alpha) = \frac{(N^2\alpha^{N+3} - (2N^2 + 2N - 1)\alpha^{N+2} + (N+1)^2\alpha^{N+1} - \alpha^2 - \alpha)}{(\alpha - 1)^3}\,.$$

In the case of resonances $ctg^2\varphi = 1$ and $\dfrac{\nu_{31}}{\gamma_{23}} = 1$ relations (10-14) reduce to

$$\langle R \rangle_s = 2 \langle R_{11} \rangle_s = \frac{2}{3} N \tag{15}$$

$$\langle R^2 \rangle_s = 2 \langle R R_{11} \rangle_s = \frac{1}{2} N \left(N + \frac{1}{3}\right) \tag{16}$$

$$\langle R_{11}^2 \rangle_s = \langle R_{22}^2 \rangle_s = \frac{1}{6} N \left(N + \frac{1}{2}\right). \tag{17}$$

III. COLLECTIVE SPECTRAL PROPERTIES OF SCATTERED LIGHT

As in ref.[23], the steady state spectrum of the spontaneous emission corresponding to transition $|2\rangle \to |3\rangle$ (Stokes line) is proportional to the Fourier transform of the atomic correlation function

$$\langle J_{23}(\tau) J_{32} \rangle_s = \lim_{t \to \infty} \langle J_{23}(t+\tau) J_{32}(t) \rangle .$$

Using the secular approximation and the quantum regression theorem[26], one can find the equation of motion for the correlation functions $\langle R_{ij}(\tau) J_{32} \rangle_s$ (i, j = 1,2,3) in the form

$$\frac{d}{d\tau} \langle R_{13}(\tau) J_{32} \rangle_s = i(\Omega_3 - \Omega) \langle R_{13}(\tau) J_{32} \rangle_s - \langle \Gamma_{13}(\tau) R_{13}(\tau) J_{32} \rangle_s \tag{18}$$

$$\frac{d}{d\tau} \langle R_{23}(\tau) J_{32} \rangle_s = i(\Omega_3 + \Omega) \langle R_{23}(\tau) J_{32} \rangle_s - \langle \Gamma_{23}(\tau) R_{23}(\tau) J_{32} \rangle_s , \tag{19}$$

where

$$\begin{aligned} \Gamma_{13}(\tau) = {} & \gamma_{21} \sin^2\varphi + 2\gamma_{23} \sin^2\varphi + \nu_{31} \sin^2\varphi \\ & + \gamma_{21}(\sin^2\varphi - \cos^2\varphi) R_{22}(\tau) + (\nu_{31} \sin^2\varphi - \gamma_{23} \cos^2\varphi) R_{22}(\tau) \\ & + (\gamma_{23} \sin^2\varphi - \nu_{31} \cos^2\varphi)(R_{33}(\tau) - R_{11}(\tau)) \end{aligned} \tag{20}$$

$$\begin{aligned} \Gamma_{23}(\tau) = {} & \gamma_{21} \cos^2\varphi + 2\gamma_{23} \cos^2\varphi + \nu_{31} \cos^2\varphi \\ & + \gamma_{21}(\cos^2\varphi - \sin^2\varphi) R_{11}(\tau) + (\nu_{31} \cos^2\varphi - \gamma_{23} \sin^2\varphi) R_{11}(\tau) \\ & + (\gamma_{23} \cos^2\varphi - \nu_{31} \sin^2\varphi)(R_{33}(\tau) - R_{22}(\tau)) . \end{aligned} \tag{21}$$

For the one-atom case one can use the well-known operator relation[25]

$$R_{ij} R_{ke} = R_{ie} \delta_{kj}$$

and eqs.(18,19) reduce to

$$\frac{d}{d\tau} \langle R_{13}(\tau) J_{32} \rangle_s = i(\Omega_3 - \Omega) \langle R_{13}(\tau) J_{32} \rangle_s - \beta_{13} \langle R_{13}(\tau) J_{32} \rangle_s \tag{22}$$

$$\frac{d}{d\tau} \langle R_{23}(\tau) J_{32} \rangle_s = i(\Omega_3 + \Omega) \langle R_{23}(\tau) J_{32} \rangle_s - \beta_{23} \langle R_{23}(\tau) J_{32} \rangle_s , \tag{23}$$

where

$$\beta_{13} = \gamma_{21} \sin^2\varphi + \gamma_{23} \sin^2\varphi + \nu_{31} \tag{24}$$

$$\beta_{23} = \gamma_{21} \cos^2\varphi + \gamma_{23} \cos^2\varphi + \nu_{31} . \tag{25}$$

The value β_{13} and β_{23} can be considered as the widths of two spectrum components of Stoke line located at the frequencies $\omega_{23} - \frac{\delta}{2} - \Omega$ and $\omega_{23} - \frac{\delta}{2} + \Omega$ respectively. It is easy to show that the values β_{13} and β_{23} in relations (24,25) coincide with the results of the previous papers of the one-atom Raman scattering[23].

It is also easy to see that in the case of resonance $\mathrm{ctg}^2\varphi = 1$ and $\frac{\nu_{31}}{\gamma_{23}} = 1$ the operators $\Gamma_{13}(\tau)$ and $\Gamma_{23}(\tau)$ in eqs.(20,21) become the C-numbers and spectrum widths of the stokes line for the collective case are the same as in the single-atom spectrum.

For the general case by analogy with the papers[11,22], we factorize

$$\begin{aligned} \langle \Gamma_{13}(\tau) R_{13}(\tau) J_{32} \rangle_s &= \langle \Gamma_{13} \rangle_s \langle R_{13}(\tau) J_{32} \rangle_s \\ \langle \Gamma_{23}(\tau) R_{23}(\tau) J_{32} \rangle_s &= \langle \Gamma_{23} \rangle_s \langle R_{23}(\tau) J_{32} \rangle_s \end{aligned} \tag{26}$$

as in references[11,22]. By using the relations (10-14) one can show that in the case of large N the factorization (26) yields a small error (with an order higher than $1/\sqrt{N}$) in the calculation of the steady-state fluorescent intensity spectrum.

Using the factorization (26) and solution (4), one can find the solution of eqs.(18,19) and write the atomic correlation function in the form

$$\langle J_{23}(\tau) J_{32}\rangle_s = \sin^2\varphi \langle R_{13}R_{31}\rangle_s \, e^{i(\Omega_3-\Omega)t-\langle\Gamma_{13}\rangle_s t} + \cos^2\varphi \langle R_{23}R_{32}\rangle_s \, e^{i(\Omega_3+\Omega)t-\langle\Gamma_{23}\rangle_s t}, \quad (27)$$

where

$$\langle R_{13}R_{31}\rangle_s = (N+1)\langle R_{11}\rangle_s - \langle R R_{11}\rangle_s \quad (28)$$

$$\langle R_{23}R_{32}\rangle_s = (N+1)(\langle R\rangle_s - \langle R_{11}\rangle_s) - \langle R^2\rangle_s + \langle R R_{11}\rangle_s . \quad (29)$$

The values $\langle R\rangle_s$, $\langle R_{11}\rangle_s$, $\langle R^2\rangle_s$ and $\langle R R_{11}\rangle_s$ can be found in relations (10-14). Expression (27) yields the two-peaked structure of the Stoke spectrum. The spectrum components located at the frequencies $\omega_{23}-\frac{\delta}{2}-\Omega$ and $\omega_{23}-\frac{\delta}{2}+\Omega$ have the intensities

$$I_{-\Omega} = \sin^2\varphi \langle R_{13}R_{31}\rangle_s$$ and

$$I_{+\Omega} = \cos^2\varphi \langle R_{23}R_{32}\rangle_s$$

and the widths $\langle\Gamma_{13}\rangle_s$ and $\langle\Gamma_{23}\rangle_s$, respectively. For the case of resonance $ctg^2\varphi = 1$ the intensities and widths of two-spectrum components are equal (i.e., $I_{-\Omega} = I_{+\Omega}$ and $\langle\Gamma_{13}\rangle_s = \langle\Gamma_{23}\rangle_s$).

Using relations (15-17), it is easy to show that in the case of $ctg^2\varphi = 1$; $\nu_{31}/\gamma_{23} = 1$ the peak intensity of each spectrum component of the Stoke line in (27) varies as N^2 while, as has been mentioned before, the width of each component is the same as in the single-atom spectrum. The spectrum picture changes for the case of $ctg^2\varphi = 1$. By using the relations (27-29) and (10-14), one can show that for the case of $ctg^2\varphi \neq 1$ or $\nu_{31}/\gamma_{23} \neq 1$ and the number of atoms N large enough (take for example for the case of $X = \frac{\nu_{31}}{\gamma_{23}} tg^2\varphi > 1$; $XZ = \frac{\nu_{31}}{\gamma_{23}} ctg^2\varphi > 1$ it is necessary $N \gg 1$ so that $X^N \gg 1$ and $(XZ)^N \gg \frac{\gamma_{23}}{\nu_{31}}$) the intensities and widths of all spectrum components of the Stoke line are proportional to N .

The detailed behaviour of intensities per atom of the two Stoke spectra $I_{-\Omega}/N^2$ and $I_{+\Omega}/N^2$ as a function of $ctg^2\varphi$, where $\frac{\nu_{31}}{\gamma_{23}} = 1$ is shown in fig.2, and as a function of $\frac{\nu_{31}}{\gamma_{23}}$, where $ctg^2\varphi = 1$ is shown in fig.3. For all finite values of N one observes a smoth variation of functions $I_{-\Omega}/N^2$ and $I_{+\Omega}/N^2$ with the parameters

$ctg^2\varphi$ or $\frac{\nu_{31}}{\gamma_{23}}$. For large N the intensities of spectrum components are large only in the around vicinity of the point $ctg^2\varphi = 1$, $\nu_{31}/\gamma_{23} = 1$ (see figs. 2,3). For the cooperative limit $N \to \infty$ the peak intensities per atoms $I_{-\Omega}/N^2$ and $I_{+\Omega}/N^2$ have a discontinuous behaviour analogous to a typical nonequilibrium first-order phase transition[14,15;20,22].

In conclusion we want to note that the characteristics for spectra of the Rayleight line can be obtained using an analogous approach.

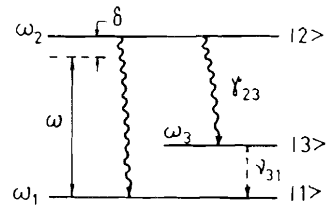

Fig.1. Three-level system of atoms interacting with the monochromatic applied field and with radiation.

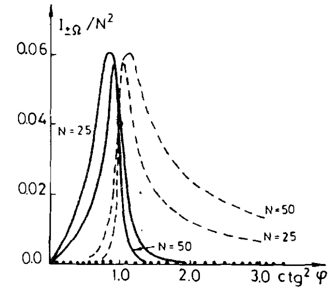

Fig.2. Peak intensities per atom $I_{-\Omega}/N^2$ (dashed curves) and $I_{+\Omega}/N^2$ (Solid curves) as a function of $ctg^2\varphi$ when $\nu_{31}/\gamma_{23} = 1$. The dotted curve indicates the behaviour as $N \to \infty$.

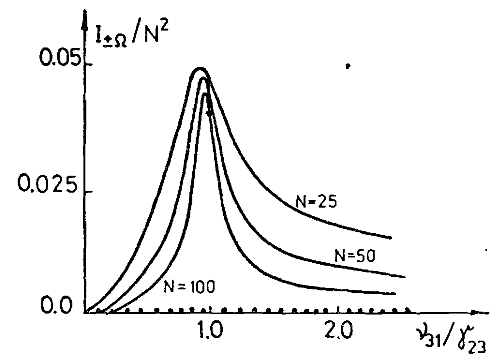

Fig.3. Peak intensities per atom $I_{\pm}/N^2$ as a function of ν_{31}/γ_{23} when $ctg^2\varphi = 1$. The dotted curve indicates the behaviour as $N \to \infty$

REFERENCES

1. Dicke R.H., Phys.Rev. 93 (1954) 99.
2. Agarwal G.S., in: Quantum optics (Springer, Berlin, 1974).
3. MacGillivray J.C., Phys.Rev. A14 (1976) 1169.
4. Bonifacio R. and Lugiato L.A., Phys.Rev. A11 (1975) 1507, A12 (1975) 587.
5. Polder P., Shurmans M.F.H., Vrehen Q.H.F., Phys.Rev.A19(1979),1192.
6. Haake F., King H., Schroeder G., Haus J., Glauber R., Phys.Rev. A20 (1979) 2047.
7. Gibbs H.M., Vrehen Q.H.F., Hikspoors H.M.J., Phys.Rev.Lett. 39 (1977) 547.
8. Skribanowitz N., Herman J.P., MacGillivray J.C., Feld M.S., Phys. Rev.Lett. 30 (1973) 309.
9. Florian R., Schwan L.O. and Schmid O., Phys.Rev. A29 (1984) 2709.
10. Moi L., Goy P., Gross M., Raimond J.M., Fabre C., Haroch S., Phys. Rev. A27 (1989) 2043 and A27 (1983) 2065.
11. Compagno G., Persico F., Phys.Rev. A25 (1982) 3138.
12. Agarwal G.S., Narducci L.M., Feng P.H., Gilmore R., Phys.Rev.Lett., 42 (1979) 1260.
13. Narducci L.M., Feng P.H., Gilmore R., Agarwal G.S., Phys.Rev. A18 (1978) 1571.
14. Puri R.R., Lawande S.V., Phys.Lett. 72A (1979) 200.
15. Drummond P.D., Phys.Rev. A22 (1980) 1179.
16. Bogolubov(jr) N.N., Shumovsky A.S., Tran Quang, JINR (1986), E4-86-347, Dubna.
17. Bonifacio R., Lugiato L.A., Phys.Rev., A18 (1978) 1129.
18. Drummond P.D., Walls D.F., J.Phys. A13 (1980) 725.
19. Drummond P.D., Walls P.F., Phys.Rev. A23 (1981) 2563.
20. Bogolubov N.N.(jr), Shumovsky A.S., Tran Quang, Phys.Lett., 112A (1985) 323.
21. Raymer M.G., Walmsley I.A., Mostowski J., Sobolevska B., Phys. Rev. A32 (1985) 332.
22. Bogolubov N.N.(jr), Shumovsky A.S., Tran Quang, JINR (1985) E17-85-679; J.of Phys.B 1986 (to be published).
23. Agarwal G.S., Sudhashu S.Jha., J.of Phys.B, 1979, 12, 2655.
24. Schwinger J.V. in: Quantum Theory of Angular Momentum ed. by L.C.Biedenharm and H.VanDam (Academie press, New-York, 1985).
25. Louisell W.H., Radiation and Noise in Quantum Electronics (Mc. Grwo-Hill Book Company, New-York).
26. Lax M., Phys.Rev. 172 (1968) 350.

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Боголюбов Н.Н./мл./, Шумовский А.С. Чан Куанг E4-86-684
Коллективные спектральные свойства рассеяния Рамана

Развита теория коллективного рассеяния Рамана на основе применения квантового уравнения типа "Master Equation" и секулярного приближения. Исследованы влияния расстройки резонанса и других параметров на коллективные свойства рассеянного света.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1986

Bogolubov N.N., Jr., Shumovsky A.S., Tran Quang E4-86-684
Collective Spectral Properties of Raman Scattering

The theory of collective Raman scattering has been developed by using the quantum-mechanical master-equation approach and secular approximation. The influence of the frequency detuning of resonance and other parameters on the collective spectral properties of scattered light is investigated.

The investigation has been performed at the LAboratory of Theoretical Phasics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1986