INTRODUCING THE MICROSCOPIC DISTRIBUTION OF PARTICLES FOR THE QUANTUM OPTICAL AVERAGES

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In this work the representation of the quantum optical expressions for the absorption coefficient in terms of collisional integrals of the corresponding semi-classical kinetic equations is discussed. It was shown, that in certain approximation, the given gradient field of particle number distribution in the phase space (of coordinates and momentums) can determine the absorption properties of a system. The atom-photon and atom-atom collisions are formally represented here in the form of the corresponding items in the kinetic equation. The proposed approximation can be used to introduce the chronology of absorption/reemission and interatomic collision events in the system within an impact theory or a semi-classical evolution operator in the kinetic equation. The single-atom methods, such as the equation of motion for the one-particle population matrix, to find the number of quanta, imbibed by atoms or liberated into the environment per unit time, are not used here. The derived expression for the local absorption coefficient non-linearly depends on atomic density and initial intensity. It was found that the ability of the system to absorb or emit quanta can quantitatively be expressed through the semi-classical form of collision integrals (see details in [1]).

$$\alpha_{tot} \approx \mathrm{Re}\frac{\delta}{\delta z}\ln\sum_{\Psi}\langle\Psi|\hat{I}_\tau\hat{\rho}_\Psi|\Psi\rangle$$

$$f\left(\mathbf{X},\hat{\mathbf{D}}\right)=\sum_{i=1}^{N}\delta\left(\mathbf{X}-\mathbf{X}_i\right)\delta\left(\hat{\mathbf{D}}-\hat{\mathbf{D}}_i\right)$$

$$\left[\hat{H}^{AF},\hat{I}\right]\to\int d\mathbf{X}'d\hat{\mathbf{D}}f\left(\mathbf{X}',\hat{\mathbf{D}}\right)\left[\hat{\mathbf{D}}\cdot E(\mathbf{r}'),\hat{I}\right]$$

$$\sum_{\Psi}\langle\Psi|\left[\hat{H}^{AF},\hat{I}\right]\hat{\rho}_\Psi|\Psi\rangle\to C_{AF}\frac{\Delta t}{\tau_1}+iC_{AF}^{F}n_A$$

$$\left[\hat{H}^{AA},\hat{I}(\mathbf{r})\right]\to\int d\mathbf{X}'d\hat{\mathbf{D}}'d\mathbf{X}''d\hat{\mathbf{D}}''f\left(\mathbf{X}',\hat{\mathbf{D}}'\right)f\left(\mathbf{X}'',\hat{\mathbf{D}}''\right)\left[\hat{H}^{AA},\hat{I}\right].$$

$$\sum_{\Psi}\langle\Psi|\left[\hat{H}^{AA},\hat{I}(\mathbf{r})\right]\hat{\rho}_\Psi|\Psi\rangle\to C_{AA}\frac{\Delta t}{\tau_2}+iC_{AA}^{F}n_A^2,$$

$$\alpha_{tot}\approx\frac{1}{2}\frac{\frac{\delta}{\delta z}\left\{\Delta\Omega^2+\Gamma^2\right\}}{\Delta\Omega^2+\Gamma^2}$$

$$d\Psi=d\mathbf{X}^N d\Psi^{red}\qquad d\mathbf{X}^N=d\mathbf{X}_1 d\mathbf{X}_2\ldots d\mathbf{X}_N$$

$$\Delta_{coll}f\left(t,\mathbf{X}\right)=\left(I_{AF}^{coll}+I_{AA}^{coll}\right)\Delta t=\Delta t\left(\frac{\partial}{\partial t}+\frac{\mathbf{p}}{m}\cdot\frac{\partial}{\partial\mathbf{r}}+\mathbf{F}\cdot\frac{\partial}{\partial\mathbf{p}}\right)f(t).$$

$$C_{AF}\frac{\Delta t}{\tau_1}=\int d\mathbf{X}'d\hat{\mathbf{D}}\,\mathrm{Re}\left(I_{AF}\left(\mathbf{X}'\right)\right)\left\langle I_{AF}^{coll}\left(\mathbf{X}',\hat{\mathbf{D}}\right)\right\rangle\Delta t$$

$$C_{AF}^{F}n_A=2\left\langle\mathrm{Im}\left(I_{AF}\left(\mathbf{X}',\hat{\mathbf{D}}\right)\right)\right\rangle N$$

$$C_{AA}\frac{\Delta t}{\tau_2}=2\int d\mathbf{X}'d\hat{\mathbf{D}}'d\mathbf{X}''d\hat{\mathbf{D}}''\,\mathrm{Re}\left(I_{AA}\left(\mathbf{X}',\mathbf{X}''\right)\right)\times$$

$$\left\langle f\left(\mathbf{X}'',\hat{\mathbf{D}}''\right)I_{AA}^{coll}\left(\mathbf{X}',\hat{\mathbf{D}}'\right)\right\rangle\Delta t$$

$$C_{AA}^{F}n_A^2=2N^2\left\langle\mathrm{Im}\left(I_{AA}\right)\right\rangle_{\mathrm{int}}$$

$$\Delta\Omega=I_0\frac{\mathrm{h}}{\tau}-n_A\left(C_{AF}^{F}+C_{AA}^{F}n_A\right)\qquad\Gamma=C_{AF}\frac{\Delta t}{\tau_1}+C_{AA}\frac{\Delta t}{\tau_2}$$

[1] A. S. Sizhuk, S. M. Yezhov, Introducing the microscopic distribution of particles for the quantum optical averages, *Bulletin of Taras Shevchenko National University of Kyiv Series Physics & Mathematics* **3**, P. 159 – 162,