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A comparative study of parameters of Quantum device

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ABSTRACT

Zeeman effects are important in quantum electronics because they make possible a method by which the value of the energy level can be slightly changed, causing fine tuning of emission or absorption frequencies in optical and infrared regions. It is a theoretical approach of calculation for quantum electronic devices on the basis of semi classical theory of laser. The theory of Zeeman laser had been worked out by Lamb and his coworkers. The electromagnetic field is treated classically for a general state of polarization in a cavity with any desired degree of cavity anisotropy. The self– consistency requirement is that a quasistationary field should be sustained by the induced polarization lead to the equations which determine the amplitudes and frequencies of multimode oscillations as functions of the laser parameters. We here derived the self-consistency equations using semi classical theory of laser considering the complex conjugate terms excluded by Lamb earlier. Equations of electric field and polarization with complex conjugate terms give rise to additional equations having physical significance and terms effect on Lande's g factor. The parameters involving utilization of the splitting of the magnetic sublevels obtained in the calculation may be utilized.

Key words: Zeeman laser, Semiclassical theory of laser, quantum electronic device, Lande's g factor.

INTRODUCTION

Scope

Quantum electronics is the area of physics dealing with the effects of quantum mechanics on the behavior of electrons in matter, and their interactions with photons. Zeeman Effect [1] provides the distinct energy levels whose separations are in the microwave or radio frequency range ideal for lasers.

Magnetic field strength of a surface can be calculated with Zeeman splitting technique. It is a theoretical approach of calculation for quantum electronic devices [2] on the basis of semiclassical theory of laser. Lamb and coworkers [3-6] had worked out the theory of Zeeman Laser and explained about Electromagnetic field equations, polarization of the medium [7,8], equation of motion, cavity anisotropy, transverse magnetic field, atomic decay rate, Lande's factor etc in laser.

Objectives

- ➢ In earlier calculation of parameters of self-consistency equations the complex conjugate terms are ignored. So to derive equations with these terms
- ➢ To verify whether complex conjugate terms have a significant effect as the real term.
- ➢ To calculate overall effect may change the parameters of self-consistency equations.
- ➢ To work out parameters of quantum electronic devices that involved the utilization of the splitting of the magnetic sublevels.

MATERIALS AND METHODS

The active medium consists of thermally moving atoms of varying isotopic abundance which have two electric states with arbitrary angular momenta. The electromagnetic field is treated classically for a general state of polarization in a cavity with any desired degree of cavity anisotropy. The self-consistency requirement is that a quasi-stationary field should be sustained by the induced polarization lead to the equations which determine the amplitude and frequencies of multimode oscillations as functions of the laser parameters. The Maxwell's equations in mks unit as

$$\vec{\nabla}.\vec{D} = 0 \quad ; \quad \vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

$$\vec{\nabla}.\vec{B} = 0 \quad ; \quad \vec{\nabla}\times\vec{H} = \vec{J} + \frac{\partial\vec{D}}{\partial t}$$

Where $\vec{D} = \varepsilon_0\,\vec{E} + \vec{P} \quad ; \quad \vec{B} = \mu_0\,\vec{H}$

Here P, polarization will be used to describe the induced atomic polarization of the active medium. It is desirable to provide for different cavity resonant frequencies for the linearly polarized radiation along orthogonal Cartesian axes transverse to the maser axis. And J is current density. The wave equation will be

$$\frac{\partial^2 E(z,t)}{\partial t^2} + \mu_0\,\vec{\sigma}\,\frac{\partial E(z,t)}{\partial t} + \mu_0\,\varepsilon_0\,\frac{\partial^2 E(z,t)}{\partial t^2} = -\mu_0\,\frac{\partial^2 P(z,t)}{\partial t^2} \quad \text{--- (1)}$$

If electric fields have two transverse degrees of freedom and cavity has anisotropic loss, the losses related to field by the tensor constitutive relation

$$\vec{J} = \vec{\sigma}\,\vec{E}$$

The vectorial electric field with two transverse degrees of freedom is particularly convenient choice of representation with circularly polarized components.

$$\vec{E}(z,t) = \frac{1}{2}\{\hat{\varepsilon}_+ E_+(t)\exp[-i(\upsilon_+ t + \phi_+) + \hat{\varepsilon}_- E_-(t)\exp[-i(\upsilon_- t + \phi_-)]\}U(z) + cc \quad \text{--- (2)}$$

Where the complex circularly polarized unit vectors $\hat{\varepsilon}_\pm = 2^{-\frac{1}{2}}(\hat{x} \mp i\,\hat{y})$, and amplitudes E_+ and E_- and phases φ_+, φ_- are slowly varying functions of time. The induced polarization of the medium corresponding to field has the form

$$\vec{P}(z,t) = \frac{1}{2}\{\hat{\varepsilon}_+ P_+(t)\exp[-i(\upsilon_+ t + \phi_+) + \hat{\varepsilon}_- P_-(t)\exp[-i(\upsilon_- t + \phi_-)]\}U(z) + cc \quad \text{--- (3)}$$

Where, the complex Fourier components of polarization P_+, P_- are slowly varying functions of time.

Putting the values from (2) & (3) in (1), ignoring complex conjugate term and also neglecting smaller terms $\dot{\varphi}_+, \sigma\dot{\varphi}_+, \sigma\dot{E}_\div$ and $\dot{E}_\div$, we finally find

$$(\upsilon_+ + \dot{\phi}_+ - \Omega)E_+ + i\{\dot{E} + \frac{1}{2}\upsilon[g_{++}E_+ + g_{--}E_- \exp(i\psi)]\} = \frac{1}{2}\frac{\upsilon}{\varepsilon_0}P_+ \quad \text{--- (4)}$$

Where the relative phase angle is

$$\psi = \upsilon_+ t + \dot{\varphi}_+ - \upsilon_- t + \dot{\varphi}_-$$

And the conductivity matrix

$$G = \begin{pmatrix} g_{++} & g_{+-} \\ g_{-+} & g_{--} \end{pmatrix} = (\varepsilon_0 \upsilon)^{-1}\sigma$$

The frequency $\upsilon \cong \upsilon_\div \cong \upsilon_-$ and g $g_{++} = Q^{-1}{}_+, g_{--} = Q^{-1}{}_-$

RESULTS AND DISCUSSION

Equating the real and imaginary part of equation (4) separately to zero, the self consistency equations

$$E_+ + \frac{1}{2}\upsilon(g_{++}E_+) + \mathrm{Im}[ig_{+-}E_-\exp(i\psi)] = \frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Im}(P_+) \quad \text{--- (5)}$$

$$(\upsilon_+ + \phi_+ - \Omega)E_+ + \frac{1}{2}\upsilon\mathrm{Re}[ig_{+-}E_- + \exp(i\psi)] = \frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Re}(P_+) \quad \text{--- (6)}$$

Physical significance:

For diagonal losses, the self-consistency equations, (5) & (6) reduces to

$$\dot{E}_+ + \frac{1}{2}\upsilon(g_{++}E_+) = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Im}(P_+)$$

$$\text{or } \dot{E}_+ + \frac{1}{2}\upsilon/Q_+ E_+ = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Im}(P_+) \quad \text{--- (7)}$$

$$(\upsilon_+ + \phi_+ - \Omega) = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0} E^{-1}{}_{+} \, Re(P_+) \qquad \text{--- (8)}$$

These equations are the same as equations of semiclassical theory of laser of which Eq^n (7) represents the oscillation conditions of laser and Eq^n(8) the dispersion of the medium.

Using the complex conjugate terms and following the same procedure we get

$$(2\upsilon_+ - \frac{\Omega_+}{\upsilon_+})\dot{\phi}_+ - \Omega_+]E_+ + i\{\frac{1}{2}\upsilon[g_{++}E_+ + \dot{g}_{+-} E_- \exp(i\psi)]\} = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0}(P_+) \qquad \text{--- (9)}$$

Equating the real and imaginary parts these equations to zero; we obtain the self -consistency equations

$$\dot{E}_+ + \frac{1}{2}\upsilon[g_{++}E_{++} + \mathrm{Im}\{ig_{+-}E_- + \exp(i\psi)] = \frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Im}(P_+) \qquad \text{--- (10)}$$

$$(2\upsilon_+ - \frac{\Omega_+}{\upsilon_+})\dot{\phi}_+ - \Omega_+]E_+ + \frac{1}{2}\upsilon Re[ig_{+-}E_- \exp(i\psi)] = \frac{1}{2}\frac{\upsilon}{\varepsilon_0} Re(P_+) \qquad \text{--- (11)}$$

For diagonal losses, these become

$$\dot{E}_+ + \frac{1}{2}\upsilon/Q_+ \, E_+ = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0}\mathrm{Im}(P_+) \qquad \text{--- (12)}$$

and
$$(2\upsilon_+ - \frac{\Omega_+}{\upsilon_+})\dot{\phi}_+ - \Omega_+] = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0} E^{-1}{}_{+} Re(P_+) \qquad \text{--- (13)}$$

In absence of active medium $P_+ = 0$, we get

$$\dot{E}_+ = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0} E_+$$

$$(2\upsilon_+ - \frac{\Omega_+}{\upsilon_+})\dot{\phi}_+ = \Omega_+$$

Proceeding in the same way considering both the real and complex conjugate terms simultaneously, then equating real and imaginary parts separately we get

$$\dot{E}_+ = -\frac{1}{2}\frac{\upsilon}{\varepsilon_0} E_+ \qquad \text{--- (14)}$$

$$3\upsilon_+ - (\frac{\Omega_+}{\upsilon_+})\dot{\phi}_+ - 2\Omega_+ = 0 \qquad \text{--- (15)}$$

CONCLUSION

Eq^n (13) can be rewritten in two parts as

$$(\upsilon_+ + \dot{\phi}_+) = \Omega_+ - \frac{1}{2}\frac{\upsilon}{\varepsilon_0} E^{-1}{}_{+} Re(P_+) \qquad \text{--- (16)}$$

which is same as that of the Eq^n.(8). But the other part is

$$[\upsilon_+ - \dot{\phi}_+] = \frac{\Omega_+}{\upsilon_+}\dot{\phi}_+ \qquad \text{--- (17)}$$

Here the Eq^n(16) is the equation representing dispersion as the original of the semiclassical theory and Eq^n(17) also represents dispersion in different form. It is reasonable to believe that the additional term will be contributed in the determination of atomic decay rates and g values for the laser atoms.

From the Eq^n s (16) & (17) we observe a serious difference of dispersion relations. These equations are similar as the equations in absence of active medium in the former calculations with real or complex conjugate term only. So equations in presence of active medium similar to equations without active medium leads to the conclusion that complex conjugate term may have control on the dispersion relations. It also leads to somewhat conclution due to some unknown reason.

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