Lėti optiniai solitonai atomams apibūdinamiems Lamba ir tripodo lygmenų sandara

Slow optical solitons for atoms characterized by combined Lambda and tripod level structure

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We consider nonlinear propagation of a probe pulse [1, 2] in an atomic medium characterized by a combined tripod and Lambda (Λ) closed loop atom-light coupling scheme [3, 4] shown in Fig. 1. The scheme involves three atomic ground states $|a\rangle$, $|c\rangle$ and $|d\rangle$ coupled to two excited states $|b\rangle$ and $|e\rangle$ by five light fields Ω_1, Ω_2, Ω_3, Ω_4 and Ω_p.

Our goal is to demonstrate shape-preserving optical pulses which can propagate in the medium under consideration without significant distortion and loss. The idea is to include the optical Kerr nonlinearity of the probe laser field into the light propagation, and show that the Kerr nonlinear effect can compensate the dispersion effects and result in shape-preserving optical pulses. To balance the dispersion effects and optical nonlinearity, a theoretical model was employed for the nonlinear pulse propagation based on a coupled set of the Maxwell-Bloch equations

$$\dot{\rho}_{ba}^{(1)} = d_1 \rho_{ba}^{(1)} + i\,\Omega_1 \rho_{ca}^{(1)} + i\,\Omega_2 \rho_{da}^{(1)} + i\,\Omega_p , \qquad (1a)$$

$$\dot{\rho}_{ca}^{(1)} = d_2 \rho_{ca}^{(1)} + i\,\Omega_1^* \rho_{ba}^{(1)} + i\,\Omega_3^* \rho_{ea}^{(1)} , \qquad (1b)$$

$$\dot{\rho}_{da}^{(1)} = d_2 \rho_{da}^{(1)} + i\,\Omega_2^* \rho_{ba}^{(1)} + i\,\Omega_4^* \rho_{ea}^{(1)} , \qquad (1c)$$

$$\dot{\rho}_{ea}^{(1)} = d_3 \rho_{ea}^{(1)} + i\,\Omega_3 \rho_{ca}^{(1)} + i\,\Omega_4 \rho_{da}^{(1)} , \qquad (1d)$$

and

$$\frac{\partial \Omega_p}{\partial z} + c^{-1} \frac{\partial \Omega_p}{\partial t} = i\,\eta \rho_{ba}^{(1)} , \qquad (1e)$$

with $\eta = \dfrac{2N\,\omega_p\,|\mu_{ba}|^2}{\hbar c}$, $d_1 = -\Gamma_b/2 + i\,\Delta_p$, $d_2 = i(\Delta_p - \Delta_2)$ and $d_3 = -\Gamma_e/2 + i(\Delta_p + \Delta_3 - \Delta_2)$, where $\Gamma_i\,(i = e, b)$ and $\Delta_j\,(j = 2, 3, p)$ denote the decay rates and the corresponding detunings, respectively.

The Kerr nonlinearity coefficient is obtained by solving Eqs. (1a)-(1d). Substituting it into the wave equation (1e), we arrive at the nonlinear wave equation for the slowly varying envelope Ω_p

$$i\,\frac{\partial}{\partial \zeta}\Omega_p - \kappa_{2r} \frac{\partial^2}{\partial \eta^2}\Omega_p = \Theta_r\,|\Omega_p|^2\,\Omega_p . \qquad (2)$$

where κ_{2r} and Θ_r represent the group velocity dispersion and Kerr nonlinearity, respectively.

Equation (2) represents the conventional nonlinear Schrodinger (NLS) equation which describes the nonlinear evolution of the probe pulse and allows bright and dark soliton solutions. Therefore by properly choosing the parameters of the system, the propagation of slow optical dark solitons is possible in our model due to the balance between dispersion effects and the Kerr nonlinearity of the medium.

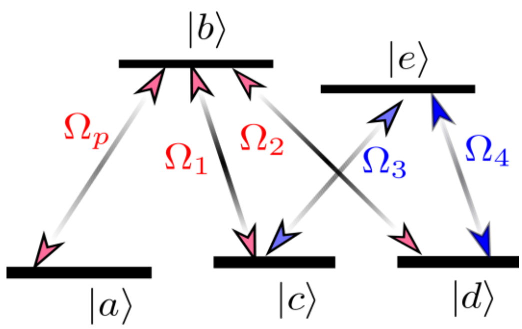

Fig. 1. Schematic diagram of the five-level Lambda-tripod quantum system.

Reikšminiai žodžiai: lėta šviesa, optiniai solitonai, elektomagnetiškai sukeltas praskaidrėjimas, atomų terpė.

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