Elektromagnetiškai sukeltas praskaidrėjimas Lamba ir tripodo lygmenų atomams

Electromagnetically induced transparency using combined Lambda and tripod level structure

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Electromagnetically induced transparency (EIT) [1] plays an important role in controlling the propagation of light pulses in resonant atomic media. Due to the EIT a weak probe beam of light tuned to an atomic resonance can propagate slowly and with almost no dissipation when the medium is driven by one or several control beams of light with a higher intensity [2]. The EIT is formed because the control and probe beams drive the atoms to their dark states representing a special superposition of the atomic ground states immune to the atom-light coupling.

There has been a considerable amount of activities on single- [3] and two-component (spinor) [4] slow light in atomic media induced by the EIT. The single-component slow light involves a probe beam of light and one or several control beams resonantly interacting with atomic media characterized by three level Lambda type or four level tripod type atom-light coupling schemes. The spinor slow light can be formed using a double-tripod (DT) atom-light coupling scheme that supports a simultaneous propagation of two probe beams in such an atomic medium.

In this work, we consider propagation of a probe pulse in a resonant atomic medium affected by four control laser fields of larger intensities. The probe and control fields are assumed to co-propagate along the *z* direction. We shall analyze the light propagation in an ensemble of atoms using a five-level Lambda-tripod atom-light coupling scheme shown in Fig. 1. The atoms are characterized by three ground levels $|a\rangle$, $|c\rangle$ and $|d\rangle$, as well as two excited states $|b\rangle$ and $|e\rangle$. The probe beam described by a Rabi frequency Ω_p induces a resonant transition between the initially populated ground state $|a\rangle$ and the excited state $|b\rangle$. Four coherent control fields with the Rabi frequencies Ω_1, Ω_2, Ω_3, and Ω_4 drive resonant dipole-allowed transitions $|b\rangle \leftrightarrow |c\rangle$, $|b\rangle \leftrightarrow |d\rangle$, $|e\rangle \leftrightarrow |c\rangle$, and $|e\rangle \leftrightarrow |d\rangle$, respectively. As a result, the control fields couple two excited states $|b\rangle$ and $|e\rangle$ via two different pathways $b\rangle \xrightarrow{\Omega_1^*} |c\rangle \xrightarrow{\Omega_3} |e\rangle$ and $|b\rangle \xrightarrow{\Omega_2^*} |d\rangle \xrightarrow{\Omega_4} |e\rangle$ making the four level closed-loop coupling scheme. The Hamiltonian for such a four level sub-system reads ($\hbar = 1$):

$$H_{4\text{Levels}} = -\Omega_1^* |c\rangle\langle b| - \Omega_2^* |d\rangle\langle b| - \Omega_3^* |c\rangle\langle e| - \Omega_4^* |d\rangle\langle e| + \text{H.c.}. \qquad (1)$$

Totally there are five atomic levels, with the probe beams Ω_p inducing the dipole-allowed optical transition $|a\rangle \leftrightarrow |b\rangle$. This leads to a combined Λ and tripod level atom-light coupling scheme described by the atomic Hamiltonian

$$H_{5\text{Levels}} = -\left(\Omega_p^* |a\rangle\langle b| + \Omega_p |b\rangle\langle a|\right) + H_{4\text{Levels}}. \qquad (2)$$

We have demonstrated that dark states can be formed for such an atom-light coupling. This is essential for formation of the EIT and slow light. In the limiting cases the scheme reduces to conventional Lambda- or N- type atom-light couplings providing, respectively, the EIT or absorption. Thus the atomic system can experience a transition from the EIT to the absorption by changing the amplitudes or phases of control lasers [6].

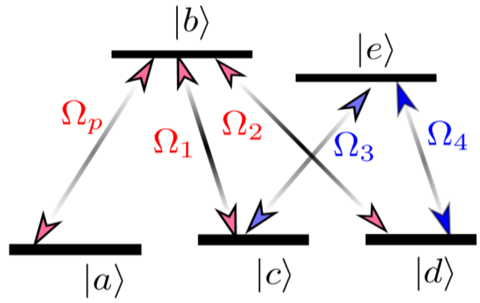

Fig. 1. Schematic diagram of the five-level Lambda-tripod quantum system.

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

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