Switching properties of a waveguide directional coupler based on quantum nanostructures with decay interference

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Optical nonlinearity plays a crucial role in the switching characteristics of the two-waveguide directional coupler and leads to several interesting phenomena, such as soliton switching [1]. In a particular study, Wabnitz and co-workers [2,3] analyzed the switching properties of a nonlinear two-waveguide directional coupler where the constituent waveguides are made of a linear host material doped with two-level type resonant impurities. For the propagation of ultrashort pulses they showed that this device can work as a self-induced transparency soliton switch, with digital transmission characteristics.

Controlled propagation of electromagnetic pulses and the creation of slow light have been studied in several quantum nanostructures that exhibit decay interference [4-7]. Here, we propose a two-waveguide directional coupler where the constituent waveguides are made of a linear host material doped with a quantum system that exhibits decay interference. For the analysis of the propagation dynamics of electromagnetic pulses in the proposed device we use a modified coupled-mode theory analogous to that of reference [3]. Solving analytically, under proper approximations, and numerically the generalized coupled Maxwell-Bloch equations we show that the dynamics of the pulse propagation depends critically on the parameters of the quantum system and on the duration of the electromagnetic pulse. Loss-free propagation and slow light switching between the two waveguides are found to occur in the studied system.

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