Electromagnetically Induced Transparency and nonlinear optics with Rydberg Excitons in Cu_2O

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Recently, a lot of attention has been directed to the subject of Rydberg excitons in bulk crystals due to experimental observation of the so-called yellow exciton series in Cu_2O up to a large principal quantum number of $n = 25$ [1]. The unique combination of their huge size, long radiative lifetimes and miniaturization of samples can be exploited to perform robust light-exciton quantum interfaces for quantum information processing purposes [2,3]. Electromagnetically induced transparency (EIT) [4] is one of the important effect in quantum optics as it allows for the coherent control of material optical properties. In general, this phenomenon leads to the significant reduction of absorption of a resonant probe weak laser field by irradiating the medium with a strong control field making an otherwise opaque medium transparent. However, the strong dipol-dipol interaction between excitons with high n, manifested as the dipole-blockade mechanism, is mapped onto an optical transition using EIT resulting in an optical nonlinearity. The blockade suppresses Rydberg excitons within a sphere of the radius R_b of the order of a few microns. Interaction between Rydberg excitons is modeled by van der Waals potential $V_{ij} = C_6 \mid r_i - r_j \mid^6$. Since the coefficient $C_6 \sim n^{11}$, the strong coupling between Rydberg pairs inhibits multiple excitons within a volume of the radius R_b giving rise to a strongly nonlinear response of a medium described by a complex, the first- (linear) and the third-order (non-linear), susceptibility

$$\chi = \chi^{(1)} + \chi^{(3)}.$$

The cw beam transmission is given by

$$T = T_0 \frac{ln(1+p)}{p},$$

where $p \sim \frac{\chi^{(3)}}{\chi^{(1)}}$ and T_0 is the first-order transmission [5]. We discuss the the transmission of the probe beam, which in turn creates the exciton density, for different probe and control beams powers and we indicate the optimal states with well justified parameters to attempt the observation of EIT and its nonlinear modification in Rydberg excitons Cu_2O media.

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