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Original Paper

2D optical photon echo spectroscopy of a self-assembled quantum dot

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Simulations of two dimensional coherent photon echo (2D-PE) spectra of self-assembled InAs/GaAs quantum dots (QD)

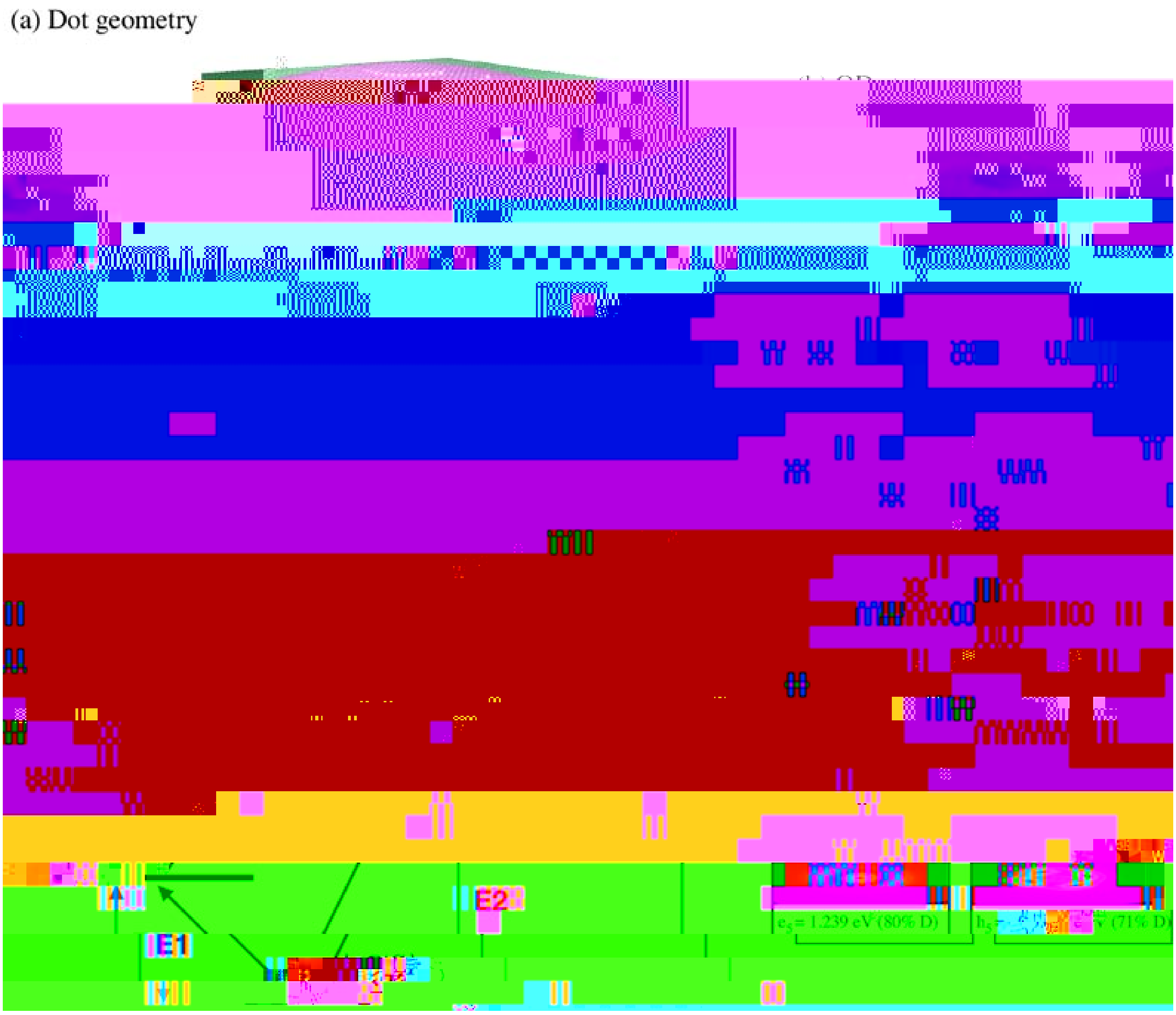

Figure 1 (online color at: www.ann-phys.org) (a) Schematic of a lens-shaped InAs dot with base of 25 nm and 2 nm heigh, sitting on one monolayer wetting layer, embedded in a GaAs matrix. The dot contains 41,776 atoms and the matrix contains 1,948,880 atoms. (b) Wavefunction square of six lowest energy single-particle electron states and six highest hole states. The percentage of its dominant orbital character (S, P and D) and its energy with respect to h_0 are given underneath the corresponding wavefunction plot. (c) Ladder diagrams excited state emission (ESE), ground state bleach (GSB) and excited state absorption (ESA) contributing to the 2D photon echo signal $S^{(3)}_{\mathbf{k}_I}$. (d) Schematic of the bi-exciton stabilization due to many-body e ects in QD.

2 Theoretical methods

25 2

XX^q (. 1 ( )). 41,776

1, 48,880 . -1.3

.(-613.5) ( ),

( ) ()0.3

annalen der physik

. G^q

, , -

G_0^q.

X^q XX^q

$P_e - P_h$ (1.1 , . 2)

$G^q \to X^q$ ≈ 2.31 $G^q - XX^q$ -

.

2 - -

-

- -

.

144 X^0 4356 XX^0 , 500 X^+ X^-

1000 XX^+ XX^- -

2 -

. G^q (12

) $6 \cdot 10^7$

2 - . -

.

2

. -

. 1, -

- (

. 1 . 2).

- -

. $G^q \to X^q$ -

)-2 7.6( ) .-378.24((()02.7(- .7(5( ) .()02.743 . (252-0)0( )0)-7.625214. ( )-2( ) 833.8346-60)-7.4( )

(. .) (. .)

(. . $e_0 - h_4$)

(. . $S_e - S_h$ $P_e - P_h$

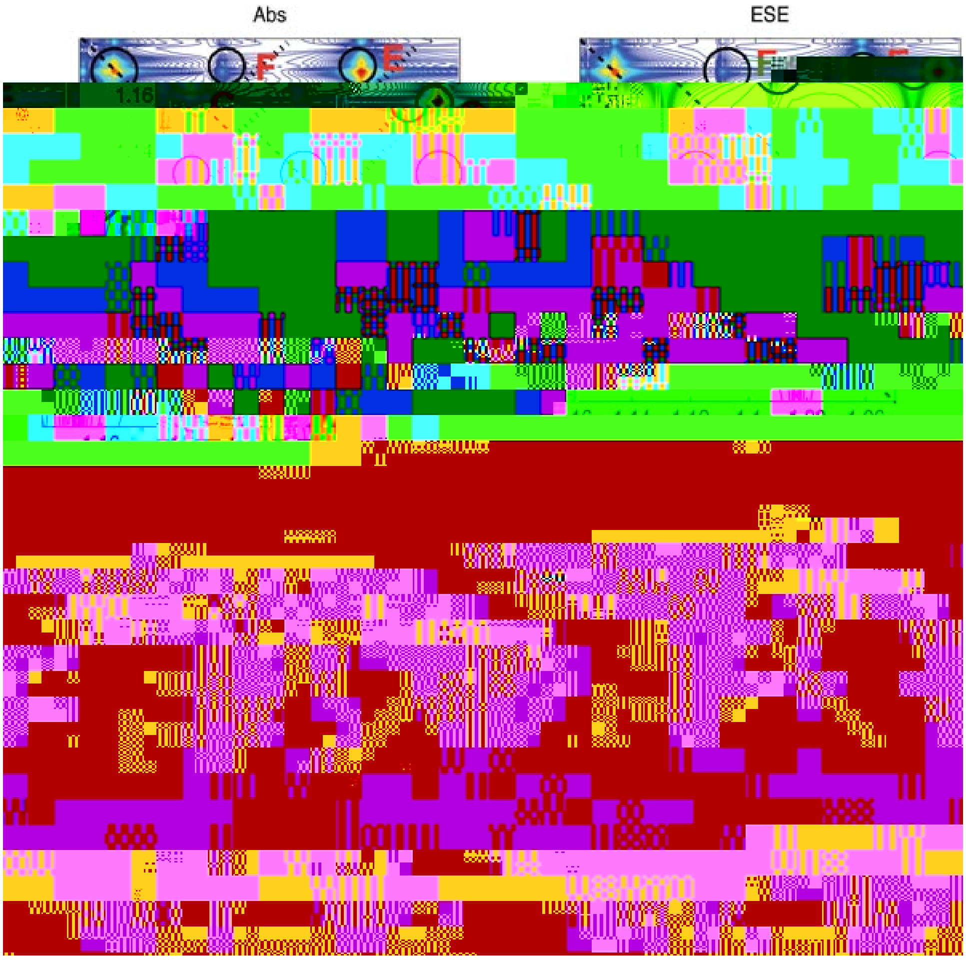

Figure 3 (online color at: www.ann-phys.org) 2D-Photon echo signal $S^{(3)}_{k_I}(\hbar\Omega_3, t_2, \hbar\Omega_1)$ of the neutral QD: the three ladder diagrams excited state emission (ESE), ground state bleach (GSB) and excited state absorption (ESA, compare Fig. 1) contribute to the total signal $S^{(3)}_{k_I}(\hbar\Omega_3, t_2, \hbar\Omega_1)$ (depicted as absolute value (Abs)). The signals are depicted on a nonlinear scale, de ned by eq. (10). The colour scale is the same as in Fig. 2

A C
$e_0 - h_4$ (B).
A
($S_e - S_h$ $-\hbar\Omega_1 = \hbar\Omega_3 = 1.083$, . 2 ( ))

- ($X^q \leftarrow G^q$).
(
)
$-\hbar\Omega_1 \approx 1.08$, $\hbar\Omega_3 \approx 1.16$ (
) $S_e - S_h$ $P_e - P_h$
(- E, E', G, G').
(. 2 ( ))
- E G,
(. 2 ( ) ( ))
- E G.
-

$P_e - P_h$ (-
, . 2 ,
) -
$S_e - S_h$ $e_0 - h_4$ (-
$D, D', -\hbar\Omega_1 \approx 1.08$ $\hbar\Omega_3 \approx 1.13$)
$e_0 - h_4$ $P_e - P_h$ (- $F, F', -\hbar\Omega_1$
≈ 1.13 $\hbar\Omega_3 \approx 1.17$). $\hbar\Omega_1$
-
, $\hbar\Omega_3$
(- $G, G', H, \hbar\Omega_3 \approx 1.07$
$\hbar\Omega_3 \approx 1.158$ $\hbar\Omega_3 \approx 1.115$).
-
- X^q - XX^q -
. 1 ( ).
2 - $S^{(3)}_{k_I}(\hbar\Omega_3, t_2, \hbar\Omega_1)$ $X^q \leftarrow G^q$ -
- .

Key words. Self-assembled quantum dots, non-linear optical spectroscopy, many-body e ects.

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