iopscience.iop.org

Home Search Collections Journals About Contact us My IOPscience

Multi-excitons in self-assembled InAs/GaAs quantum dots: A pseudopotential, many-body approach

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2001 Europhys. Lett. 53 59

(http://iopscience.iop.org/0295-5075/53/1/059)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 128.138.65.115
This content was downloaded on 14/07/2015 at 22:15

Please note that terms and conditions apply.

E . ., (1), pp. 59–65 (2001)

Multi-excitons in self-assembled A /G A quantum dots: A pseudopotential, many-body approach

A. . W (*), A. F II and A. G
N n n E n - n, C 80401, A

(received 22 February 2000; accepted in final form 31 October 2000)

PACS. .0. – Electron states in low-dimensional structures (superlattices, quantum well structures and multilayers).
PACS. . – Optical properties of specific thin films, surfaces, and low-dimensional structures.

A . . – We use a many-body, atomistic empirical pseudopotential approach to predict

the di erence in the electron and hole wave functions. It vanishes artificially in single-band e ective-mass calculations that use an infinite well depth, such as those in refs. [1,2,7]. Second, there is an exchange shift, $\delta^{\mathrm{h}}_{N\to N-1}$, given by the second term in brackets in eq. (2). This exchange shift is familiar from theories of band gap renormalization [9] where the existence of high carrier densities during high power photoexcitation acts to reduce the band gap. In addition, since the exchange interaction depends on the spin orientation of the carriers, the exchange contribution (second term in eq. (2)) can split the excitonic transitions.

In the N = even, "closed shell" series, the initial state contains no open shells while the final state contains one open shell. This results in one- and four-fold degeneracies for the initial and final states, and hence 4 transitions. These 4 transitions are split by the small electron-hole ex-

same lens-shape, alloyed dot with a 1.1 eV PL peak. Unfortunately, although numerous experiments were conducted on this dot, no multi-exciton spectra were taken since the lowest PL is outside the range of conventional CCD detection equipment, so quantitative comparison awaits a future measurement.

Having obtained the single-particle levels ($e_0, e_1 \ldots, h_0, h_1 \ldots$) from the pseudopotential method, we then calculate numerically the screened Coulomb and exchange integrals

$$J = \frac{\psi^*(\boldsymbol{r}_1)\psi(\boldsymbol{r}_2)\psi^*(\boldsymbol{r}_1)\psi(\boldsymbol{r}_2)}{\bar{\epsilon}(\boldsymbol{r}_1 - \boldsymbol{r}_2)|\boldsymbol{r}_1 - \boldsymbol{r}_2|\ \boldsymbol{r}} \mathrm{d}\boldsymbol{r}_1 \mathrm{d}\boldsymbol{r}_2, \quad K = \psi^*_{\boldsymbol{r}})$$

excitons. For all the transitions shown here, the correlation shift, δ^{CI}, for the initial state with N excitons is greater than that for the final $N-1$ exciton state. Therefore, all the CI n n peaks are red shifted with respect to those from the ($+J+K$) approximation. ii) This (δ^{CI}) red shift is larger for the $2 \rightarrow 1$ transition than for the $1 \rightarrow 0$ transition and is able to overcome the Coulomb blue shift and "bind" the biexciton. Our calculated binding energy is ~ 3 meV, however, our model QMC calculations suggest that a fully converged value would be closer to 5 meV. iii) As the number of spectator excitons increases, the n in the red shift for the initial and final states decreases, so that the red shift of the n n energy decreases. For $3 \rightarrow 2$ and $4 \rightarrow$