

Excitons, biexcitons, and trions in self-assembled (In,Ga)As/GaAs quantum dots: Recombination energies, polarization, and radiative lifetimes versus dot height

$$E_{\text{exc}} = E_{\text{dot}} + E_{\text{exc}}^{\text{dot}} - E_{\text{exc}}^{\text{bulk}} \quad (1)$$

The energy of the exciton in the quantum dot is given by $E_{\text{exc}}^{\text{dot}} = E_{\text{dot}} - E_{\text{exc}}^{\text{bulk}}$, where E_{dot} is the energy of the lowest energy state in the quantum dot and $E_{\text{exc}}^{\text{bulk}}$ is the energy of the lowest energy state in the bulk material. The energy of the exciton in the quantum dot is given by $E_{\text{exc}}^{\text{dot}} = E_{\text{dot}} - E_{\text{exc}}^{\text{bulk}}$, where E_{dot} is the energy of the lowest energy state in the quantum dot and $E_{\text{exc}}^{\text{bulk}}$ is the energy of the lowest energy state in the bulk material.

$\{|\Psi^{(v)}(i)\rangle\}$ 是 $\mathcal{H}^{(v)}$ 的一组正交归一基矢。由式 (1) 可知, $|\Psi^{(v)}(i)\rangle$ 是 $\mathcal{H}^{(v)}$ 中满足 $\hat{H}^{(v)}|\Psi^{(v)}(i)\rangle = E_i^{(v)}|\Psi^{(v)}(i)\rangle$ 的本征态。因此, $|\Psi^{(v)}(i)\rangle$ 是 $\mathcal{H}^{(v)}$ 的本征态。

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$$|\Psi^{(v)}(i)\rangle = \sum_{\kappa} C_{\kappa}^{(v)}(i) |\Phi_{\kappa}(i)\rangle \quad (2)$$

其中 $C_{\kappa}^{(v)}(i)$ 是待定系数, $|\Phi_{\kappa}(i)\rangle$ 是 $\mathcal{H}^{(v)}$ 的本征态。

由式 (2) 可知, $|\Psi^{(v)}(i)\rangle$ 是 $\mathcal{H}^{(v)}$ 的本征态。因此, $|\Psi^{(v)}(i)\rangle$ 是 $\mathcal{H}^{(v)}$ 的本征态。

$$\int \int_{\mathbf{R}, \mathbf{R}'} [\psi_{\mathbf{h}}^{(\mu)}(\mathbf{R})] [\psi_{\mathbf{h}'}^{(\mu')}(\mathbf{R}')] [\psi_{\mathbf{h}'}^{(\mu')}(\mathbf{R}')] [\psi_{\mathbf{h}}^{(\mu)}(\mathbf{R})]$$

$$\left\{ \left(\frac{\partial}{\partial t} + \mathcal{L} \right) \rho + [E_0^{(0)}(\mathbf{r}) + E_1^{(0)}(\mathbf{r})] \rho \right\} \quad (1)$$

where ρ is the density matrix, \mathcal{L} is the Liouville superoperator, $E_0^{(0)}$ and $E_1^{(0)}$ are the static and dynamic parts of the electric field, respectively. The static part is given by $E_0^{(0)}(\mathbf{r}) = \sum_{\mathbf{k}} \mathbf{e}(\mathbf{k}) e^{-i\mathbf{k} \cdot \mathbf{r}}$ and the dynamic part is given by $E_1^{(0)}(\mathbf{r}) = \sum_{\mathbf{k}} \mathbf{e}(\mathbf{k}) e^{-i\mathbf{k} \cdot \mathbf{r}} e^{-i\omega_{\mathbf{k}} t}$. The Liouville superoperator is defined as $\mathcal{L} \rho = -i[H, \rho]$, where H is the Hamiltonian. The density matrix is expanded in terms of the eigenstates of the static part of the electric field, $|\Psi_n^{(0)}(\mathbf{r})\rangle$, as $\rho = \sum_n |\Psi_n^{(0)}(\mathbf{r})\rangle \langle \Psi_n^{(0)}(\mathbf{r})| \rho_n$. The eigenstates are given by $H_0 |\Psi_n^{(0)}(\mathbf{r})\rangle = E_n^{(0)} |\Psi_n^{(0)}(\mathbf{r})\rangle$, where H_0 is the static part of the Hamiltonian. The eigenvalues are given by $E_n^{(0)} = \sum_{\mathbf{k}} \mathbf{e}(\mathbf{k}) \cdot \mathbf{e}(\mathbf{k}) e^{-i\mathbf{k} \cdot \mathbf{r}}$. The density matrix is then expanded in terms of the eigenstates of the static part of the electric field, $|\Psi_n^{(0)}(\mathbf{r})\rangle$, as $\rho = \sum_n |\Psi_n^{(0)}(\mathbf{r})\rangle \langle \Psi_n^{(0)}(\mathbf{r})| \rho_n$. The eigenstates are given by $H_0 |\Psi_n^{(0)}(\mathbf{r})\rangle = E_n^{(0)} |\Psi_n^{(0)}(\mathbf{r})\rangle$, where H_0 is the static part of the Hamiltonian. The eigenvalues are given by $E_n^{(0)} = \sum_{\mathbf{k}} \mathbf{e}(\mathbf{k}) \cdot \mathbf{e}(\mathbf{k}) e^{-i\mathbf{k} \cdot \mathbf{r}}$.

$$\lambda(\mathbf{r}, \mathbf{r}') = \langle \Psi_n^{(0)}(\mathbf{r}) | \rho | \Psi_n^{(0)}(\mathbf{r}') \rangle + \langle \Psi_n^{(0)}(\mathbf{r}) | \rho | \Psi_n^{(0)}(\mathbf{r}') \rangle \alpha$$

$$\rightarrow |\Psi^{(e)}(\vec{r}, t)\rangle = \int d^3r' |\Psi^{(e)}(\vec{r}', t)\rangle$$

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