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A simple model—the single-configuration perturbation theory—has traditionally been used to explain the main features of the multiexcitonic spectra of quantum dots, where an electron and a hole recombine in the presence of other -1 electrons and -1 holes. The model predicts the (,) values for which such spectra consist of a single line or multiple lines and whether singlet lines of different (,) values are

the hole wave functions, i.e., -electron orbital equals -hole orbital, -electron orbital equals -hole orbital, etc. In the context of the − channel, this rule was described previously by Bayer [5] and by Hawrylak[8] and was referred to as hidden symmetries. The hidden-symmetry rules were originally derived under rather stringent conditions of (i) transitions from and to orbitally degenerate shells (e.g., and shells

sion lines. We first concentrate on flat dots with cylindrically symmetric shape: $In_{0.6}Ga_{0.4}As/GaAs$ lens-shaped QD with diameter 25 nm and height of 3.5 nm sitting on a 2 ML wetting layer (a range of other shapes is considered below). The calculated multiexcitonic emission spectra are shown in Fig. 2. Measured peak positions in the high excitation PL spectra of Ref. 5 are represented by blue open symbols (dark gray inverted triangles); our results are seen to be in good agreement with the experimental data. Next, we observe that the simple SCPT indeed explains many of the results of the complex calculation. Figure 1 indicates below the PTSM designation also the CI designation, describing the result of the full calculation.

We find that the PTSM rule is obeyed by all of the -channel transitions and by the $(1,1)\rightarrow(0,0)$, $(2,2)\rightarrow(1,1)$, $(5,5)\rightarrow(4,4)$, and $(6,6)\rightarrow(5,5)$ -channel transitions. There are three exceptions in the case of the -recombination channel.

(i) The PTSM rule predicts a multiplet, but the CI calculation shows a dominant peak: this is the case, for example, of the $(3,3)\rightarrow(2,2)$ emission spectrum. Figure 3(a) shows the recombination spectra of the (3,3) multiexciton calculated using SCPT and CI. In the SCPT approximation the initial state has two electrons in the level and one in the level (the same for the holes), so the ground state is: $\Phi^{GS}_{(3,3)}=$. The final state in the recombination channel has one electron (hole) in the orbital and one in the orbital: $\Phi_{(2,2)}=$. CI introduces mixing of different configurations. We find that the initial many-p4o2al

Also, the - , , -. , and -. interactions do not have to be identical to create alignment because of an approximate cancellation of different terms (see expressions in Fig. 1). However, there are also exceptions to the peak-alignment rule; most notably, the singlet $(6,6)\rightarrow(5,5)$ in the channel does not align with $(1,1)\rightarrow(0,0)$.

It is natural to enquire if the PTSM and PTPA rules depend on the detailed morphology of the dot or if they are general rules. For this purpose we have constructed several model dots representing a broad range of possibilities, as shown at the top of Fig. 4. (i) Structural dependence vs universality of the PTSM rule: for the − recombination channel, the rule correctly predicts singlets vs multiplets for all QD structures. For the − channel, the PTSM rule does not work for $(3,3)\rightarrow(2,2)$ and $(4,4)\rightarrow(3,3)$ and fails for all dots. The stability of the PTSM rule with respect to QD morphology appears to be an intrinsic feature of In Ga_{1-} As/GaAs QDs. Interestingly, the multiexcitonic transition $(3,4)\rightarrow(2,3)$ is particularly sensitive to structural properties, as shown in Fig. 4: the intensity is attenuated in close-to-symmetric flat QDs (lens 1) but increases when increasing the dot height, composition, and base elongation or by modifying the base from circular to square. (ii) Structural dependence vs universality of the PTPA rule: Table I shows the misalignment of singlet peaks defined for the − recombination channel as the distance in eof[61 09gy322.4eoF2 1 T-346.9i