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Characterization and Modeling of Single-particle Energy Levels and Resonant Currents in a Coherent Quantum Dot Mixer

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Abstract. We characterize and model the single-particle energy level position and resonant current strength at a three-level crossing in a coherent mixer composed of two weakly coupled vertical quantum dots. In addition to clear anticrossing behavior, an otherwise strong resonance is completely extinguished at the center of the crossing. Despite the strong variation in energy level position and resonant current strength throughout the crossing region, the resonance widths and the sum of the branch currents are found to be approximately constant.

Keywords: Quantum dots, Resonant tunneling, Coherent level mixing
PACS: 73.21.La, 73.21.Fg, 73.43.Jn.

INTRODUCTION

Level anticrossing physics and quantum superposition phenomena are of broad interest in semiconducting nano-systems. One example, with superposition at its core, is the strong suppression of current due to destructive interference (see the all-electrical schemes involving quantum dots outlined in Refs. [1-5]).

Recently we have performed magneto-resonant-tunneling measurements to probe single-particle energy spectra of the constituent weakly coupled dots in vertical quantum dot molecules [6-9]. The measured energy spectra are well modeled by calculated spectra for dots with confinement potentials that are elliptical and parabolic in form. However, in the regions where two, three or four single-particle energy levels are naively expected to cross in the presence of a magnetic (B-) field, we observe pronounced level anticrossing behavior and strong variations in the resonant currents as a consequence of coherent mixing induced by small deviations in the nearly ideal dot confinement potentials.

To understand the underlying physics we seek to well characterize and model the level crossings. This is usually straightforward when the anticrossing branches are well separated, but more challenging when the anticrossing branches are very close or appear to cross. For this reason we are interested in extra information from the data which may assist us in the analysis. Here, we outline evidence for approximate conservation rules using a three-level crossing as test subject.

EXPERIMENT

Panels (a) and (b) in Fig. 1 show respectively the B-field dependence of the energy level position and resonant current for each branch of a three-level crossing with well separated branches (see Ref. [8] for full details). Clearly evident is the pronounced splitting of the anticrossing lower and upper branches (~0.8 meV), and the suppression of an otherwise

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strong center branch resonance due to destructive interference. This behavior is reproduced well by model calculations based on a coherent tunneling picture [see panels (c) and (d) in Fig. 1]. An essential ingredient is the inclusion of higher degree terms to account for deviations from an ideal elliptical parabolic confining potential in realistic dots [6,7].

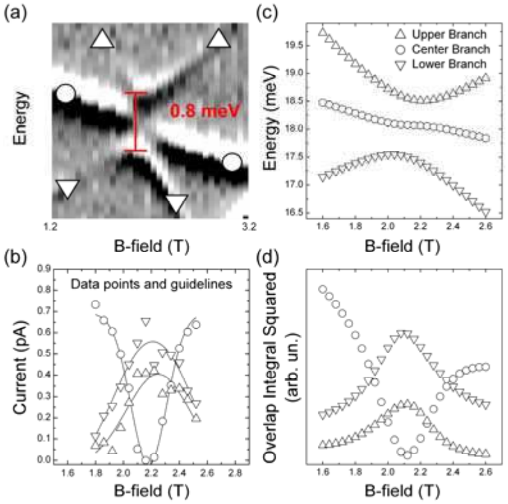

FIGURE 1. (a) and (b) show respectively the B-field dependence of the energy level position and resonant current for each branch of a particular three-level crossing. The behavior is reproduced by model calculations based on a coherent tunneling picture [panels (c) and (d)].

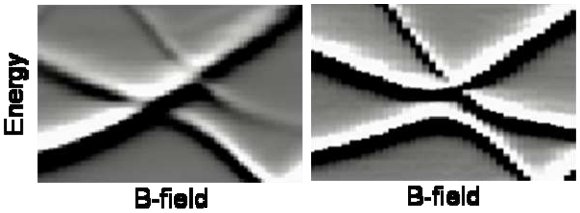

FIGURE 2. Two examples of more challenging three level crossings where the branches are not all well separated [9].

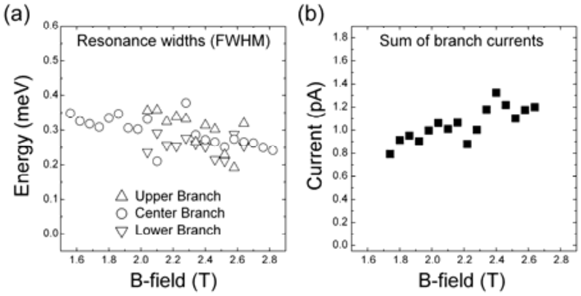

FIGURE 3. (a) and (b) show respectively the B-field dependence of the resonance width and the sum of the branch currents for the three level crossing in Fig. 1.

For the crossing in Fig. 1 all the relevant information is easily extractable from fits of the data. However, other crossings are more challenging (see for instance the two examples in Fig. 2). Towards a better understanding of these equally interesting crossings, we are motivated to examine other spectral properties like the resonance width and the sum of the branch currents. For the three-level crossings in Fig. 1, but also for two and four level crossings with well separated branches (not shown), these quantities are found to be approximately constant throughout the crossing region [see panels (a) and (b) in Fig. 3]. These quantities may prove useful as extra constraints in the modeling of challenging level crossings like those in Fig. 2.

Our quantum transport measurements can help towards the general engineering and understanding of coupling and consequent mixing between many quantum levels in coupled quantum dot systems [1-5], as well as shed light on the physics of tunneling for the high bias voltage conditions applied in the measurements [6-9].

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REFERENCES

1. T. Brandes, *Phys. Rep.* **408**, 315 (2005).
2. A. D. Greentree *et al.*, *Phys. Rev.* B **70**, 235317 (2004).
3. B. Michaelis, C. Emary and C. W. J. Beenakker, *Europhys. Lett.* **73**, 677 (2006).
4. E. Del Valle, F. P. Laussy and C. Tejedor, *Europhys. Lett.* **80**, 57001 (2007).
5. C. Emary, C. Pöltl and T. Brandes, *Phys. Rev.* B **80**, 235321 (2009).
6. C. Payette *et al.*, *Phys. Rev. Lett.* **102**, 026808 (2009).
7. C. Payette *et al.*, *Appl. Phys. Lett.* **94**, 222101 (2009).
8. C. Payette *et al.*, *Phys. Rev.* B **81**, 245310 (2010).
9. C. Payette *et al.*, arXiv:0908.4561.