

Two-path transport measurements with bias dependence on a triple quantum dot

M. Kotzian, M. C. Rogge, and R. J. Haug

Citation: [AIP Conference Proceedings](#) **1566**, 213 (2013); doi: 10.1063/1.4848361

View online: <http://dx.doi.org/10.1063/1.4848361>

View Table of Contents: <http://scitation.aip.org/content/aip/proceeding/aipcp/1566?ver=pdfcov>

Published by the [AIP Publishing](#)

Articles you may be interested in

[Measurement of the transmission phase of an electron in a quantum two-path interferometer](#)

Appl. Phys. Lett. **107**, 063101 (2015); 10.1063/1.4928035

[Two-path quantum interference in a liquid](#)

Phys. Today **54**, 9 (2001); 10.1063/1.4796468

[A method of calculating average array signal response in a two-path medium](#)

J. Acoust. Soc. Am. **67**, 2068 (1980); 10.1121/1.384450

[Errata: A Two-Path Method for Measuring Flame Temperatures and Concentrations in Low-Pressure Combustion Flames](#)

J. Chem. Phys. **19**, 1434 (1951); 10.1063/1.1748096

[A Two-Path Method for Measuring Flame Temperatures and Concentrations in Low Pressure Combustion Chambers](#)

J. Chem. Phys. **19**, 272 (1951); 10.1063/1.1748193

Two-path Transport Measurements with Bias Dependence on a Triple Quantum Dot

M. Kotzian, M.C. Rogge and R.J. Haug

Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Abstract. We present transport measurements on a lateral triple quantum dot with a star-like geometry and one lead attached to each dot. [1] The system is studied in a regime close to established quadruple points, where all three dots are in resonance. The specific sample structure allows us to apply two different bias voltages to the two source leads and thus to study the influence between the paths with serial double dots.

Keywords: triple quantum dots, electronic transport, Coulomb blockade

PACS: 73.21.La, 73.23.Hk, 73.63.Kv

INTRODUCTION

Technical and scientific improvement allow the fabrication of triple quantum dots and their detailed analysis. [2,3,4] The research on triple quantum dots is motivated by fundamental physics and by the fact that such a system can work as a single qubit. [5] It is also the smallest system with quantum dots being part of a qubit chain, which is needed for quantum computation.

Our sample design stands out from previous investigated systems as it has one lead connected to each of the three dots which are arranged in a star-like geometry. [1,6] This allows a variable measurement setup, as transport through two dots in series with a capacitively coupled third dot can be measured separately in both paths and be compared or combined. In contrast to former investigations [1], we used two of the leads as source contacts and one as a drain, to change the potential of the serial double dots separately and investigate the influence on the system.

SAMPLE STRUCTURE AND ELECTRONIC SETUP

The structure is produced by local anodic oxidation (LAO) with an atomic force microscope (AFM) on a GaAs/AlGaAs heterostructure with a two-dimensional electron gas in 33 nm depth. Five in-plane gates control the dots' potential and couplings to the leads (Fig.1). In the measurement setup, two of the leads are used as source contacts and one lead as a drain contact.

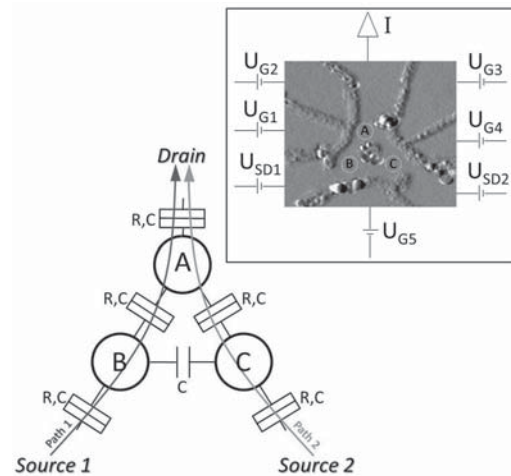


FIGURE 1. Schematic of the triple dot setup. Each of the dots is coupled to the other two and to one lead via tunneling barriers. The coupling between Dot B and C is of capacitive nature only. Transport is measured via dots A and B along path 1 and via dots A and C along path 2. Insert: AFM image of the triple dot structure defined by oxide lines. The applied gate voltages are labeled $U_{G1} - U_{G5}$ and the bias voltages U_{SD1} and U_{SD2} . The top lead is used as a drain contact.

MEASUREMENT RESULTS

Gate-Gate Measurements

The potentials of the dots are controlled by varying two gates of the triple dot structure and keeping the others at a constant value to establish a quadruple point. The differential conductance through the dots was measured in the two paths separately. Signatures of all three dots are visible via both transport paths. A region, where all

three dots are in resonance (Fig.2), is chosen for the bias measurements.

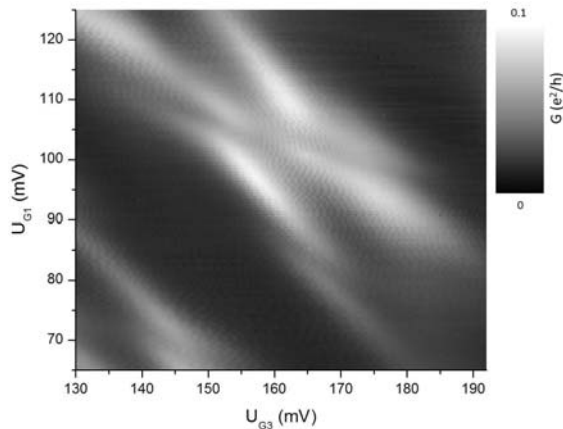


FIGURE 2. Differential conductance of path 2 with varying gate voltages at gate 3 and 1. A triple dot resonance is established. The remaining gate voltages are $U_{G2} = -55 \text{ mV}$, $U_{G4} = 0 \text{ mV}$ and $U_{G5} = -140 \text{ mV}$.

A crossing of three dots in resonance can be seen where the lines of charge transition of the respective dots meet. When two sequential dots in one path are in resonance with each other and with the adjacent leads, transport can be observed. In case of a triple dot resonance, the double dot resonances of the two sequential double dots meet. Due to finite temperature and strong coupling of the dots, transport is observed in the region near the triple dot resonance. The regions with a higher differential conductance are associated with quadruple points, of which in general six are spacially distributed in the 3D stability diagram, but do not all lie in one measurement plain. [6] The lower current at the center of the resonance indicates that right there no quadruple point is located. The additional splitting at $U_{G1} = 80 \text{ mV}$ and $U_{G3} = 165 \text{ mV}$ and at $U_{G1} = 70 \text{ mV}$ and $U_{G3} = 145 \text{ mV}$ is due to a crossing of the next charging lines of the dots.

Bias Measurements

To investigate whether changing the potential at one path influences the transport through the other serial double dot, bias measurements with sweeping the source voltage on one path and keeping the other at a constant value were done in the regime of a triple dot resonance.

Fig. 3 shows the differential conductance along path 2 via dots A and C with varying the bias voltage at source 1 and keeping the other voltages at a constant value. The bias voltage at source 2 is $U_{SD2} = -1 \text{ mV}$, the voltages at the gates are $U_{G1} = 110 \text{ mV}$ and $U_{G3} = 168 \text{ mV}$. The remaining gate voltages are the same as

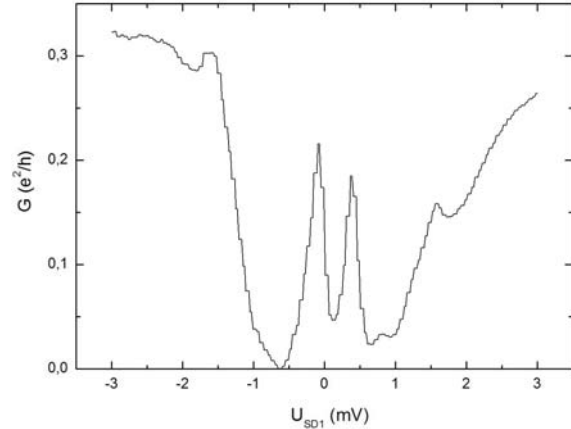


FIGURE 3. Differential conductance of path 2 with varying bias voltage at source 1. The other voltages are constant.

in the stability diagram measurement (Fig.2). At this point the bias measurement is particularly specific. The influence from path 1 on path 2 can be observed clearly. The differential conductance has two peaks which are nearly symmetric around zero bias. For higher absolute values of bias voltage the differential conductance rises, which resembles the Coulomb diamond where inside the diamonds no transport channel exists because of Coulomb repulsion of the electrons on the dots and the width of the diamonds being twice the expected charging energy of the dot. The smaller peaks at about $U_{SD1} = \pm 1.5 \text{ mV}$ can be associated with excited states.

CONCLUSION AND OUTLOOK

We observe unexpected features in transport measurements of a triple quantum dot with two paths of serial double dots.

For a better understanding of these effects further investigations and a theoretical approach is needed.

REFERENCES

1. M. C. Rogge, et al., *Phys. Rev. B* **77**, 193306 (2008).
2. D. Schröder, et al., *Phys. Rev. B* **76**, 075306 (2007).
3. A. Vidan, et al., *Appl. Phys. Letters* **85**, 3602 (2004).
4. L. Gaudreau, et al., *Phys. Rev. Letters* **97**, 036807 (2006).
5. P. Hawrylak, et al., *Solid State Comm.* **136**, pp. 508-512 (2005).
6. M. C. Rogge, et al., *New Journal of Physics* **11**, 113037 (2009).