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Short Communication

**Conductance in quantum wires by three
quantum dots arrays**

ABSTRACT

A.Azari
S. Zabihi A.*
K. Seyyedi.S

*Islamic Azad University, Tabriz
Branch, Tabriz, Iran*

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A noninteracting quantum-dot arrays side coupled to a quantum wire is studied. Transport through the quantum wire is investigated by using a noninteracting Anderson tunneling Hamiltonian. The conductance at zero temperature develops an oscillating band with resonances and antiresonances due to constructive and destructive interference in the ballistic channel, respectively. Moreover, we have found the number of antiresonant exactly depends on the number of quantum dot in every array and increasing array make antiresonants wide increase.

Keywords: *Quantum wire; Quantum dot arrays; Hamiltonian model.*

INTRODUCTION

Recent progress in nanofabrication of quantum devices enables us to study electron transport through quantum dots (QDs) in a very controllable way. QDs are very promising systems due to their physical properties as well as their potential application in electronic devices. These structures are small semiconductor or metal structures in which electrons are confined in all spatial dimensions. As a consequence, discreteness of energy and charge arise. For this reason QDs are often referred as artificial atoms [1-5]. Two or more QDs can be coupled to form an artificial molecule sharing electrons. This analogy opens the way to look for new electronic effects that might resemble quantum optics. The systems such as uniform QD array, nano-wires and nano-ring [6-7] which are side-coupled to a quantum wire act as a scatter system for electron transmission through the QW and have a major effect on electronic conductance of nano-device. For a uniform QD-chains array with M sites, it was shown that the transmission characteristic has M antiresonances and $M-1$ resonance, M mini-gaps and $M-1$ allowed mini-bands arise [7]. In this work we study electron transport properties of QDs arrays side attached to a quantum wire (QW).

* Corresponding author:
Sima Zabihi Agdam
Islamic Azad University Tabriz
Branch, Tabriz,Iran.
Tel +98 9144154962
Fax +98 4114436211
Email sima.zabihi@yahoo.com

We examine the linear conductance at zero temperature and we find conductance have resonant and antiresonant that the number of antiresonant is the same as the number of quantum dot in every chain and we show that increasing the number of chain makes antiresonants wide increase too. This configuration can be regarded as a quantum wave guide with side-stub structures, similar to those reported in Refs 1-2.

EXPERIMENTAL

Model

Figure 1 shows a general form of quantum dot-chains as a scatter system for manipulating of electron transport through a quantum wire

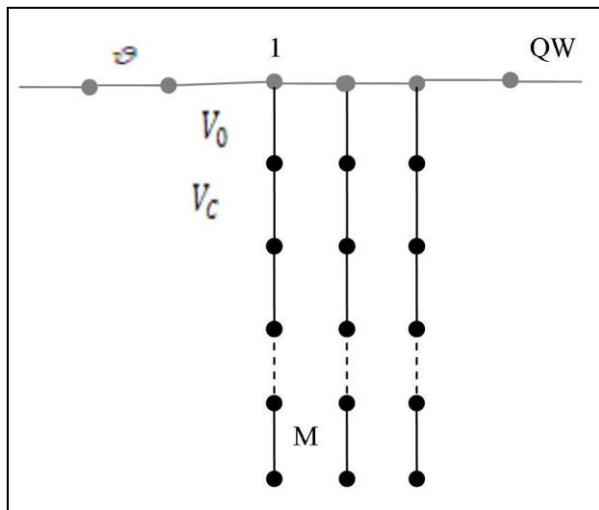


Fig. 1. Shows three quantum dot chains connected to the quantum wire. In this part we show calculation of this system.

$$H_{QW} = \mathcal{G} \sum_{j=-\infty}^{+\infty} a_j^\dagger a_{j+1} + h.c \quad (1.a)$$

$$H_{QCH} = \varepsilon_0 \sum_{m=1}^M d_m^\dagger d_m + V_c \sum_{m=1}^{M-1} d_m^\dagger d_{m+1} + h.c \quad (1.b)$$

$$H_{QCH-QW} = V_0 (d_1^\dagger a_1 + h.c + d_1^\dagger a_2 + h.c + d_1^\dagger a_3 + h.c) \quad (1.c)$$

Here, H_{QW} describes the dynamics of the QW, v being the hopping between neighbor sites of

the QW, and $a_j^\dagger(a_j)$ creates (annihilates) an electron in the j th site. H_{QCH} is the Hamiltonian of the asymmetric QD-scatter system $d_n^\dagger(d_n)$ is the creation (annihilation) operators of an electron in the quantum dots m of the QD-chain. ε_0 is the corresponding single level energy and V_c the tunneling coupling between sites in the quantum dots in every chains assumed all equal H_{QCH-QW} is the coupling of the QW with the asymmetric QD-chains.

For the calculation of transmission equation, it is assumed that the electrons are described by a plane wave incident from the far left of QW with unity amplitude and a reflection amplitude r and at the far right of QW by a transmission amplitude, t . Therefore we can write [6]:

$$a_j^k = e^{ikdj} + r e^{-ikdj} \quad j < 1 \quad (2.a)$$

$$a_j^k = t e^{ikdj} \quad j > \beta \quad (2.b)$$

Simulation results

In this section we show the effect of chain in conductance. Figure 2 shows the electron transport through quantum wire for one quantum dot in every chain ($M=1$). When the number of chain (N) increases the wide of antiresonant increase and the number of antiresonant exactly depend on the number of quantum dot in every chain. Figure 3 shows conductance of electron through quantum wire for 3 quantum dots in every chain, as seen in this Figure conductance have two resonants and three antiresonants. Then we can control the number of resonant and width of conductance through quantum wire. It is clear that the point of antiresonant is independent to number of chains. We recognize that If the number of quantum dots in each chain is odd (even), an anti-resonance (resonance) is observed at $\varepsilon=0$.

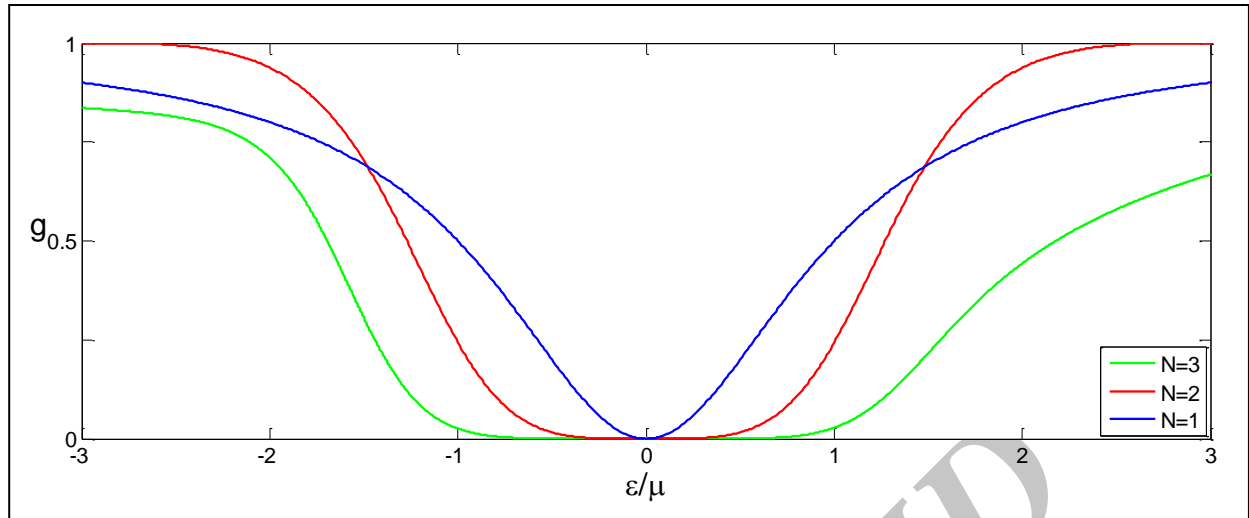


Fig. 2. Dimensionless conductance versus Fermi energy in units of μ , for one, two and three-chains for $M=1$, with $V_c=\mu$ and $\epsilon_0=0$

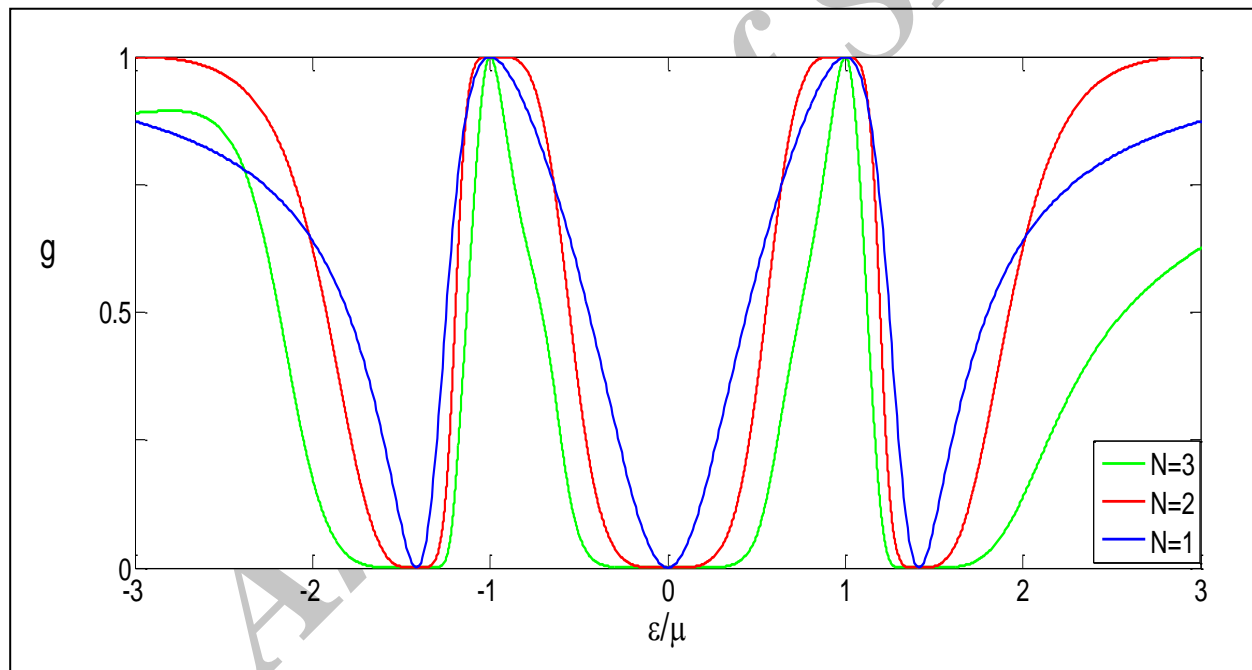


Fig. 3. Dimensionless conductance versus Fermi energy in units of μ , for one, two and three chains for $M=3$ with $V_c=\mu$ and $\epsilon_0=0$

RESULTS AND DISCUSSION

In this paper, we introduced a new structure of quantum dot chains connected quantum wire that influences electron transport through quantum wire with new resonant as a scatter system. It was shown that the QD-scatter system allows us to manipulate the spectrum and amplitude

of QW conductance characteristic and increasing the number of quantum dots increases the number of anti-resonances so the system develops a set of alternating forbidden and allowed mini-bands in the range $[-V_c; V_c]$. It was obvious that the width of the mini-bands becomes narrower in the condition where the chains increase.

CONCLUSION

In conclusion, a description of effect of the quantum dot chains as a scatter system on electronic transport through a quantum wire has been studied using a non interacting Anderson tunneling Hamiltonian model. It was found that the transmission probability displays a different spectrum for different configuration of QD-chains scatter system. When the number of quantum dots in chains was M , the number of forbidden mini-bands became M . Also when the number of chain increased the wide of conductance increased too.

As a final result, the particular setup which we suggested, allows us to manipulate the spectrum and amplitude of QW-nanostructure conductance in an independent fashion. Finally, the proposed QW- system by asymmetric side-attached QD- chains can be used as the basic cell in the design of new resonant-tunneling (RT) electronic devices.

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