Fano resonances through quantum dots in tunable Aharonov-Bohm rings

Y. S. Joe[1], J. S. Kim, E. R. Hedin, R. M. Cosby, and A. M. Satanin[1, 2]

[1]*Center for Computational Nanoscience, Department of Physics and Astronomy, Ball State University, Muncie, IN 47306, USA*

[2]*Institute for Physics of Microstructures, RAS, Nizhny Novgorod, Russia*

Email: ysjoe@bsu.edu , website: http://www.bsu.edu/physics/joe

Phase coherence effects in quantum wires and quantum rings are currently of much interest. At the present, various Aharonov-Bohm (AB) rings with embedded quantum dots in the arms have been fabricated, and quantum interference experiments for these systems have been performed [1, 2]. If a quantum ring supports coherent transmission, the wave amplitudes through the two arms interfere. The scattering of the waves on the dots results in an additional phase shift. Thus, the interference of the waves coming from the two arms provides information about the amplitude and phase of the waves and the internal potential.

The main goal of the present work is to investigate novel resonant phenomena which may arise in the AB rings with specially-designed dots. First, we investigate the total transmission probability through the coupled double quantum dots (QDs) embedded in one of the arms of the AB ring with a magnetic flux passing through its center. We calculate the electron transmission through this AB ring with three short-range potential barriers using a scattering matrix at each junction and a transfer matrix in each arm. The Fano resonance splitting and disappearing in the transmission can be seen by adjusting the interaction between coupled QDs, whose coupling is controlled by the modulation of the center potential barrier (Fig. 1). We also show the Fano resonance shifting to the higher energy by changing the interaction parameter, and the swing from Breit-Wigner to Fano resonance (or vice-versa) by tuning the magnetic AB flux threading through the AB ring. Secondly, we study the effects of an asymmetry in the arm by inserting an attractive potential well (dot) in one arm (Fig. 2). The combined transmission resonance effects (Young's interference, T-stub and Fano resonances) as a function of parameters of the ring structure and the potential well will be presented. For large amplitude of the potential dot, the transmission zeroes are seen to match the theory of resonance due to reflections from a closed "T-stub". Fano-interference in an asymmetric AB ring with an embedded attractive potential appears when quasi-bound states in the dot coherently interact and interfere with propagating waves in the arms. Our theoretical AB-ring model is compared to experimental results from measurements of an asymmetric ring fabricated in a GaAs/AlGaAs-heterostructure, where Fano resonances have been observed [2].

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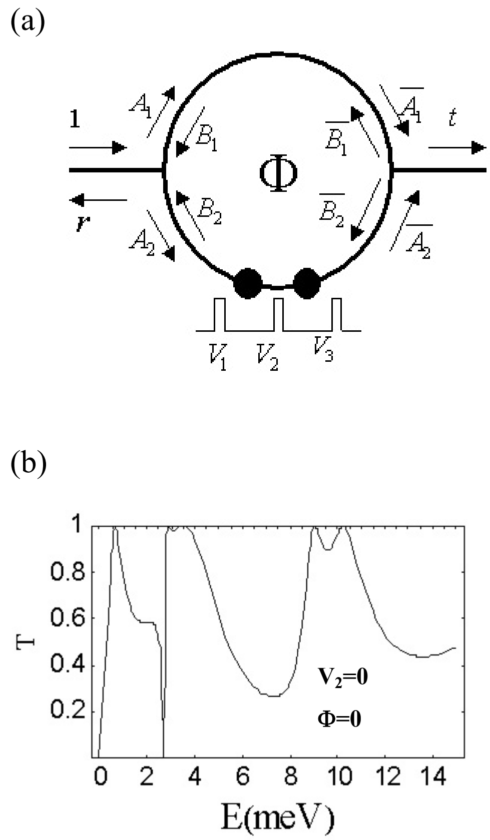

Fig. 1. (a) AB ring with embedded coupled QDs. The coupling of the double QDs in series can be controlled by the modulation of centered potential barrier V_2. (b) The Fano and Breit-Wigner resonances in the transmission as a function of electron energy are shown for V_2=0 and Φ=0.

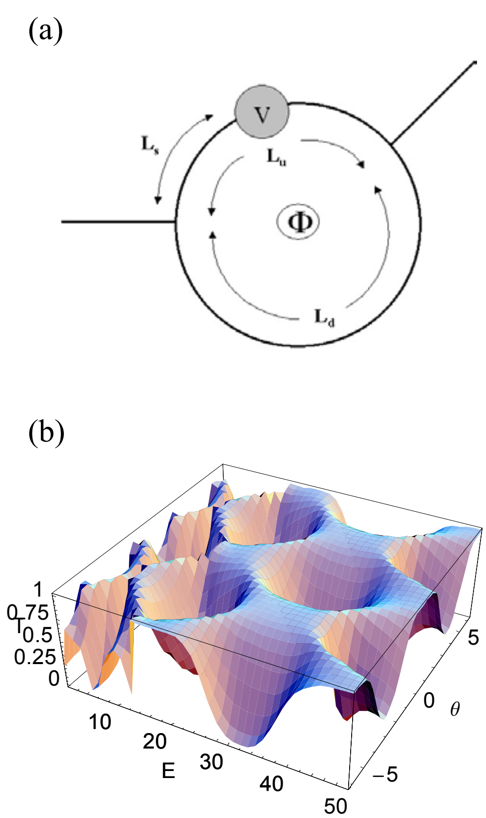

Fig. 2. (a) Geometry of an asymmetric ring with an attractive potential dot. The lengths of upper and lower arms are L_u and L_d correspondingly, and L_s is distance of the dot from left junction. (b) 3D plot of electron transmission through the asymmetric ring, showing variation with electron energy and threaded magnetic flux.

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