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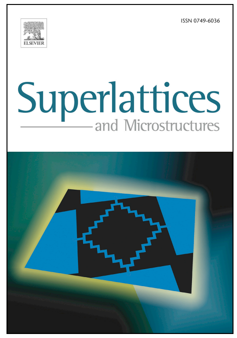

Infinite dwell time and group delay in resonant electron tunneling through double complex potential barrier

Nikola Opačak, Vitomir Milanović, Jelena Radovanović

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Infinite dwell time and group delay in resonant electron tunneling through double complex potential barrier

Nikola Opačak[(1)], Vitomir Milanović and Jelena Radovanović

School of Electrical Engineering, University of Belgrade, Bulevar Kralja Aleksandra 73, Belgrade, Serbia

Abstract

Let us consider the case of potential barrier and incident free particle, whose energy is lower than the barrier height. Tunneling times in complex potentials are investigated. Analytical expressions for dwell time, self-interference time and group delay are obtained for the case of complex double delta potentials. It is shown that we can always find a set of parameters of the potential so that the tunneling times achieve very large values and even approach infinity for the case of resonance. The phenomenon of infinite tunneling times occurs for only one particular positive value of the imaginary part of the potential, if all other parameters are given.

Keywords: double quantum barrier, tunneling, complex potential, transmission, tunneling times

Introduction

Let us consider the case of potential barrier and incident free particle, whose energy is lower than the barrier height. Quantum mechanics implies, as is known, a finite, non-vanishing probability for the particle to cross the barrier (i.e. the tunnel effect). Electron tunneling through double barrier structures has been the subject of intensive theoretical and experimental study due to its potential application in high speed electronic devices. One of the aspects of great importance of the tunnel effect is the traversal time needed for the electrons to pass through the barrier. Over the years, many answers have been proposed to the question of what time the process of tunneling takes [1-9] and it may seem surprising that none have gained general acceptance yet. Among many definitions of relevant times, two are generally used [10]: the dwell time, which is the time a particle spends in the barrier, whether transmitted or reflected; and the phase time or group delay which considers a tunneling of a wave packet built around some central wave number. It was unknown for a long period whether the dwell time and group delay, which are equal in the classical domain, are somehow related to each other under the quantum tunneling conditions, until a satisfactory answer was given in [11-12]. In [13] it was shown that that the group delay is equal to the sum of the dwell time and the self-interference time, which led to the explanation of the paradox of the Hartmann effect [14] in quantum tunneling and alleged violation of causality.

In quantum mechanics, a non-vanishing imaginary part of the potential is introduced to describe situations where we have change in the incident probability flux. The case of absorptive medium where we have reduction of the incident flux, corresponds to the potential with negative imaginary part, and conversely, the case where the absorption is negative and we have gain of the incident flux corresponds to the potential with positive imaginary part. This model has been used to describe numerous effects [15-18] and extensive review on complex potentials and absorption is given in [19-20]. Many applications have been found regarding potentials with negative imaginary part, but there are few concerning potentials with positive imaginary part which inject the probability flux and represent a source. The construction of a

(1) E-mail: opacaknn@gmail.com (corresponding author)