Universality of lifetime statistics in quantum chaotic scattering

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Abstract

We study a 1D model of a crystal electron in combined dc and ac fields. After an appropriate rescaling the Hamiltonian of the system can be presented in dimensionless form

$$\widehat{H} = \hat{p}^2/2 + \cos x + Fx + F_\omega x \cos(\omega t) \ , \tag{1}$$

where the momentum operator contains the scaled Planck constant $\hbar'$ as a system parameter. First we show that in the classical limit $\hbar' = 0$ the system (1) is a typical example of chaotic scattering with exponential decay. The quantum analysis of the problem is essentially more subtle and involves the condition of commensurability between the Bloch period $T_B = \hbar'/F$ and the driving period $T_\omega = 2\pi/\omega$:

$$T_\omega/T_B = r/q \ . \tag{2}$$

Provided the condition (2) is satisfied, we introduce an efficient scattering matrix of the size $q \times q$, the complex poles of which are the system quasienergy spectrum [1]. We calculate numerically the quasienergy resonances in the deep quantum ($\hbar' > 1$) and the semiclassical ($\hbar' \ll 1$) regions. For $\hbar' \ll 1$ the poles statistics and the statistics of the delay time is given for different number of channels and different system symmetries. These results are compered with the prediction of Random Matrix Theory adopted to the case of circular ensemble. For $\hbar' > 1$ the results are compared against the experimental data of Raizen's group [2], where the system (1) has been studied by using cold atoms in an accelerated optical lattice. The prospects of the laboratory study of this system in the semiclassical region of the parameters (where RMT is supposed to work) is briefly discussed.

[1] M. Glück, A. R. Kolovsky, H. J. Korsch, Phys. Rev. Lett. **82**, 1534 (1999); Phys. Rev. E, in press.

[2] S. R. Wilkinson, C. F. Bharucha, K. W. Madison, Qian Niu, and M. G. Raizen, Phys. Rev. Lett. **76**, 4512 (1996);