Sub-diffusion, localisation and decoherence in kicked rotor

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Kicked rotor is a fundamental model of quantum chaos [1]. Physically it corresponds to a particle periodically kicked by a sinusoidal potential. The classical and quantum dynamics of this system has been well studied in the last four decades. For large kick strengths, the kicked rotor system is largely chaotic and it manifests as quasi-linear diffusive growth of mean energy of the system. On the other hand, the quantum regime of kicked rotor strongly suppresses the classical diffusive mean energy growth. It leads to saturation of mean energy and the corresponding Floquet states are exponentially localised in the momentum basis. This is the dynamical localisation scenario. It was experimentally realised in an atom-optics set up, i.e., cold atoms interacting with flashing optical potentials [2]. This is brief summary of the results for kicked rotor as a representative system that follows the assumptions of Kolmogorov-Arnold-Moser (KAM) theorem.

In this work, we discuss how this standard scenario for the chaotic dynamics of kicked rotor is modified by the presence of the additional singular potentials. Main motivation comes from tunneling problems in the presence of double well potentials and their realisations in terms of resontant tunnelling devices. This is also a non-KAM system and its dynamics is not well understood. In general, presence of singular and stationary potentials would lead to a Hamiltonian of the form,

$$H = \frac{p^2}{2} + V(q) + \epsilon \cos(q) \sum_{n=-\infty}^{\infty} \delta(t-n), \qquad (1)$$

where $V(q)$ is the stationary potential taken to be of double-barrier type, $\theta(.)$ is the unit step function, V_0 and b are the height and width of the potential barrier respectively, ϵ is the kick strength, ϕ is the phase of the kicking field and $R = w/\lambda$ is the ratio of width of the well to the wavelength of the kicking field. The presence of singularities in $V(q)$ violates the assumptions of the KAM theorem and absrupt transition to chaos is observed for kick strength $\epsilon > 0$.

We show that the effect of non-KAM dynamics mainfests as subdiffusion of mean energy and this can be related to tori hoppings in the system. Classical mean energy is strongly suppressed by non-KAM structures and tori hoppings. In the quantum regime, localisation emerges due to destructive interferences. The quantum break-time and the saturated mean energy depend on exponents that characterise the classical subdiffusion. Thus, we directly relate the non-KAM classical features in this system to the quantum regime.

Subdiffusion can also be observed in the kicked rotor in the presence of noise. Presence of noise in the quantum kicked rotor results in decoherence and loss of dynamical localisation. In order to control the decay of quantum coherences, we study the standard kicked rotor, i.e., Eq. 1 with $V(q) = 0$. In this case, we show that the timing noise in the quantum kicked rotor leads to quantum subdiffusion. By appropriately choosing the properties of timing noise, such as from a Levi distribution, we show that the decoherence in the quantum kicked rotor can be controlled [3].

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