first band from those that made transitions to higher bands.

When there is no strong field present we obtain a spectrum of the unperturbed Bloch band structure. As the modulation strength is increased the second band flattens and side peaks in the spectrum, spaced at multiples of the strong field frequency, grow in size. For a modulation index of $\lambda = 3.8$, the condition for band suppression is fulfilled. As the modulation index is increased further the central peak broadens and the previously distinct side peaks overlap, producing broad tails on the central resonance.

In the theoretical analysis of this problem we calculated the quasienergies and the corresponding coupling strengths between the first and higher bands in order to generate a prediction for the experimental spectral distributions. This calculation goes beyond the single-band and tight-binding approximations, and is in good agreement with the observed spectra.

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QThK3 **5:15 pm**

Quantum signatures of anomalous diffusion

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It is well established that classical chaotic motion is suppressed by quantum mechanics. A paradigm theoretical system for the study of this suppression is the kicked rotor, where the suppression manifests itself as dynamical localization. This effect is the saturation of momentum growth after the quantum break time, with a resulting exponentially localized distribution. Classical analyses of this system have also identified regimes of anomalous diffusion, characterized by Lévy flights in phase space.[1] This behavior is considerably more complex than normal diffusion and has attracted much interest in recent years. In the quantum case, recent theoretical work suggests that the transport properties of the system can again be strongly modified when anomalous diffusion occurs in the classical system.[2]

We report here an experimental study of quantum signatures of anomalous diffusion in an atom optics realization of the quantum kicked rotor. Our system consists of laser-cooled cesium atoms in a pulsed standing wave of light. Our experiment begins with $\sim 10^6$ cesium atoms cooled to $\sim 10\ \mu$K in a magneto-optic trap. We then turn on a pulsed standing wave of light with a period of $\sim 20\ \mu$s and a pulse duration of around 300 ns. The atomic momentum distribution is measured after the interaction with the pulsed light by a time-of-flight method, in which the atoms are frozen and imaged in optical molasses after a ballistic expansion period. The classical description of this system, in the limit of short pulse duration, is governed by the stochasticity parameter K, which is proportional to both the laser intensity and pulse period. The quantum model depends an additional parameter, the scaled Planck constant k, which is proportional to the pulse period.

Classically, anomalous diffusion has two clear manifestations that are relevant to our experiments. The first is that stable phase space structures lead to an oscillatory dependence of the (short-time) momentum diffusion rate as a function of K.[3] The second is that when certain stable structures, called accelerator modes, are present, the diffusion rate diverges for long times, because the accelerator modes lead to streaming (Lévy flights) in phase space rather than random-walk behavior. In our experiments, we observe corresponding oscillations in the momentum distribution widths, and we verify a prediction due to Shepelyansky[4] that the oscillations in the quantum system should follow those of the classical system if K is replaced by K_q, where

$$K_q = K\left(\frac{2}{k}\right)\sin\left(\frac{k}{2}\right). \qquad (1)$$

We also observe that when accelerator modes are present, the momentum distributions do not settle into the expected exponentially localized form over the timescales of our experiments. Furthermore, the evolution of the distributions at short times is qualitatively different from the evolution that leads to exponential localization.[5]

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QThK4 **5:30 pm**

Experimental observation of phase space resonances in the quantum chaotic dynamics of cold atoms

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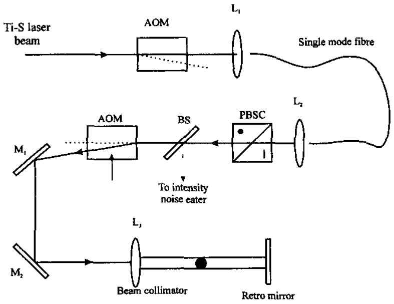
In our experiments ultra-cold Rubidium atoms are loaded into an optical standing wave. The amplitude of the standing wave is then modulated, creating a time dependent potential given by

$$V(x, t) = \kappa(1-2\varepsilon \sin(2\pi f_m t))\cos(2kx)$$

where κ is the strength of the potential, ε is the amplitude of modulation and f_m is the frequency of modulation. The dynamics of atoms in such a potential is chaotic except for small islands of stability which exist for certain values of κ, ε and f_m. These islands are phase space resonances and rotate in phase space at the modulation frequency. By viewing the dynamics of the interaction stroboscopically, at intervals of the modulation frequency it is possible to observe these resonances in the final atomic velocity distribution.



QThK4 Fig. 1. Experimental setup used to observe dynamics of atoms in a modulated standing wave. We use a noise eater before a single mode polarisation preserving fibre, but detect light for the stabilisation after the fibre, this allows us to stabilise intensity, pointing and polarisation noise to the 1% level.

In our setup, shown in Fig. 1, an ensemble of cold Rb atoms with a velocity width of 12 photon recoils are produced in a Magneto-optical trap. These atoms are released from the trap and interact with an optical standing wave. The standing wave is produced using a Ti-Saphire laser beam which is intensity stabilised to better than 1%. Coupling of the standing wave into the MOT is achieved using a single mode polarisation preserving optical fibre, thus ensuring excellent beam quality and good beam pointing stability. An acousto-optic modulator is used to modulate the intensity of the standing wave, and achieves a spectral purity of approximately 1 part in a thousand.

To experimentally detect resonances, we turn on the modulated standing wave for a precise period of time. The starting phase of the modulation is chosen such that the resonances are centered on zero velocity, while the stopping phase allows maximum resonance velocity. After the standing wave is turned off the atoms are allowed to ballistically expand. After an expansion period of many milliseconds the distribution of the atoms is detected using freezing molasses.[1] An example of one of these distributions is shown in Fig. 2, where the resonances are the large side peaks.

Our results show resonances for a range of modulation frequencies, with the fastest detected resonance traveling at 40 recoils and the slowest at 4 recoils (see Fig. 3). The slowest resonance was observed for a modulation frequency of 160 kHz, for which the effective Planck's constant for the system is around ~ 0.2, in this regime quantum mechanical effects are observable. Furthermore, the resonances were seen for a modulation time on the order of 500 cycles of the modulation frequency, opening up a good opportunity to observe quantum tunneling of atoms between resonances using our system.[2]