Report on CRInt Winter Internship Program 2013 at IFSC

CARL-Bloch Oscillations in a Self-Generated Optical Lattice

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Recent attempts to improve gravimeters based on atom interferometry have achieved remarkable precision. A particularly attractive technique translates the gravitational acceleration force into a frequency measurement of Bloch oscillations of laser-cooled atoms confined in a stationary vertical light wave. In modern gravimeters oscillations are measured via the state of the atoms detected after a variable evolution time. The process is laborious since a new atomic samples must be prepared for each preset evolution time, and it suffers from uncertainties and fluctuations in the initial state in which the atomic cloud is prepared. In order to overcome the destructive nature of the measurements in atomic gravimeters a new technique has been proposed, which allows monitoring of Bloch oscillations in vivo [1]. To realize the idea we confine a standing wave filled with cold atoms inside a vertical ring cavity operated in the regime of cavity quantum electrodynamics (see Fig.1). For a sufficiently high cavity finesse, the cavity fields carry signatures of Bloch oscillations which can be monitored in a non-destructive way via the light leaking through the cavity mirrors. ^{88}Sr atoms driven on their narrow intercombination line are taken as a preferable atomic species since it allows to approach the desirable regime, while with alkali atoms such as rubidium or sodium commonly used in experiments involving optical cooling, this regime remains inaccessible for ring cavities due to their macroscopic dimensions.

In ring cavities the atomic motion is characterized by the effect known as collective atomic recoil lasing (CARL) [2]. Just like Bloch oscillations, CARL relies on Raman adiabatic passages between atomic momentum states: photons are absorbed from the pump beam and reemitted into the probe mode of the cavity at a Doppler-shifted frequency. This generates a standing wave in a self-organized manner with a shifting phase and accelerates the atoms. Starting from the basic equations describing the CARL-BEC model [3] in the absence of the atomic interaction assuming that the atomic cloud is sufficiently dilute, we investigate the effect of gravity on the CARL-Bloch dynamics. We restrict ourselves to the quantum CARL regime, since numerical simulations

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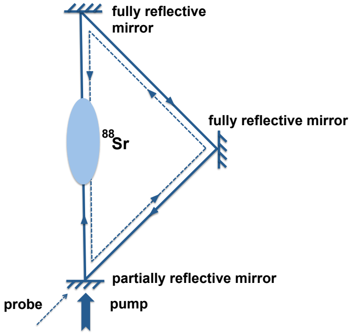

FIG. 1. Scheme of the CARL-BEC system in a vertical ring cavity.

show that in the classical CARL regime the momentum distribution tends to diffuse over many momentum states. Bloch oscillations and the CARL dynamics are deeply connected as seen in Fig.2. We show that the CARL effect in a pumped ring cavity provides direct signatures for Bloch oscillations assuming the coupling strength and the cavity finesse are maintained in defined parameter regimes. Moreover, every Bloch oscillation is accompanied by a burst of light in the probe mode, which can be conveniently detected.

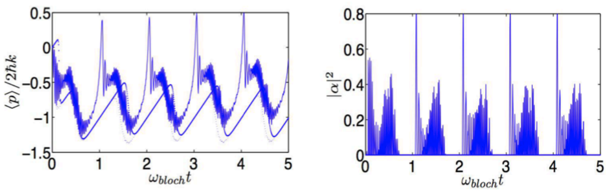

FIG. 2. Bloch oscillations (left) and radiation field intensity (right) for different values of the probe field.

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