Big Time Crystals in a Bouncing BEC

K Giergiel[1], K Sacha[1], J Wang[2], B J Dalton[2], Tien Tran[3], A Zaheer[3], A Singh[3], C Gunawardana[3], A Sidorov[3], and P Hannaford[3]

[1] *M. Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland*
[2] *Centre for Quantum Technology Theory, Swinburne University of Technology, Melbourne, Australia*
[3] *Optical Sciences Centre, Swinburne University of Technology, Melbourne, Australia*
Contact Email: phannaford@swin.edu.au

Discrete-time crystals (DTC) created in a Bose-Einstein condensate bouncing resonantly on a periodically driven mirror allow dramatic breaking of discrete-time translation symmetry [1] and the creation of big-time crystals with response periods up to about 100 times the driving period [2]. Here, we present an experimental protocol for creating big time crystals for a potassium-39 BEC bouncing resonantly on a repulsive light-sheet mirror. Such a bouncing BEC system provides a suitable platform for demonstrating a broad range of condensed matter phenomena in the time dimension [3]. We also present calculations of many-body effects and quantum fluctuations in a bouncing BEC system using a fully comprehensive multi-mode quantum treatment based on the truncated Wigner approximation for the case of a period-doubling DTC [4]. We find that the quantum depletion due to the quantum fluctuations is strongly suppressed, except at interaction strengths close to the critical value for DTC formation, and that the mean energy per particle remains essentially constant, indicating no significant heating by the driving for times out to at least 2000 driving oscillations. We also find that two modes are predominantly occupied, which allows us to apply a simple two-mode model to study the long-time dynamical behaviour of the system [5]. After typically about 50,000 driving oscillations, initial product states relax from a transient to a steady-state, where close to a critical interaction strength the period of the bouncing atom cloud changes abruptly from the driving period T to a response period 2T.

References

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