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Dissipative time crystals in an atom-cavity system

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We experimentally realize various dynamical phases such as a dissipative discrete time crystal [1], dynamical bond density wave phase [2-4], and limit cycle phase [5]. Our setup consists of a Bose-Einstein condensate of ^{87}Rb atoms overlaps with a single mode optical cavity. The key feature of the cavity is a very small field decay rate ($\kappa/2\pi$ = 3.6kHz), which is in an order of the recoil frequency ($\omega_{rec}/2\pi$ = 3.6kHz). This leads to a unique situation where cavity field evolves with the same timescale as the atomic density distribution. For standing wave pumping, transversely with respect to the cavity axis, the system undergoes a phase transition from a normal homogeneous phase to a superradiant self-organization phase, accompanied by spontaneously breaking of Z2 symmetry. Modulating the amplitude of the pump field leads to the realization of a dissipative discrete time crystalline phase, whose signature is a rigid sub-harmonic oscillation between the two symmetry broken states [1]. Modulation of the phase of the pump field give rise to an incommensurate time crystalline behaviour and a condensate formation in a dark state [2,3,5]. For a blue-detuned pump light with respect to the atomic resonance, we observe limit cycles. Since the used pump protocol is time-independent, the emergence of a limit cycle phase heralds the breaking of continuous time-translation symmetry [4].

[1] H. Keßler et al., PRL 127, 043602 (2021)
[2] P. Kongkhambut et al., PRL 127, 253601 (2021)
[3] J. Skulte et al., PRA 104, 063705 (2021)
[4] P. Kongkhambut et al., Science 377, 6606 (2022)
[5] J. Skulte et al., PRL 130,163603 (2023)

Primary author: KONGKHAMBUT, Phatthamon (Zentrum für Optische Quantentechnologien and Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany)

Co-authors: HEMMERICH, Andreas (Universität Hamburg); KESSLER, Hans (Universität Hamburg); COSME, Jayson (University of the Philippines); SKULTE, Jim (Universität Hamburg); MATHEY, Ludwig (Universität Hamburg)

Presenter: KONGKHAMBUT, Phatthamon (Zentrum für Optische Quantentechnologien and Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany)

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