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Parametric instabilities in shaken atomic gases

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Statement of the Problem: Submitting an ultracold atomic gas to a time-dependent modulation has proven an efficient tool to design artificial gauge fields and topological phases for neutral atoms. More generally, such "driven" systems open numerous perspectives in the general program of quantum simulation with ultracold atoms. However, most of the theory for driven systems still relies on a single-particle description, while recent experiments in interacting regimes have reported significant heating, losses, and instabilities in modulated Bose-Einstein condensates. A precise understanding of the physics at stake would therefore be highly welcomed to guide experiments to stable regimes, opening new perspectives in quantum simulation, among which the realization of novel topological phases that have never been observed with ultracold atoms.

Methodology: It is report here on a theoretical study of the instabilities that arise in weakly-interacting Bose gases subjected to a time-dependent modulation. A generic numerical method able to determine ab initio the stability regimes of a wide class of modulated systems, and to extract the associated instability rates is presented. In a second step, an analytical approach is developed which allows to trace the observed instabilities back to the phenomenon of parametric resonances, and provide quantitative analytical estimates of the heating rates.

Findings: Different dynamics instability regimes associated with different timescales, as well as clear signatures of those instabilities that could be directly probed in experiments are identified. Extensions to other types of modulated systems are discussed.

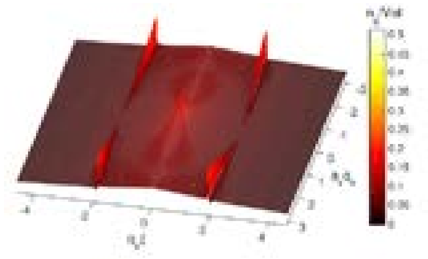

FIG. 1. The quasiparticle momentum distribution n_q of a 2D shaken BEC develops unique resonance structures in the presence of a periodic drive.

Recent Publications

1. N Goldman and J Dalibard (2014) Periodically driven quantum systems: effective Hamiltonians and engineered gauge fields. Physical Review X. 4(3):031027.
2. M Aidelsburger et al. (2013) Realization of the Hofstadter Hamiltonian with ultracold atoms in optical lattices. Physical Review Letters. 111:185301.
3. H Miyake et al. (2013) Realizing the Harper Hamiltonian with laser-assisted tunneling in optical lattices. Physical Review Letters. 111:185302.
4. S Lellouch et al. (2017) Parametric instability rates in periodically driven band systems. Physical Review X. 7(2):021015.
5. S Lellouch and N Goldman (2018) Parametric instabilities in resonantly-driven Bose-Einstein condensates. Quantum Science and Technology. 3(2):024011.

Biography

Samuel Lellouch graduated from Ecole Polytechnique (France) with an Engineering Diploma and a Master in Physics; pursued his PhD in 2014 from Graduate School Optics Institute of University of Paris XI. He carried out his Postdoctoral Research at the Free University of Brussels (Belgium) and University of Lille 1 (France). He is an expert in the theory of quantum gases, mastering advanced numerical and analytical methods, and has acquired a sharp expertise in many-body systems, disordered quantum systems, and artificial gauge fields. His works are all published in reputed journals and have permitted significant advances in quantum simulation with ultracold atoms.

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