# Investigating non-equilibrium physics and universality using two-dimensional quantum gases

**A. J. Barker**, **K. Luksch, S. Sunami, B. Yuen, E. Bentine and C. J. Foot**
*Department of Physics, University of Oxford, Parks Road OX1 3PU, United Kingdom*

e-mail: *adam.barker@physics.ox.ac.uk*

We have developed multiple radiofrequency (RF) dressed magnetic potentials for ultracold atoms, forming trap geometries such as a double well or a broad single well [1]. We have recently characterised these potentials in an extensive RF spectroscopy investigation [2]. Reducing the amplitude of RF dressing fields can lead to two-dimensional (2D) confinement for trapped atoms [3]. Our plan is to use a two-dimensional double well system in order to illuminate the route to thermal equilibrium of a non-integrable closed quantum system. It is expected that 2D quantum systems thermalise since their dynamics are sufficiently unconstrained, i.e. they are non-integrable [4]. The enhanced role of density fluctuations makes 2D systems very different, as predictions suggest they thermalise because of the creation of vortex-antivortex pairs which alter phonon propagation [5]. Ultracold quantum gases are very well suited to observe thermalisation dynamics because they can be isolated from the environment and their dynamics can be spatially and temporally resolved. Our planned experiments will begin with a pair of 2D, degenerate Bose gases prepared in an non-equilibrium state via a sudden quench and we will investigate the relaxation of their relative local phase through matter-wave interferometry. In addition, we will investigate scaling exponents both near and far from the Berezinskii-Kosterlitz-Thouless phase transition and probe the system's universal behaviour close to the critical point.

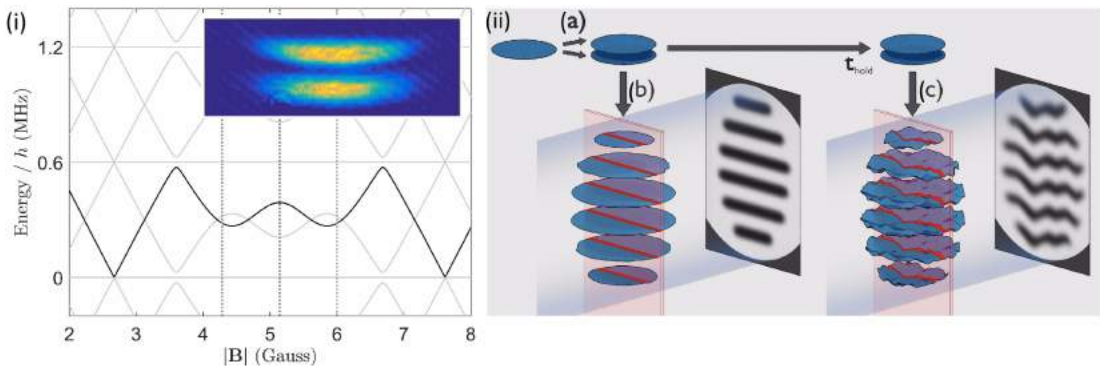


Figure 1: (i) A double well potential formed by coupling the Zeeman substates of an $F = 1$ atomic Hamiltonian with a multi-frequency RF field. Inset: absorption image of thermal atoms trapped in a double well potential. (ii) (a) We prepare a 2D Bose gas in a single well potential before performing a sudden quench by splitting the gas. (b) We will perform matter-wave interferometry, combined with tomographic imaging, to determine the relative phase between the clouds. (c) The temporal evolution of the phase following the quench also be measured by varying the hold time in the double well.

[1] T. L. Harte, E. Bentine, K. Luksch, A. J. Barker, D. Trypogeorgos, B. Yuen, and C. J. Foot. Ultracold atoms in multiple radio-frequency dressed adiabatic potentials. *Physical Review A*, 97(1):013616, 1 2018.

[2] K. Luksch, E. Bentine, A. J. Barker, S. Sunami, B. Yuen, and C.J. Foot. RF Spectroscopy of Ultracold Atoms in Multiple-RF Dressed Potentials. *In preparation.*

[3] K. Merloti, R. Dubessy, L. Longchambon, A Perrin, P-E Pottie, V. Lorent, and H. Perrin. A two-dimensional quantum gas in a magnetic trap. *New Journal of Physics*, 15(3):033007, 3 2013.

[4] L. Mathey and A. Polkovnikov. Light cone dynamics and reverse Kibble-Zurek mechanism in two-dimensional superfluids following a quantum quench. *Phys. Rev. A*, 81(3):1–13, 12 2009.

[5] L. Mathey, K. J. Günter, J. Dalibard, and A. Polkovnikov. Dynamic Kosterlitz-Thouless transition in two-dimensional Bose mixtures of ultracold atoms. *Phys. Rev. A*, 95(5):053630, 5 2017.