Towards coherent splitting and recombination of bright solitary matter waves

A. Rakonjac*[1], O. J. Wales[1], T. P. Billam[2], J. L. Helm[3], S. A. Gardiner[1], and S. L. Cornish†[1]

1. Joint Quantum Centre (JQC) Durham–Newcastle, Department of Physics, Durham University
South Road, Durham DH1 3LE, UK
2. Joint Quantum Centre (JQC) Durham–Newcastle, School of Mathematics and Statistics, Newcastle University
Newcastle upon Tyne NE1 7RU, UK
3. Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics, University of Otago
730 Cumberland Street, Dunedin 9016, New Zealand

We report on the controlled creation, splitting, and recombination of bright solitary matter waves formed from Bose-Einstein condensates of ^{85}Rb atoms. These solitary wavepackets, or solitons, are long-lived, with lifetimes of over 20 seconds, and can propagate without observable dispersion over macroscopic distances. Following our previous work on classical reflection of solitons from a broad repulsive barrier [1] and quantum reflection from a narrow attractive well [2], we extend our investigations to solitons incident on a narrow repulsive gaussian barrier [3]. When the kinetic energy of the soliton wavepacket is comparable to the barrier height, we observe controllable splitting of the soliton into two daughter solitons. The splitting proportion varies according to incident velocity and barrier height with good agreement with 1-D and 3-D Gross-Pitaevskii simulations. After allowing the daughter solitons to oscillate in a weak harmonic potential, they recombine on the barrier and continue propagating as an apparent single soliton, though the recombination is in this case the result of velocity filtering rather than a coherent process. Future experiments with a narrower barrier should allow us to reach the coherent recombination regime.

The coherent splitting and recombination of solitons as well as their long lifetime leads the way to using such a scheme for soliton-based interferometry in a variety of configurations [4]. In particular, the scheme can be utilised in a ring geometry for Sagnac interferometry [5]. Future work includes implementing a soliton Sagnac interferometer using a 2-D painted ring potential and further experimental studies of bright matter-wave soliton dynamics that can be used to elucidate the wealth of theoretical work in the field, as well as to explore, for example, the realisation of Schrödinger cat states [6, 7] and the study of short-range atom-surface potentials [8].

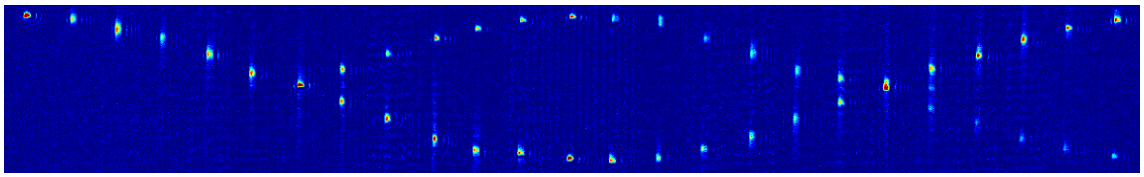

Fig. 1: A series of destructive absorption images at 30 ms time intervals showing splitting and apparent recombination of two equally populated daughter solitons on a narrow repulsive Gaussian barrier.

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*Corresponding author: ana.rakonjac@durham.ac.uk
†Corresponding author: s.l.cornish@durham.ac.uk